C-MOBILE

Accelerating C-ITS Mobility Innovation and deployment in Europe

D3.5 Updated Architecture and Challenge Report

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Main authors	Manuel Fünfrocken (HTW SAAR) Philipp Schorr (HTW SAAR) Alfonso Brazalez (CEIT) Areti Kotsi (CERTH) Geert Vanstraelen (MACQ) Jacint Castells (Applus+ IDIADA) Jos van Vlerken (CPH) Pablo Mejuto (CTAG) Patrick Hofman (MAPTM) Priyanka Karkhanis (TUE) Robbin Blokpoel (DYNNIQ) Simon Edwards (UNEW) Sven Jansen (TNO) Clement Ruffin (NeoGLS) Emi Mathews (TNO) Olatz Iparraguirre Gil (CEIT)
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Project coordination

Mr Alex Vallejo Miracle
Applus+ IDIADA
PO Box 20 Santa Oliva
43710, L'Albornar, Tarragona
Spain

Telephone: +34 977 18 93 60
E-mail: alex.vallejo@idiada.com

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Abbreviations

Abbreviation	Definition
3G	3rd generation of mobile telecommunications technology
4G	4th generation of mobile telecommunications technology
5G	5th generation of mobile telecommunications technology
AMQP	Advanced Message Queuing Protocol
ASN.1	Abstract Syntax Notation No.1
BDD	Block Definition Diagram
BIL	Bilbao
BNC	Barcelona
BOR	Bordeaux
BSD	Blind Spot Detection / Warning
CACC	Cooperative Adaptive Cruise Control
CAM	Co-operative Awareness Message
Can bus	Controller Area Network bus
C-ITS	Cooperative Intelligent Transport Systems
CPBO	Communication Provider Back Office
CPH	Copenhagen
CTL	Cooperate Traffic Light for Pedestrian
DATEX II	Second generation of a standard for the exchange of traffic related data which can be used by all actors in the traffic sector (www.DATEX2.eu).
DENM	Decentralized Environmental Notification Message
DPBO	Data Provider Back Office
EBL	Electronic Break Light
EVW	Emergency Vehicle Warning
FCD	Floating Car Data
FI	Flexible Infrastructure
GLOSA	Green Light Optimal Speed Advise
GP	Green Priority
HMI	Human Machine Interface
HTTPS	Hypertext Transfer Protocol Secure
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IP	Internet Protocol
IPv4	Internet Protocol, version 4
ISO	International Organization for Standardization
ITS	Intelligent Transport Systems
ITS G5	ITS at 5 GHz frequency band
IVI	Infrastructure to Vehicle Information service
IVS	In Vehicle Signage
JSON	JavaScript Object Notation
MAC	Media Access Control
MAI	Motorcycle Approaching Indication

MOST	Media Oriented Systems Transport
MPA	Motorway Parking Availability
MQTT	Message Queuing Telemetry Transport
MTTA	Mode and Trip Time Advise
NBR	North Brabant
NEW	New Castle
OBD	On Board Diagnostic
OBU	On Board Unit
OSI	Open Systems Interconnection model
PID	Personal Information Device
IPv6	Internet Protocol, version 4
POI	Point of Interest
PVD	Probe Vehicle Data
RHW	Road Hazard Warning
RS	Roadside System
RSE	Road Side Equipment
RSU	Road Side unit
RTM	Rest Time Management
RWW	Road Works warning
SNMP	Simple Network Management Protocol
SPAT	Signal Phase and Timing
SPATEM	Signal Phase and Timing Extended Message
SSVW	Slow or Stationary Vehicle Warning
SVW	Signal Violation Warning
TBD	To Be Defined
TCP	Transmission Control Protocol
THES	Thessaloniki
TLS	Transport Layer Security
TMC	Traffic Management Center
TMS	Traffic Management System
UC	Use Case
UML	Unified Modelling Language
UPA	Urban Parking Availability
USB	Universal Serial Bus
VIG	Vigo
VIS	Vehicle Intelligent transport Sub-system
VRU	Vulnerable Road User
WSP	Warning System for Pedestrian
XML	Extensible Markup Language

Executive Summary

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 decentralized and dynamic coupling of systems, services and stakeholders across national and organizational 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 update of the deliverable “D3.3 Low-level implementation-ready architecture” aims to provide a good understanding of the implemented architecture within the C-MobILE project. Therefor the involved partners in Work Package 3 and the different deployment sites are asked to provide their input towards this document. The writing process is in close cooperation with the different deployment sites to gather information about their current implementation of the different services, in order to generate an updated version of the architecture. Therefore, some of the content from D3.3 is partially reused as it is still valid and the corresponding service is implemented as it was planned in the former deliverable. Otherwise, the former planned architecture is updated to the current implemented architecture. To show this in more detail, each service is listed in a separate section in Chapter 2.5 “Communication/Implementation Viewpoints per Service”. Moreover, all deployment sites provide a report of their own challenges, which they had to face in the past, or still have to face now during the preparation of the large-scale deployment. These reports include technical challenges and organisational challenges as well. One of the biggest challenges is either to adopt the needed changes to the already existing GeoMessaging servers or the implementation of a new GeoMessaging server. Some deployment sites also face the problem of the integration of the already existing C-ITS infrastructure from former projects or already existing C-ITS infrastructure of the city itself. Delays within the purchase of the hardware often cause problems. These come up quite sudden and affect the whole process of the deployment. Another challenge is the costs of the implementation and the provision of the necessary hardware to use the services in large-scale.

In addition to Chapter “Technical and Organizational Challenges” each deployment site is asked to sum up their open points for the large-scale deployment. These points, which are both technical and organisational nature and often align with the challenge report of the related deployment site, are the next challenges to face and still in progress.

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

Task T3.3 “Service Design” and T3.4 “Architecture for implementation” aim at a detail the concrete-level architecture. The main objective of this deliverable is giving an updated version of the existing deliverable D3.3 “Low-level implementation-ready architecture”. D3.5 provides an overview of the final architecture that has been implemented. The document shows the difference between the planned architecture and the implemented architecture. Furthermore, it contains implemented services, organizational challenges that came up during the implementation and open points for a roll-out which may be understood as a “lessons learned” summary. D3.5 should provide enough information for those who are interested in implementing C-ITS, especially the difficulties that come up, when implementing a C-ITS framework. This deliverable also aims to give a specific look on the challenges that come up within a large-scale deployment and the services developed within C-MobILE.

1.3. Intended audience

This document is intended to provide an understanding of the implemented architecture and the different services developed within C-MobILE. It is targeted at technical people related to the definition and implementation of the architecture and at possible C-ITS stakeholder. Whilst in principal of interest for most of the C-ITS stakeholders, this document is also targeted to interested traffic managers of cities with complicated traffic flow, transport logistics and passenger logistics, who want to adopt C-ITS to optimise routing and traffic flow. Furthermore, it is intended to give system designers and developers a good definition of the interaction between systems and devices within C-MobILE.

1.4. Approach

Information is gathered from all the deployment sites to create a brief document that shows the currently implemented architecture of the different services within C-MobILE. Therefore, all the deployment sites give their feedback on the implemented services and the former architecture, published in “D3.3 Low-level implementation ready architecture” [1], gets adopted to these changes. Not too many changes are made to the former architecture, therefor many services follow the same architecture and are not updated, as this is not necessary. Furthermore, the different deployment sites are asked to provide their “open points” regarding a large scale roll out in their area. In addition to these reports, the deployment sites are also asked for a kind of challenge report, where the different deployment sites can add their most challenging problems, that come up during a large-scale roll-out of the C-MobILE C-ITS infrastructure and implementation of the services.

1.5. Document structure

This document contains seven chapters, beginning with an Introduction, followed by an Architecture overview, that contains an updated architecture of the implemented services. Subsequent the Detailed technical/protocol information is provided, to enhance the understanding of the applied protocols and technical procedures used in C-MobILE. The fourth chapter Technical and Organizational Challenges highlights the challenges that come up, if you plan and perform a large-scale implementation of Cooperative Intelligent Transport Systems. It contains the challenges of each deployment site in a separated section, to give a better understanding of the different difficulties given an implementation and a communication technique. This chapter is followed by the C-MobILE Architecture and ARC-IT section. The next chapter Open Points for a Roll-Out is a collection of points that are still in progress from each deployment side. The seventh chapter Conclusion gives a summary of the architecture and the challenges that come up, if you deploy a Cooperative Intelligent Transport System in a large-scale context.

2. Architecture overview

An architecture framework is one of the widely applied approaches used in software/system architecting of complex systems. The architecture frameworks facilitate communication and cooperation between different stakeholders during architecting and building complex systems such as C-ITS. Many different stakeholders with their interweaving concerns require a systematic approach for addressing complexity and full lifecycle of the system. We adapted and extended to the ISO/IEC/IEEE 42010:2011 standard [2] to establish an architecture framework for C-MobILE which is described in deliverable D3.1. The C-ITS architecture framework specifies stakeholders, their concerns, viewpoints, model kinds and correspondence rules. We propose a set of six core viewpoints as a part of C-ITS architecture framework: Context, Functional, Information, Implementation, Physical, and Communication. These viewpoints are described in the following sub-sections.

2.1. Context Viewpoint

The context viewpoint describes the relationships, dependencies, and interactions between the system and its environment (e.g. people, systems and external entities). The context view conforms to the context viewpoint and helps system's stakeholders (e.g. system/software architects, designers, developer and users) understand the system context.

An architect usually needs to include a definition of the system's context as part of their architectural description. The reasons for this include:

/ The system context simply not being included in the requirements gathering exercise;

/ a system context being loosely defined by requirements analysts, but at a level of detail which means that the architect needs to add significantly to it; and

/ the system/software architect needing to reference elements of the system context elsewhere in the architectural description, so making it desirable for this information to be part of the architectural description and under the control of the architect.

The context view conforms to the context viewpoint. SysML Block Definition Diagram (BDD) is identified as suitable modelling notation for capturing the context viewpoint. SysML Use Case diagram can be used to show the usage of a system as described in Figure 1.

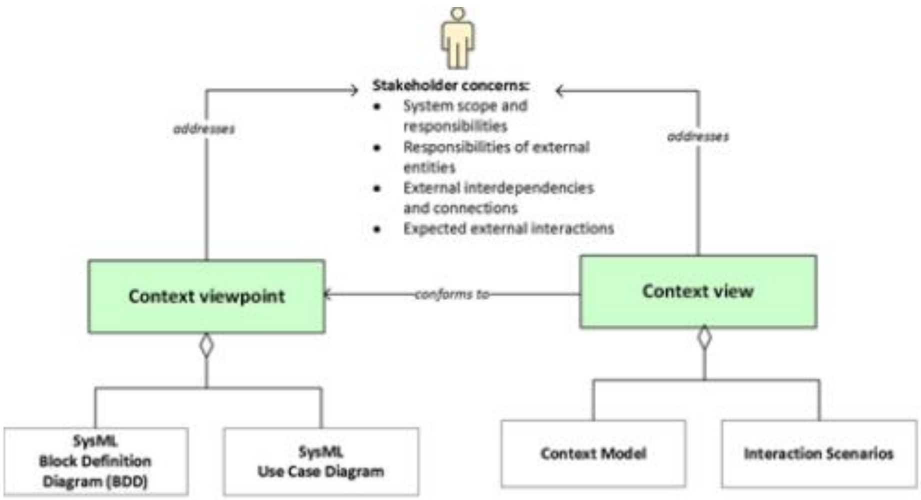

Figure 1: Context viewpoint

For the reference architecture, we defined context viewpoint and view at a very abstract level capturing the system scope and its responsibilities. The context diagrams for each System: Support, Central, Roadside, Vehicle, and VRU/Traveller were designed. For the concrete architecture (D3.2), the context viewpoint describes the relationships, dependencies, and interactions between the system and its environment (e.g. people, systems and external entities) more in detail derived from reference architecture context viewpoint. The context view conforms to the context viewpoint and helps system's stakeholders (e.g. system/software architects, designers, developer and users) understand the system context. The five main systems defined in the reference architecture are now further disseminated into sub-systems depicted as a black box and a corresponding actor's role with those sub-systems.

2.2. Functional Viewpoint

We define the concepts for the functional viewpoints, which can be used for modelling functional structures for different type of architectures. Functional viewpoint describes the system's runtime functional elements, their responsibilities, interfaces, and primary interactions. The functional view conforms to the functional viewpoint, helps the system's stakeholders understand the system structures, and has an impact on the system's quality properties.

The functional viewpoint addresses the following concerns of the stakeholders.

1. Functional capabilities:
   Functional capabilities describe the functionality that the system is required to provide. In the Architecture Viewpoint for the reference architecture, it defines what the system will explicitly do. The set of functional and quality requirements will be used to define the functionality.
2. External interfaces:
   External interfaces address the interactions between systems e.g. based on data/control flow or events. A system can send or receive data either because of an internal state change or a state change in another system. A system can send or receive a request to perform a task or notify that something has been occurred. In the functional view of the reference architecture, high-level generic interfaces are described. The interface syntax and semantics in further detail will be described in the concrete and implementation architectures.
3. Internal structure:
   A system can be further decomposed into sub-systems or components to meet its requirements. Its decomposition has an impact on the quality attributes e.g. on security, scalability, reliability, and availability. Therefore, the definition of the internal structure should take both functional and quality requirements into account. In the functional view of the reference architecture, a system is further decomposed into sub-systems, which can be further decomposed into functional components in concrete/implementation architectures.

The functional view conforms to the Functional Viewpoint. SysML Block Definition Diagram and Internal Block Definition Diagram are identified as suitable modelling notations for capturing the functional viewpoint.

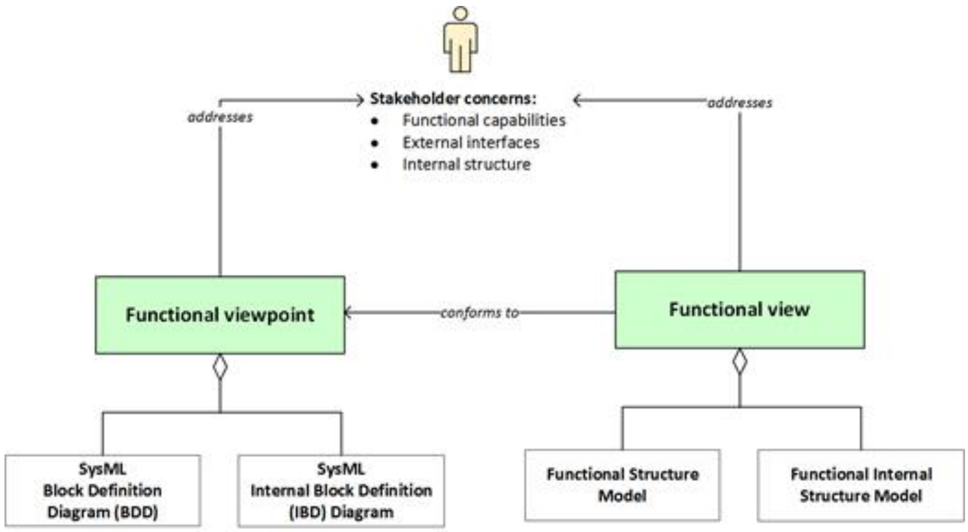

Figure 2: Functional viewpoint

The D3.1 presented a high-level functional model for C-MobILE in form of a SysML BDD, which has been deeply analysed to be extended and detailed in such a way that all internal functionalities of the defined blocks are covered and provided.

After a huge work over the reference architecture, the following activities have been performed and resulted in the complete functional architecture illustrated in concrete architecture (D3.2):

- Identification of missing blocks and concepts from the functional reference architecture. For such work, the following information has been used:
  - Information related to the current architecture of the Deployment Sites.
  - Technical requirements from Task 2.2 of C-MobILE, including security, privacy and hybrid communications.
- Determination of the internal structure/functionalities of the main blocks of the architecture.
- Determination of the interfaces connecting internal and external blocks to cover the functionalities.

2.3. Communication Viewpoint

2.3.1. Definition

Communication viewpoint describes the mode of communication through network interfaces and communication protocols between different systems deployed on different hardware environment. The communication view supports stakeholders involved in defining/enabling communication between systems and shows the interfaces between systems and sub-systems. The communication architecture for C-MobILE conforms to the general communications reference architecture defined in ETSI EN 302 665 (Figure 3).

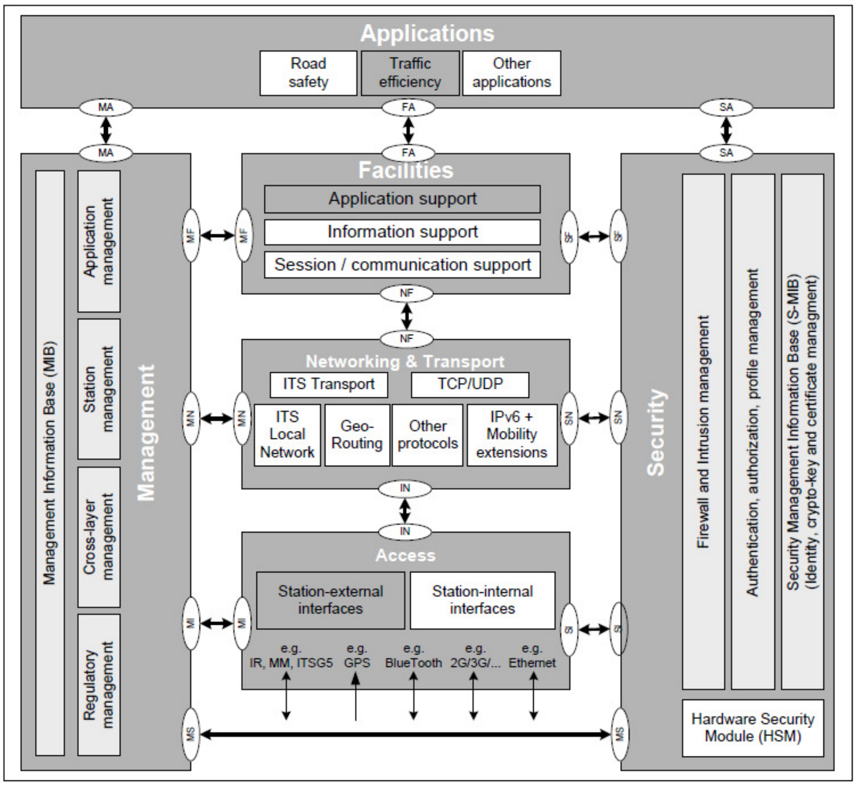

Figure 3: ITS station reference architecture

The reference communication architecture for C-ITS stations consists of four main functional domains namely applications, facilities, network & transport, and access and two support domains (security and management) [5]. This reference communication architecture is valid for all ITS systems, i.e. OBU, RSU and BO systems which are respectively named vehicle ITS, roadside ITS and central ITS in the ETSI definitions.

The communication model shows the mode of communication in terms of network interfaces and protocols. SysML Internal Block Diagram is considered to model the structure of these interfaces and protocols as well as the connection between different networks. The communication viewpoint has conformance correspondence to the physical and information viewpoints (Figure 4).

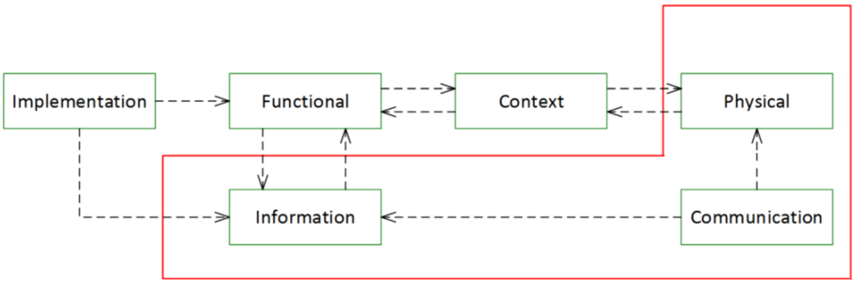

Figure 4: Correspondences for the Communication Viewpoint

2.3.2. Stakeholders and Concerns

Most of the stakeholders have some level of interest in communication viewpoint however, system architects, data modellers, network administrators, network managers, hardware managers, integrators are the main stakeholders. Concerns of these stakeholders are:

- Mode of communication between systems and subsystems;
- Specification of the network interface and protocols;
- Adequate characteristics to host communication functionality and meet supplementary requirements.

2.3.3. Communication View

In real-world deployments, the functional systems at one of the four layers (i.e. VRU, vehicle, roadside or central layer), can be deployed in one physical box. However, in case the involved functional systems are deployed in separate physical elements a communication network is needed to interconnect the functional systems. A communication network is needed for the communication between systems at the different layers as well.

The Communication Viewpoint can be mapped to the ISO's Open System Interconnection model as shown in Figure 5 below.

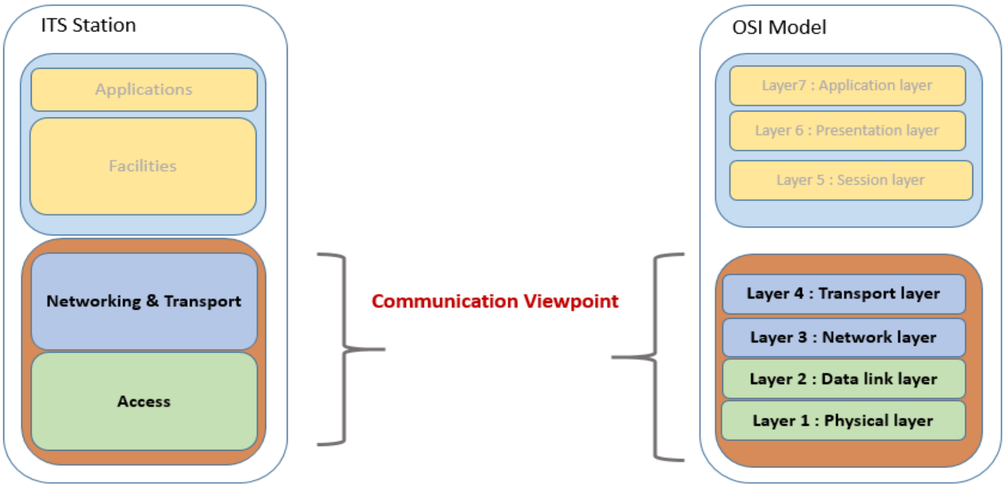

Figure 5: Communication viewpoint mapping of ITS Station and OSI Model

The following networks are identified from communication viewpoint perspective by considering VRUITS architecture [X]8:

Cooperative ad-hoc networks: best suited for cooperative applications. ITS G5 with GeoNetworking is used in these networks for VRU2VRU, VRU2V/VRU2I and V2IVRU/I2VRU communication to exchange CAM, DENM and other C-ITS defined messages between cooperative systems.

In-vehicle networks for cars and VRU vehicles like PTW three types are defined:

Car-specific networks. A serial bus is currently used in the automotive industry to allow microcontrollers and devices to communicate with each other within a car without a host computer. This type of network can be based on CAN, MOST or FlexRay. CAN (Controller Area Network) is one (out of five) message-based protocols within OBD-II and is standardized at the lower layers (physical, data link, transfer layer). Recent network protocols like MOST (Media Oriented Systems Transport) is a high-speed multimedia network technology optimized by the automotive industry which can be used for applications insider or outside the car and FlexRay as successor for CAN. However, FlexRay is not yet widely adopted. EOBD is an EU standard providing diagnostic and reporting capabilities, based on OBD-II (On-Board Diagnostics, release II).

VRU-vehicle specific networks. For motorcycles and for other VRU-specific vehicles like mopeds and eBikes such networks with (partly) standardized interfaces are not yet available. Motorcycle vendors also have a proprietary implementation of an OBD-II type of network. Another example of a VRU-vehicle specific network is EnergyBus. It is an open standard for integration of and communication between electric components of light electric vehicles based on DC. The EnergyBus specification is published through the EnergyBus Association, based in Germany.

In-vehicle IP networks. This IP network is used to interconnect in-vehicle systems for advanced driver assistance, comfort, and infotainment features. This network is used to connect devices (e.g. smartphone, communication unit) that contain one or more systems like VRU-VIS, VRU CS with HMI. This type of IP-based network can use widespread lower layer technologies like Wi-Fi, Bluetooth as lower layer protocols. Automotive Ethernet is a more recent industry standard for in-car IP networks, developed by the OPEN (onepair ether-net) alliance special interest group (SIG). Powered VRU-vehicles like eBikes with on-board computers have USB interfaces to connect external systems, (e.g. a smartphone for charging or an external diagnostics system for battery health monitoring) or to an external computer to read in-formation on trips (distance, average speed, etc.). These device-to-device network connections (based on USB or Bluetooth) could be used to connect different systems on powered VRU-vehicles.

Public mobile data networks. VRU systems and in-vehicle systems can be connected to central systems via public mobile data networks. These networks are IP-based and use different mobile radio access technologies like GPRS, UMTS, and LTE. ITS systems are mainly the only users on these networks, and mobile operators own these networks and licenses and are responsible for performance and capacity.

Other networks:

/ Internet. The central systems in the architecture can be connected via a public IP network.

/ Private IP networks: At the roadside layer, the systems are mostly connected via private IP networks, including the connections to central TMC.

Other short-range wireless networks: systems at the different layers can be connected via other short-range wireless technologies like RF, Bluetooth, BLE or Wi-Fi. IP can be used to exchange information. In some cases, only the wireless MAC identifier and signal strength are used to identify and locate a user. In addition, Bluetooth, BLE, and Wi-Fi can be used to exchange information between components installed in the VRU vehicle and nomadic devices.

2.4. Information Viewpoint

The information viewpoint and view at architectural level help to define how the systems will store, manage, manipulate, and distribute information. The information view provides a high-level view of static data structure, information flow, and data lifecycle to users, developers, testers, and maintainers. The information viewpoint is mapped to session layer, presentation layer, and application layer of the OSI Model and can be captured using SysML Block Definition Diagrams, Activity and State Diagrams.

The information viewpoint addresses the following list of stakeholder concerns.

/ Information structure and content:

It is important to define the structure and content of the information that C-ITS manages. An architect needs to define it at early stage in alignment with the system's functionality independent of where and how it would be located.

/ Data flow:

The most important data flows need to be considered during the architecture definition. The importance can be decided based on the system's primary responsibilities or its impact on system quality. Data flow can be considered in both functional and information viewpoints.

/ Data lifecycle:

The lifecycle of data is another important concern. It is about the transitions that data items go through in response to external events – transitioning from creation, changes to deletion. 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. In this section, the data flow (information exchange, protocol message types) is explained.

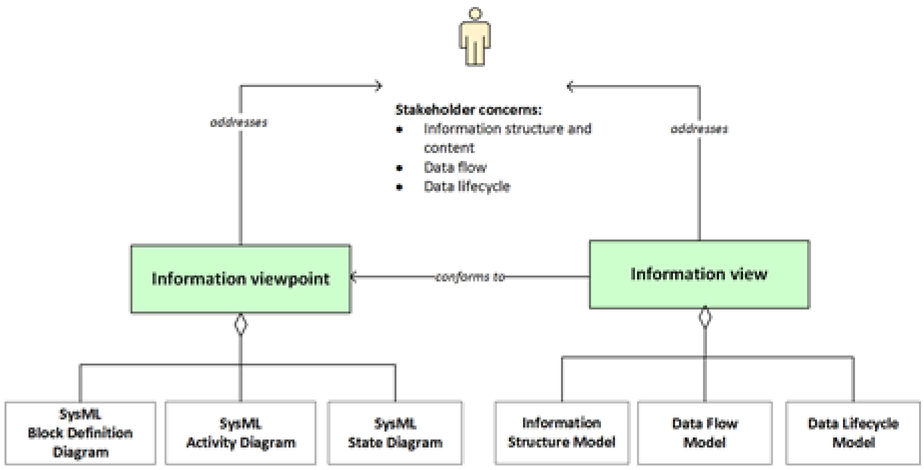

Figure 6: Information viewpoint

For the reference architecture (D3.1), the data flow models were defined and described for each system level. The data flow is explained for the different types of systems and between the systems at VRU, vehicle, roadside and central system. For concrete architecture (D3.2), a detailed data flow models are defined between systems and its sub systems.

2.5. Communication/Implementation Viewpoints per Service

The following section contains all implemented services in C-MobILE. Including a description of the involved infrastructure and clients, such as “GeoMessaging Server”, “On Board Unit” or “Communication Provider Back Office”. Farther described are the communication between those. Therefore, this section contains a specific chapter for each service with a textual and graphical description.

2.5.1. S01 - RTM (Rest-Time Management)

Rest time management supports managing the working hours of drivers engaged in the transport of goods and passengers by road. The process is regulated by policies, laws or regulations (e.g., EU regulation (EC) No 561/2006) that lay down the rules on driving times, breaks and rest periods for the drivers.

This service enables truck drivers to make a safer journey by assisting rest time management through the provision of information on parking availability, at a relevant frequency.

This service will only be deployed in North Brabant, for which an associate partnership is developed. The planned implementation of the service is shown using the general architecture of D3.3. Only the cellular path is used, connecting the in-vehicle PID directly to the service provider back office. The service provider combines rest-time management with the motorway parking availability into one service, or bundle of services.

2.5.1.1. Involved Components

This section shows, which components are involved in this service. Furthermore, it lists the various sequence diagrams, which have been created to describe the service. The foundation of the service description is the component diagram, as shown below in Figure 7.

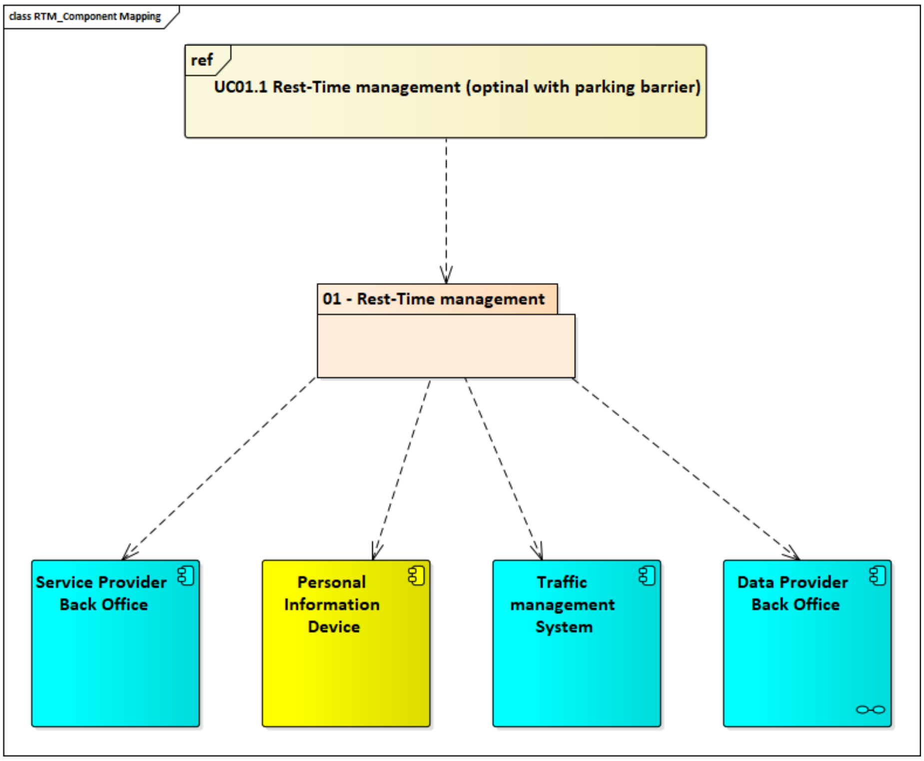

Figure 7: Rest-Time Management - Components involved in service

To implement this service, the following components are necessary.

- / Service Provider Back Office (see D3.3 section 4.2.2.2.3 for details.)
- / Personal Information Device (see D3.3 section 4.2.5.2.1 for details.)
- / Traffic Management System (see D3.3 section 4.2.2.2.5 for details)
- / Data Provider Back Office (see D3.3 section 4.2.2.2.4 for details.)

The relations between those components are described in the section 2.5.1.2, below. The general functionality of these services, as well as more detailed interactions of the involved components is further described in the ARC-IT diagram on which this service is based. These are in particular:

- / S01 Rest Time Management as shown in Appendix A of D3.3

2.5.1.2. Component Connection

The following section describes the relations between the various components. In Figure 8 all the involved components and the connections between them are listed for all use cases of the service.

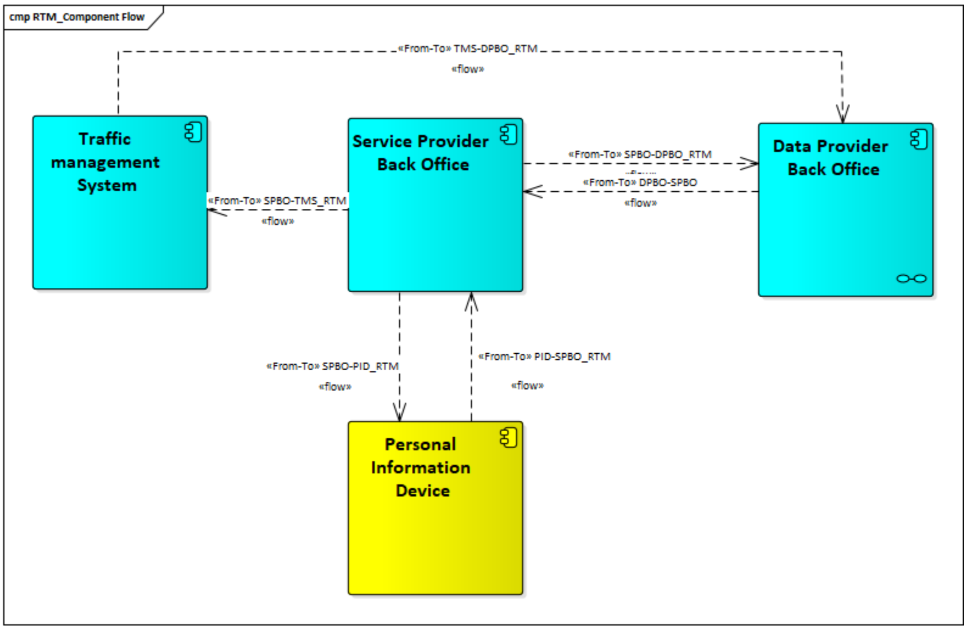

Figure 8: Rest-Time Management - Components and communication flows

The RTM connects the fleet management service (FMS) to motorway parking availability (MPA) and tachograph to provide an overview of the parking options to the chauffeur in relation to the remaining driving time. The FMS provides the destination to the navigation service, which generates the route. The MPA service provides the available parking for the parking lots along the route. The navigation service also determines the travel time to each of the parking lots, which is presented to the chauffeur together with the parking availability at those parking lots. The remaining driving time is also shown to the chauffeur, who can then decide on the parking lot to make a stop.

Table 1 Rest Time Management - Protocols used for connections

Name	From	To	Protocol Layer						Datatypes Reference
			Application	Facilities	Transport & Networking	Access	Management	Security	
TMS-DPBO_RTM	TMS	DPBO	HTTPS	JSON	TCP, IPv4, IPv6				Not defined yet
SPBO-PID_RTM	SPBO	PID	HTTPS	JSON	TCP, IPv4, IPv6	Generic Access	SNMP	TLS	Not defined yet
PID-SPBO_RTM	PID	SPBO	HTTPS	JSON	TCP, IPv4, IPv6	Generic Access	SNMP	TLS	Not defined yet
SPBO-DPBO_RTM	SPBO	DPBO	HTTPS	AMQP	TCP, IPv4, IPv6	Generic Access	SNMP	TLS	Not defined yet
DPBO-SPBO_RTM	DPBO	SPBO	HTTPS	AMQP	TCP, IPv4, IPv6	Generic Access	SNMP	TLS	Not defined yet

The table above shows the protocols which shall be used for the respective layer. Those listings may also contain alternatives, e.g. IPv4 or IPv6. The specific reference for the used protocols is listed in Appendix B of D3.3.

The protocol layers used follow the protocol stack as defined by ETSI. See ETSI EN 302 665 for details.

2.5.2. S02 - MPA (Motorway Parking Availability)

The service is meant to inform truck drivers on available truck parking spaces and extra information on those. This information can bring more comfort and security by helping the truck driver manage his/her driving times and rest periods.

The objective of the service is to provide to truck drivers information on parking spaces. Information provided are [3]:

/ The location of parking lots.

/ The number of available spaces. If not known, information provided is just “full”, “open” or “closed”.

/ Vehicle Types permitted to be parked (trucks or passenger car).

2.5.2.1. Involved components

This section presents the components involved in the Motorway Parking Availability service. Furthermore, it lists the various sequence diagrams, which were created to describe the service. The base of the service description is the component diagram, as shown below.

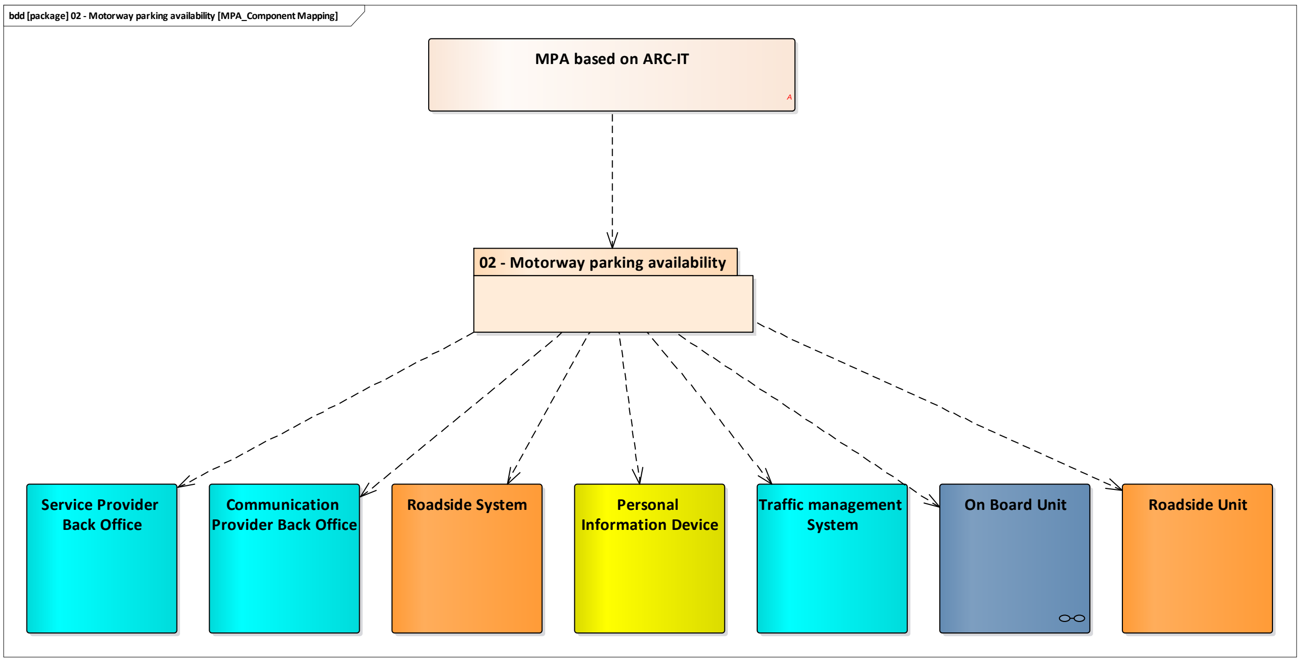

Figure 9: MPA - Components involved in the Motorway Parking Availability service

To implement this service, the following components are necessary:

/ Service Provider Back Office (see section 4.2.2.2.3 of D3.3 for details).

/ Communication Provider Back Office (see section 4.2.2.2.1 of D3.3 for details).

/ Roadside System (see section 4.2.3.2.1 of D3.3 for details).

/ Personal Information Device (see section 4.2.5.2.1 of D3.3 for details).

/ Traffic Management System (See section 4.2.2.2.5 of D3.3 for details).

/ On Board Unit (see section 4.2.4.2.1 of D3.3 for details).

/ Roadside Unit (see section 4.2.3.2.2 of D3.3 for details).

The relations between these components are described below, in the section 2.5.2.2 The general functionality of the components, as well as more detailed interactions among them, are further described in UML Sequence Diagrams, including the different use cases of the service. More specifically, the use cases are:

/ Information on parking lots location, availability and services via internet (see Appendix A of D3.3).

/ Information on parking lots location, availability and services via I2V (see Appendix A of D3.3).

/ Information about a truck parking space released by a user (see Appendix A of D3.3).

/ Reservation of a truck parking space released by a user (see Appendix A of D3.3).

/ Guide the truck in the port (terminal or truck parking) (see Appendix A of D3.3).

2.5.2.2. Component Connections

The following section describes the relations between the several components. Figure 10 presents all the involved components and the connections between them, including all the use cases of the service.

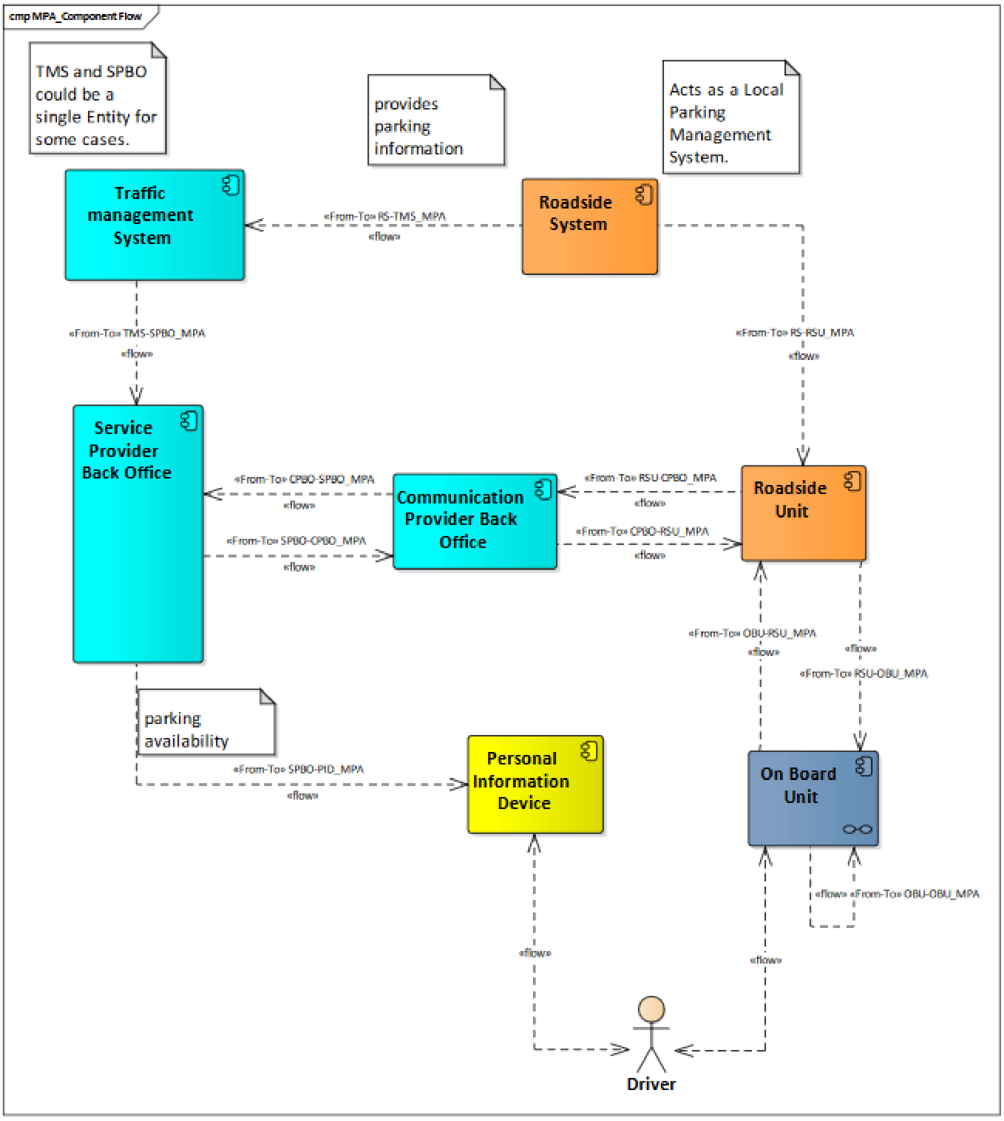

Figure 10 Motorway Parking Availability - Components and communication flows

For this service, the parking spaces information is provided in real-time by the manager of the highway where MPA is deployed. They get that data with sensors on the Truck parking spaces and provide an updated status periodically.

Then that status data is aggregated with location data and other fields configured, and the information is stored in an ITS central server. The GeoMessaging server subscribes to this server and is notified every time an updated parking information is available. When this is the case, the information is transmitted to the smartphones using the C-MobILE GeoMessaging architecture.

Table 2 Motorway Parking Availability - Protocols used for connections

Name	From	To	Protocol Layer						Datatypes Reference
			Application	Facilities	Transport & Networking	Access	Management	Security	
RS-TMS_MPA	RS	TMS	HTTPS	POI	IPv4, IPv6, TCP	Generic Access	TBD	TLS	Not defined yet
RS-RSU-MPA	RS	RSU	HTTPS	POI	IPv4, IPv6, TCP	Generic Access	TBD	ETIS ITS Security, TLS	Not defined yet
SPBO-TMS_MPA	SPBO	TMS	SFTP	Proprietary CSV	IPv4, IPv6, TCP	Generic Access	TBD	TLS	Not defined yet
SPBO-CPBO_MPA	SPBO	CPBO	TCP	Proprietary JSON	IPv4, IPv6, TCP	Generic Access	TBD	ETIS ITS Security, TLS	Not defined yet
SPBO-PID_MPA	SPBO	PID	MQTT	POI	IPv4, IPv6, TCP	3GPP 4G Suite, 3GPP 3G Suite	TBD	ETIS ITS Security, TLS	Not defined yet
CPBO-SPBO_MPA	CPBO	SPBO	TCP	Proprietary JSON	IPv4, IPv6, TCP	Generic Access	TBD	ETIS ITS Security, TLS	Not defined yet
CPBO-RSU_MPA	CPBO	RSU	MQTT	POI, MQTT	IPv4, IPv6, TCP	Generic Access	TBD	ETIS ITS Security, TLS	Not defined yet
RSU_CPBO_MPA	RSU	CPBO	MQTT	POI, MQTT	IPv4, IPv6, TCP	Generic Access	TBD	ETIS ITS Security, TLS	Not defined yet
RSU-OBU_MPA	RSU	OBU	-	POI	GeoNetworking	ETSI ITS G5	TBD	ETIS ITS Security	Not defined yet
OBU_RSU	OBU	RSU	-	POI	GeoNetworking	ETSI ITS G5	TBD	ETIS ITS Security	Not defined yet
OBU-OBU_MPA	OBU	OBU	-	POI	GeoNetworking	ETSI ITS G5	TBD	ETIS ITS Security	Not defined yet
TMS-SPBO_MPA	TMS	SPBO	SFTP	Proprietary CSV	IPv4, IPv6, TCP	Generic Access	TBD	TLS	Not defined yet

RS-TMS_MPA	RS	TMS	-	TBD	IPv4, IPv6	Generic Access	TBD	TBD	Not defined yet

The table above shows the protocols which shall be used for the respective layer. Those listings may also contain alternatives, e.g. IPv4 or IPv6. The specific reference for the used protocols is listed in Appendix B of D3.3.

The protocol layers used follow the protocol stack as defined by ETSI. See ETSI EN 302 665 for details.

2.5.3. S03 - UPA (Urban Parking Availability)

UPA provides parking availability information and guidance for drivers to make informed choices about available parking places. This service aims to reduce congestion, time loss, pollution, and stress caused by cruising for parking.

Information on urban parking availability is aimed to provide efficiency benefits to drivers and help to reduce emissions and congestions on urban areas by reducing the time spent searching for parking. [3]

2.5.3.1. Involved Components

This section presents, the components involved in the Urban Parking Availability service. Furthermore, it lists the various sequence diagrams, which were created to describe the service. The foundation of the service description is the component diagram, as shown below in Figure 11.

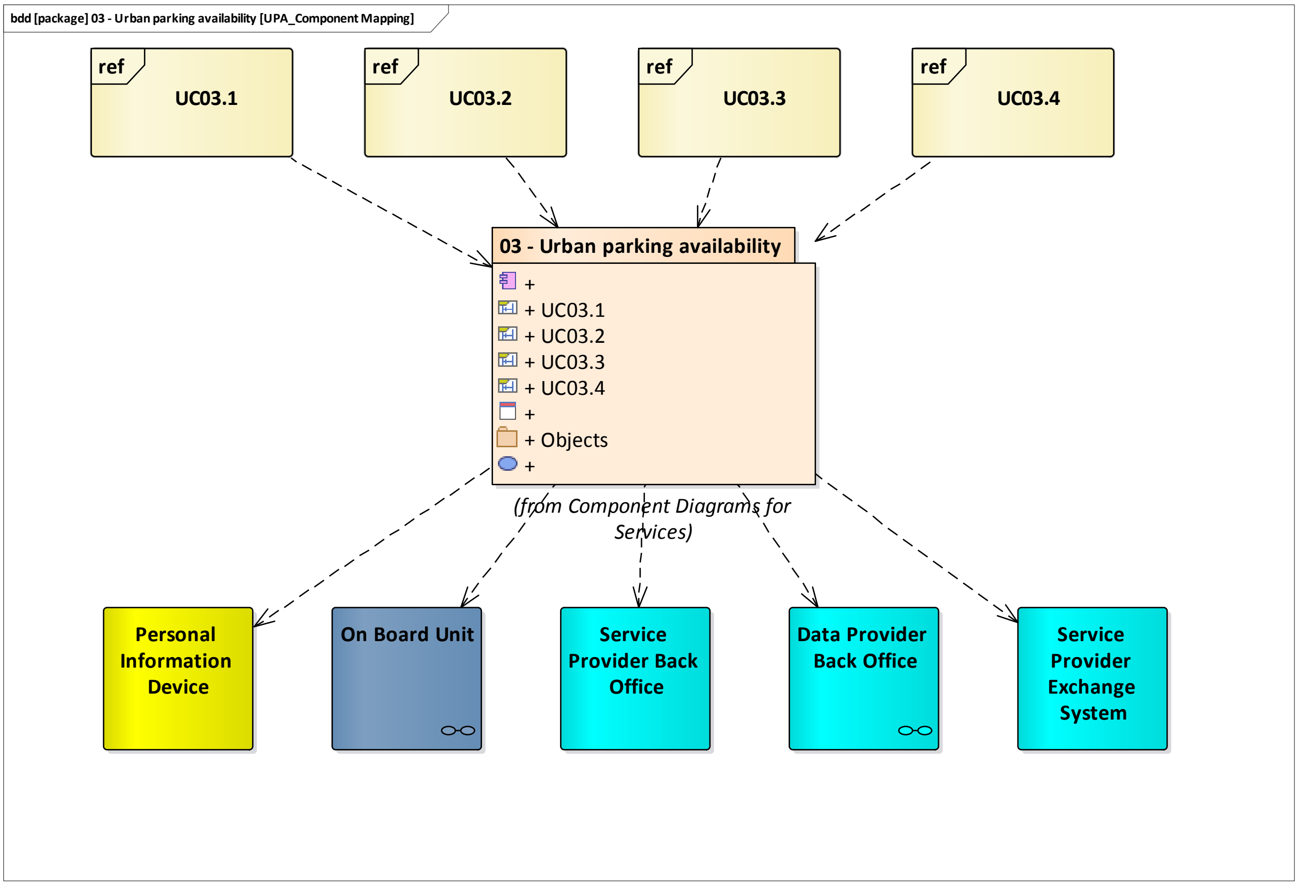

Figure 11 Urban Parking Availability - Components involved in service

Urban parking availability is described with four (4) use cases addressing a wide variety of vehicles and users. The main objective is to provide parking information and reservation information to the drivers restricted to urban areas. The four use cases are:

- UC03.1 “Information about a vehicle parking space released by a user”. (Appendix A of D3.3)
- UC03.2 “Reservation of a vehicle parking space released by a user”. (Appendix A of D3.3)
- UC03.3 “Information about on-street parking availability for urban freight (loading zones)”. (Appendix A of D3.3)
- UC03.4 “Information about on-street parking availability for private car drivers”. (Appendix A of D3.3)

The first two use cases are described using cooperative communication (Vehicle-to-Vehicle) while the last two use cases are addressed for cellular communication (connected approach).

Therefore, depending on the communication method used, the architecture for each use case as well as the relations among the components would vary. Moreover, certain particular functionalities of the use cases allowing special operations/actions from the user side may need extra connections. In general, the architecture components needed to operate the UPA service are the following:

- Personal Information Device (see section 4.2.5.2.1 of D3.3 for details.)
- On Board Unit (see section 4.2.4.2.1 of D3.3 for details.)
- Service Provider Back Office (see section 4.2.2.2.3 of D3.3 for details.)
- Data Provider Back Office (see section 4.2.2.2.4 of D3.3 for details.)
- Service Provider Exchange Systems (see section 4.2.3.2.2 of D3.3 for details.)

The following section describes the flows among the architecture components.

2.5.3.2. Component Connections

The following section describes the relations between the several components. Figure 12 presents all the involved components and the connections between them, including all use cases of the service.

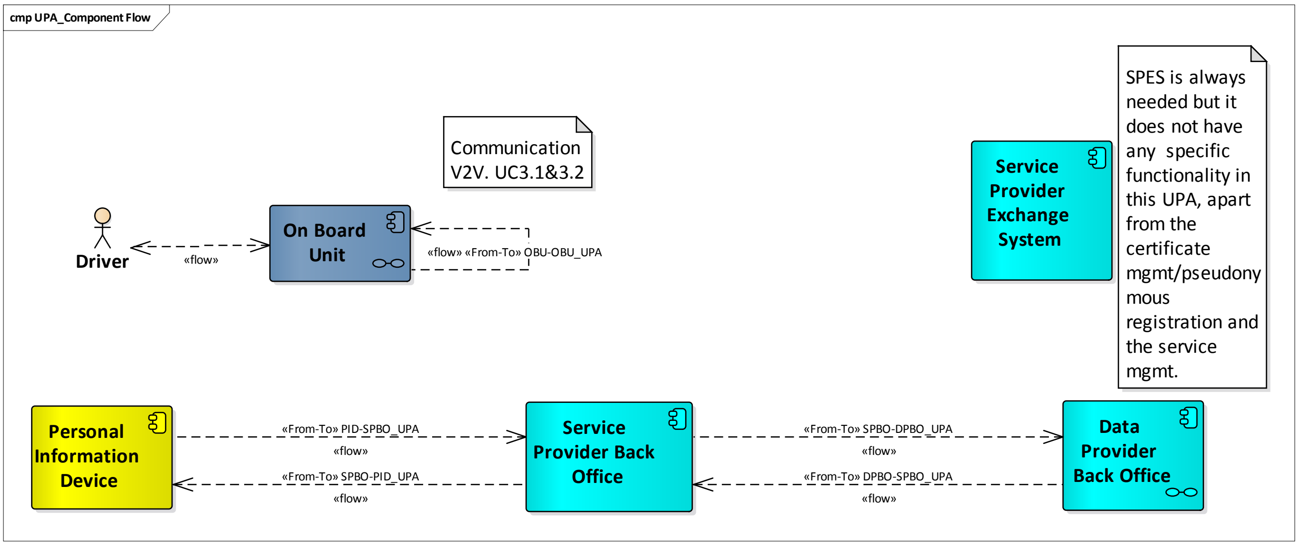

Figure 12: Urban Parking Availability - Components and communication flows

In case of Bilbao, several cars are used for scanning the street parking availability (On street parking monitoring fleet, which is the Data Provider Back Office). Next, the information is merged and processed in Service Provider Back-Office to provide information for each stretch at the city center. This information is located at Bilbao's Open Data and its interface is in DATEX II format.

On the other hand, the PID contains an API for the interface with the Registration Server and the GeoMessaging Server. The GeoMessaging Server gets the information of street parking availability from the Open Data. The User App also provides mobility data of each user to Bilbao Data Base.

Table 3 Urban Parking Availability - Protocols used for connections

Name	From	To	Protocol Layer						Datatypes Reference
			Application	Facilities	Transport & Networking	Access	Management	Security	
SPBO-DPBO_UPA	SPBO	DPBO	HTTP	SPDP, TTI(TPEG2), JSON	IPv4, IPv6, TCP	Generic Access	SNMP	TLS	Not defined yet
SPBO-PID_UPA	SPBO	PID	HTTP	SPDP, TTI(TPEG2), JSON	IPv4, IPv6, TCP	3GPP 4G Suite, 3GPP 3G Suite	SNMP	TLS	Not defined yet
PID-SPBO_UPA	PID	SPBO	HTTP	SPDP, TTI(TPEG2), JSON	IPv4, IPv6, TCP	3GPP 4G Suite, 3GPP 3G Suite	SNMP	TLS	Not defined yet
DPBO-SPBO_UPA	DP BO	SPBO	HTTP	DATEX, XML, JSON	IPv4, IPv6, TCP	Generic Access	SNMP	TLS	Not defined yet
OBU-OBU_UPA	OBU	OBU	ETSI ITS BSA	SPDP, TTI(TPEG2), JSON	GeoNetworking	ETSI ITS G5	Tpeg2-mmc	ETIS ITS Security, TPEG2-LTE	Not defined yet

The table above shows the protocols which shall be used for the respective layer. Those listings may also contain alternatives, e.g. IPv4 or IPv6. The specific reference for the used protocols is listed in Appendix B of D3.3.

The protocol layers used follow the protocol stack as defined by ETSI. See ETSI EN 302 665 for details.

2.5.4. S04 - RWW (Road Works Warning)

The Service is providing in-vehicle information and warnings about road works, changes to the road layout and applicable driving regulations. Road works usually affect the road layout, driving regulations, etc. Despite dedicated signage prior to road works zones, such changed conditions frequently come as a surprise to vehicle drivers. This may lead to increased risk and sometimes even accidents, both for road users and workers.

The objectives of this service are more attentive driving while approaching and passing a work zone by providing in-vehicle information and warnings about road works, changes to the road layout and applicable driving regulations. [3]

2.5.4.1. Involved Components

This section shows, which components are involved in this service. Furthermore, it lists the various sequence diagrams, which have been created to describe the service. The foundation of the service description is the component diagram, as shown below in Figure 13.

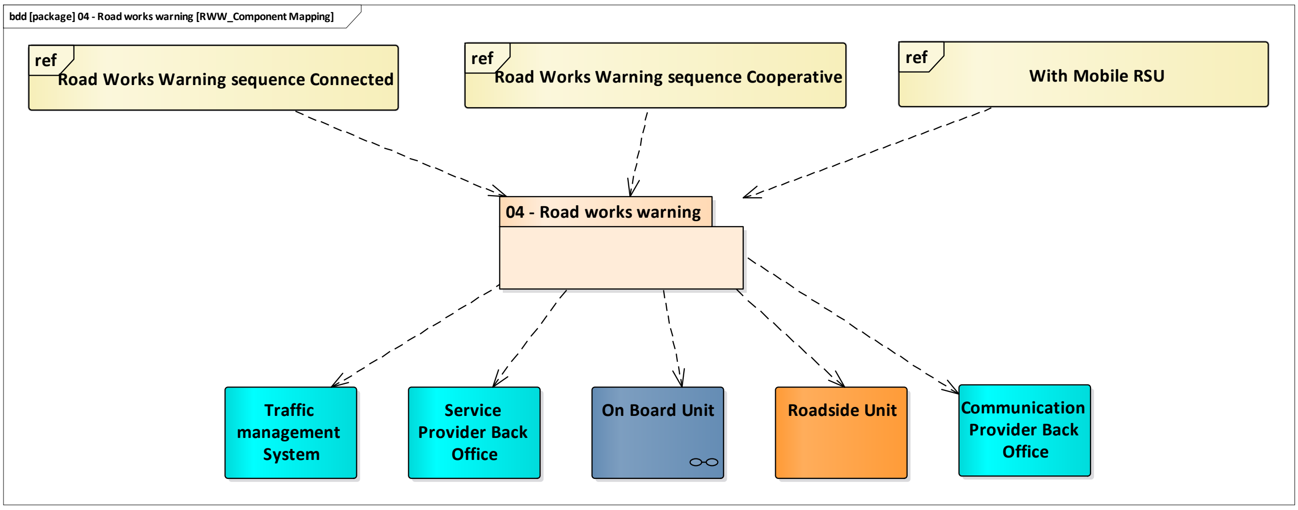

Figure 13: Road Works Warning - Components involved in service

To implement this service, the following components are necessary.

- Traffic Management System (See section 4.2.2.2.5 of D3.3 for details)
- Service Provider Back Office (see section 4.2.2.2.3 of D3.3 for details.)
- On Board Unit (see section 4.2.2.2.1 of D3.3 for details.)
- Roadside Unit (see section 4.2.2.2.2 of D3.3 for details.)
- Communication Provider Back Office (see section 4.2.2.2.1 of D3.3 for details.)

The relations between those components are described in the section 2.5.4.2, below. The general functionality of these services, as well as more detailed interactions of the involved components are further described in UML Sequence Diagrams for the different use cases on which this service is based. This are in particular:

- “Road Works Warning Sequence Connected” as shown in section 7.1.4.1.1 of D3.3
- “Road Works Warning Sequence Cooperative” as shown in section 7.1.4.1.2 of D3.3
- “With Mobile RSU” as shown in section 7.1.4.1.3 of D3.3

2.5.4.2. Component Connections

The following section describes the relations between the several components. In Figure 14 all the involved components and the connections between them are listed for all use cases of the service.

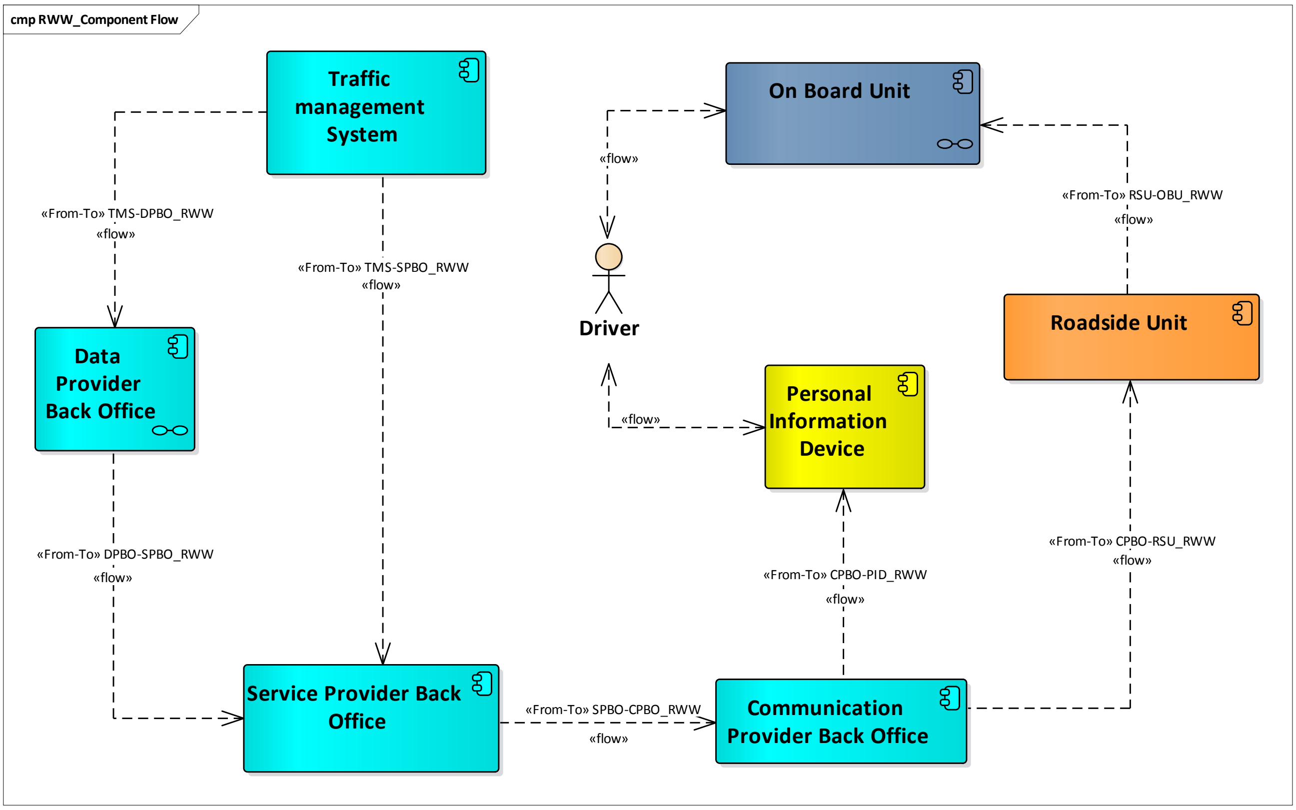

Figure 14: Road Works Warning – Components and communication flows

In the Road Works Warning Sequence Connected and Road Works Warning Sequence Cooperative scenarios, the Traffic Management System (TMS) either uses the TMS-DPBO_RWW connection to broadcast an update on roadworks to Data Provider Back Office (DPBO) (which in turn uses the DPBO-SPBO_RWW connection to update the same to Service Provider Back Office (SPBO)), or the TMS-SPBO_RWW connection to broadcast the update on roadworks directly to the SPBO. The SPBO then forwards the update to the Communication Provider Back Office (CPBO) over the SPBO-CPBO_RWW connection.

Then, in Road Works Warning Sequence Connected scenario, the CPBO forwards the message directly to the Personal Information Device (PID) for the user to view over the CPBO-PID_RWW connection, whereas in the Road Works Warning Sequence Cooperative scenario, the CPBO uses the CPBO-RSU_RWW connection to forward the message to the Roadside Unit (RSU) that in turn forwards the message to the On Board Unit (OBU) via the RSU-OBU_RWW connection, where the user can see it on the OBU.

In the Mobile RSU scenario, a Mobile RSU (basically a road works vehicle stationed downstream from the location where the road works is occurring) transmits the update on roadworks directly to the OBU via the RSU-OBU_RWW connection.

Table 4 Roads Works Warning - Protocols used for connections

Name	From	To	Protocol Layer						Datatypes Reference
			Application	Facilities	Transport & Networking	Access	Management	Security	
TMS-DPBO_RWW	TMS	DPBO	-	DATEX II or proprietary format	IPv6, IPv4, TCP	Generic Access	SNMP	TLS	Not defined
TMS-SPBO_RWW	TMS	SPBO	-	DATEX II or proprietary format	IPv6, IPv4, TCP	Generic Access	SNMP	TLS	Not defined
DPBO-SPBO_RWW	DPBO	SPBO	-	DATEX II or proprietary format	IPv6, IPv4, TCP	Generic Access	SNMP	TLS	Not defined
SPBO-CPBO_RWW	SPBO	CPBO		ETSI ITS DENM	IPv6, IPv4, TCP	Generic Access	SNMP	TLS	Figure 183 of D3.3
CPBO-PID_RWW	CPBO	PID	-	ETSI ITS DENM, MQTT	IPv4, IPv6, TCP	3GPP 4G Suite, 3GPP 3G Suite	SNMP	TLS	Figure 184 of D3.3
CPBO-RSU_RWW	CPBO	RSU	-	ETSI ITS DENM, MQTT	IPv4, IPv6, TCP	Generic Access	SNMP	TLS	Figure 185 of D3.3
RSU-OBU_RWW	RSU	OBU	-	ETSI ITS DENM	GeoNetworking	ETSI ITS G5	ETSI 102 890-1, G5 Congestion Control Mgmt.	ETSI ITS-S Security Arch.	Figure 186 of D3.3

The table above shows the protocols which shall be used for the respective layer. Those listings may also contain alternatives, e.g. IPv4 or IPv6. The specific reference for the used protocols is listed in Appendix B of D3.3.

The protocol layers used follow the protocol stack as defined by ETSI. See ETSI EN 302 665 for details.

2.5.5. S05 -RHW (Road Hazard Warning)

The road hazard warning service aims to inform the drivers in a timely manner of upcoming, and possibly dangerous events and locations. This allows drivers to be better prepared for the upcoming hazards and make necessary adjustments and maneuvers in advance (this is also known as "Hazardous location notification" (ETSI, 2009) or 'Road hazard signaling').

The objectives are enabling vehicle drivers to be better prepared for upcoming hazards by providing timely in-vehicle driving assistance information on hazardous locations downstream of the current position and in the driving direction of the vehicle. [3]

2.5.5.1. Involved Components

This section shows, which components are involved in this service. Furthermore, it lists the various sequence diagrams, which have been created to describe the service. The foundation of the service description is the component diagram, as shown below in Figure 15.

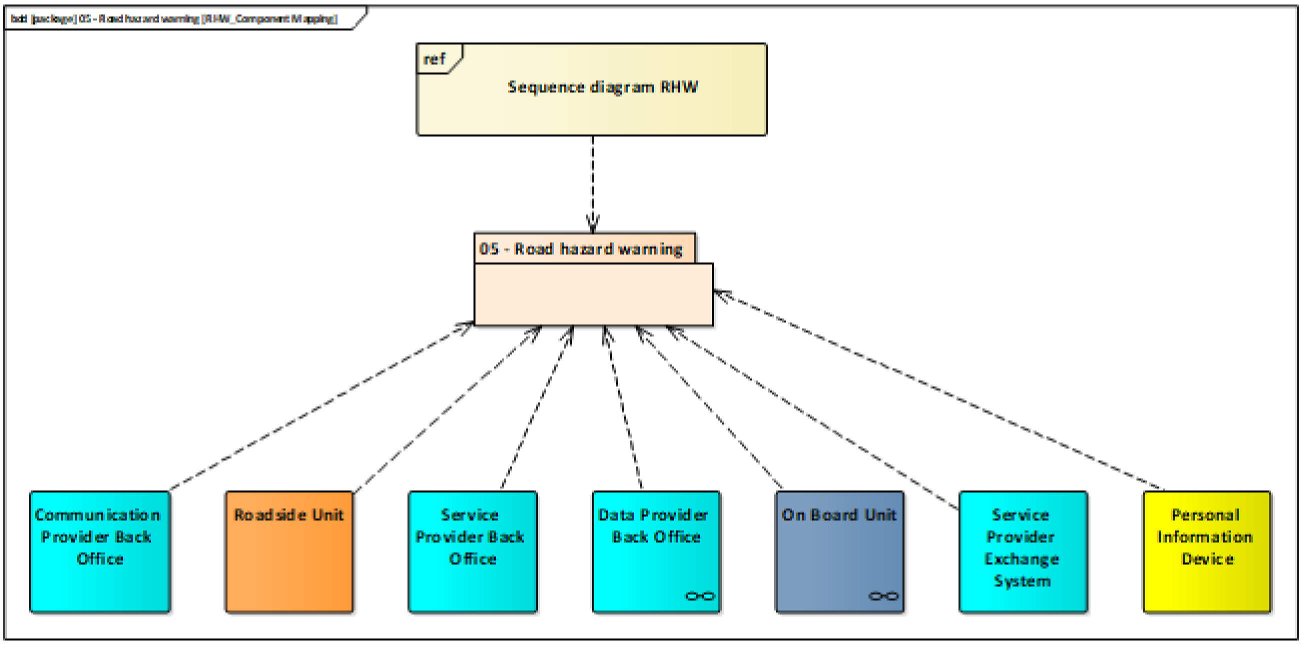

Figure 15 Road Hazard Warning - Components involved in service

To implement this service, the following components are necessary or optional:

- Communication Provider Back Office (see section 4.2.2.2.1 of D3.3 for details.)
- Roadside Unit, optional, required for 802.11p communication only (see section 4.2.3.2.2 of D3.3 for details.)
- Service Provider Back Office (see section 4.2.2.2.3 of D3.3 for details.)
- Data Provider Back Office (see section 4.2.2.2.4 of D3.3 for details.)
- On Board Unit, optional, required for 802.11p communication only (see section 4.2.4.2.1 of D3.3 for details.)
- Service Provider Exchange Systems, optional, services could connect manually as well (see section 4.2.3.2.2 of D3.3 for details.)
- Personal Information Device (see section 4.2.5.2.1 of D3.3 for details.)

The relations between those components are described in the section 2.5.5.2, below. The general functionality of these services, as well as more detailed interactions of the involved components is further described in Sequence Diagrams for the different use cases on which this service is based and can be found in Figure 187 of D3.3.

2.5.5.2. Component Connections

The following section describes the relations between the components. In Figure 16 all the involved components and the connections between them are listed for all use cases of the service.

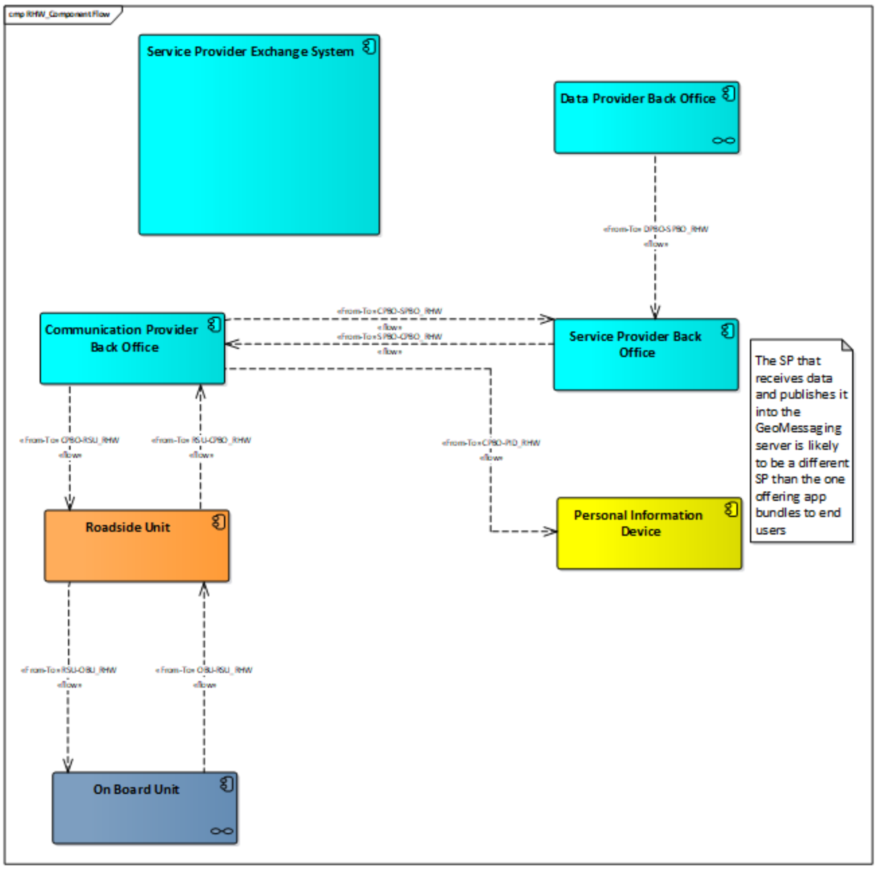

Figure 16: Road Hazard Warning – Components and communication flows

The sequence diagram above shows the communication actors in VIGO DS (as an example). The information originates at the Data Provider Back Office (DPBO), which could be a Traffic Management system (TMS), but also a data sharing platform when information is crowdsourced by a community, which is common for road hazards. The Service Provider Back Office (SPBO) then reads this data and transforms it to C-MobILE standards, which means encapsulating the information in DENM messages. One of the main challenges here is the location references as data providers often use road names instead of geographical coordinates as reference. The SPBO pushes the data into the CPBO. At this point there are two possible paths, either the information gets directly forwarded to Personal Information Devices (PIDs) in the relevant area, or 802.11p communication is used. In the latter case a Road Side Unit (RSU) in the relevant area receives the information and broadcasts the messages. These messages will be picked up by On Board Units (OBUs) and they will forward them to the HMI to display to the end-users.

Table 5 Road Hazard Warning - Protocols used for connections

Name	From	To	Protocol Layer						Datatypes Reference
			Application	Facilities	Transport & Networking	Access	Management	Security	
DPBO-SPBO_RHW	DPBO	SPBO	local	AMQP	IPv6, IPv4, TCP	Generic Access	any	any	Not defined yet
SPBO-CPBO_RHW	SPBO	CPBO	-	ETSI ITS DENM, MQTT	IPv6, IPv4, TCP	Generic Access	SNMP	TLS	Not defined yet
CPBO-PID_RHW	CPBO	PID	-	ETSI ITS DENM, MQTT	IPv4, IPv6, TCP	3GPP 4G Suite, 3GPP 3G Suite	SNMP	TLS	Not defined yet
CPBO-RSU_RHW	CPBO	RSU	-	ETSI ITS DENM, MQTT	IPv4, IPv6, TCP	Generic Access	SNMP	TLS	Not defined yet
RSU-OBU_RHW	RSU	OBU	-	ETSI ITS DENM	GeoNetworking	ETSI ITS G5		ETSI ITS-S Security Architecture	Not defined yet

The table above shows the protocols which shall be used for the respective layer. Those listings may also contain alternatives, e.g. IPv4 or IPv6. The specific reference for the used protocols is listed in Appendix B of D3.3. It should be noted that the DPBO is out of scope of C-MobILE with many projects under the umbrella of C-Roads setting the standards at that level (e.g. NordicWay, SCOOP@F and InterCor). This is therefore labelled as “local” to indicate that deployment sites can have different protocols here. Once the data reaches the SPBO, there is no applicable application anymore. MQTT is the highest-level protocol used by the communicating applications, which is used to push DENMs via backend GeoMessaging to the receiver.

The protocol layers used follow the protocol stack as defined by ETSI. See ETSI EN 302 665 for details.

2.5.6. S06 - EVW (Emergency Vehicle Warning)

The main objective of Emergency Vehicle Warning (EVW) is to provide an early warning indication of an emergency vehicle that is approaching and to allow other traffic participants to timely give way to emergency vehicles.

There is no update of the architecture compared to D3.3, and therefore the relevant section and descriptions remain the same.

2.5.6.1. Involved Components

This section shows which components are involved in this service. Furthermore, it lists the various sequence diagrams, which have been created to describe the service. The foundation of the service description is the component diagram, as shown below in Figure 17.

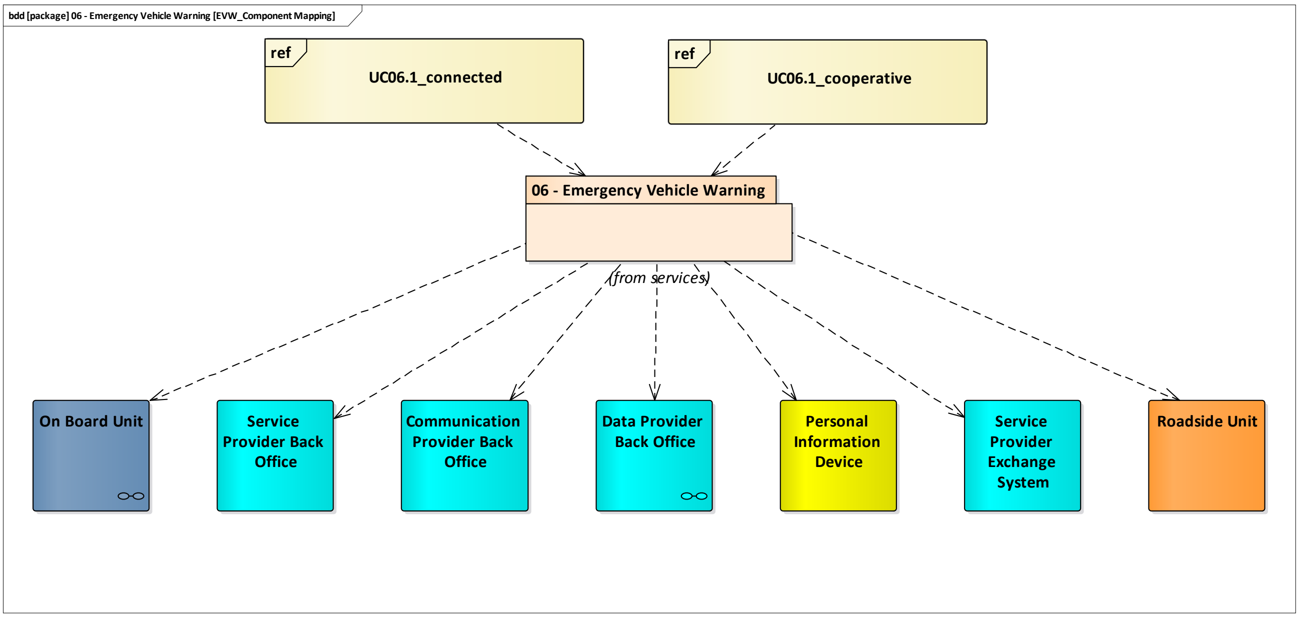

Figure 17: Emergency Vehicle Warning – Components involved in service

The use case (UC06.1) foreseen for this service can be implemented with both communication protocols (cooperative and connected). In general, in order to implement this service, the following components are necessary:

- / On Board Unit (see section 4.2.4.2.1 of D3.3 for details.)
- / Service Provider Back Office (See section 4.2.2.2.3 of D3.3 for details)
- / Communication Provider Back Office (See section 4.2.2.2.1 of D3.3 for details)
- / Data Provider Back Office (see section 4.2.2.2.4 of D3.3 for details.)
- / Personal Information Device (see section 4.2.5.2.1 of D3.3 for details.)
- / Service Provider Exchange Systems (see section 4.2.3.2.2 of D3.3 for details.)
- / Roadside Unit (see section 4.2.3.2.2 of D3.3 for details.)

2.5.6.2. Component Connections

The following section describes the relations between the components. In Figure 18 all the involved components and the connections among them are listed for all use cases of the service.

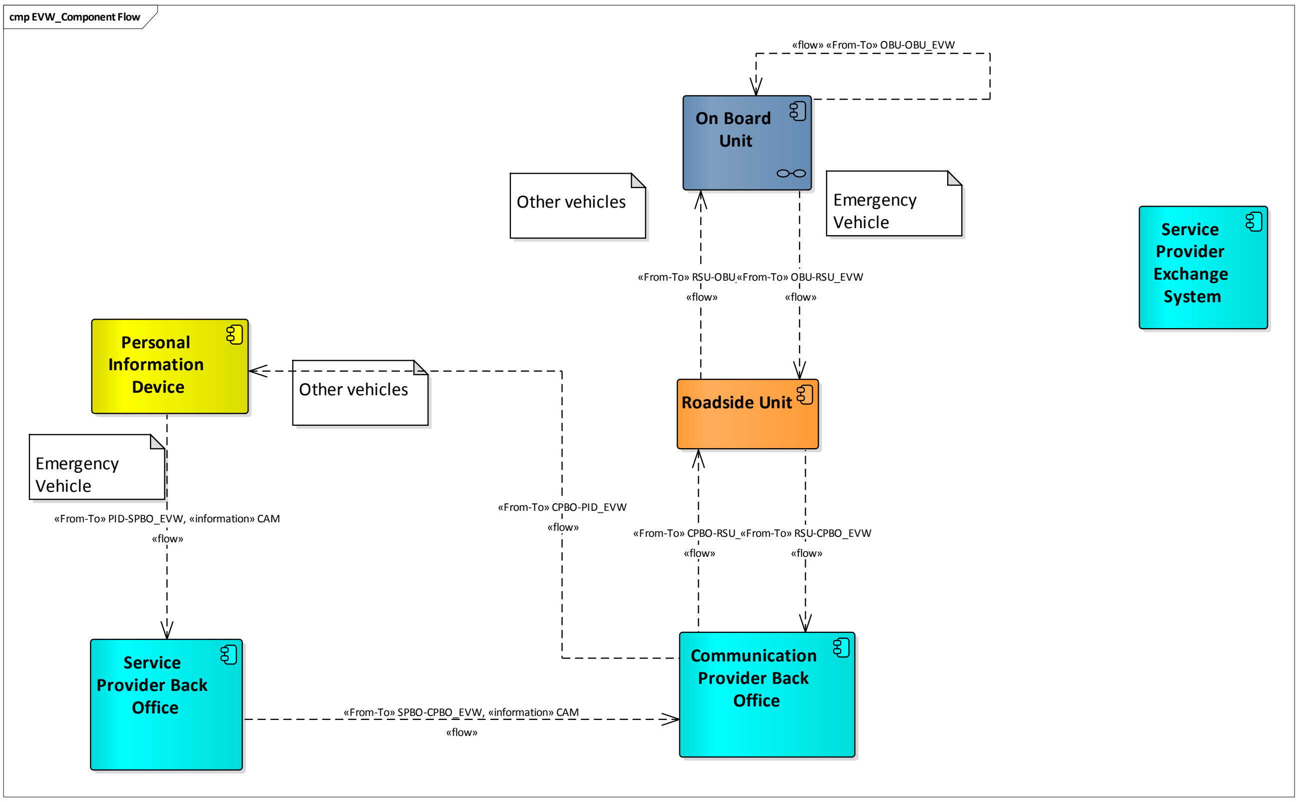

Figure 18: Emergency Vehicle Warning – Components and communication flows

The component flow diagram comprises the relation among the blocks of the architecture for both communication mechanisms at the same time.

In the case of cooperative communication (IEEE 802.11p), the use case starts with the emergency vehicle disseminating a CAM message, via the interface OBU-OBU_EVW in the diagram. This broadcasted message is received by nearby equipped stations (vehicles and Roadside Units) in the communication range of the sending emergency vehicle. Once received, the vehicles determine if the event is relevant for them and show a warning to the driver accordingly. In the case of the Roadside Units (RSU), they need to convert the CAM message into a DENM message and disseminate it down to the vehicles again in the wanted relevance zone.

In the Connected Communication use case (UC06.1), the Personal Information Device (PID) of the emergency vehicle uses the PID-SPBO_EVW to send the CAM message to the Service Provider Back Office (SPBO) using a cellular communication. The SPBO forwards the message to the Communication Provider Back Office (CPBO) over the SPBO-CPBO_EVW connection in order to initiate the dissemination of the message to the other vehicles (PIDs). Therefore, the CPBO uses the GeoMessaging to be able to “broadcast” the original CAM message or a CAM-based DENM message to the relevant vehicles using a cellular communication.

In both cases, the vehicles equipped with the corresponding communication mechanism can receive the message. This means that in the cooperative case, the message can be sent from the RSU to the CPBO in order to reach the cellular stations and, in the connected case, the CPBO can also forward the CAM message to the RSU to reach the OBUs (after creating the corresponding DENM from the CAM message).

Table 6 Emergency Vehicle Warning - Protocols used for connections

Name	From	To	Protocol Layer						Datatypes Reference
			Application	Facilities	Transport & Networking	Access	Management	Security	
SPBO-CPBO_EVW	SPBO	CPBO	-	ETSI ITS CAM, MQTT	IPv4, IPv6, TCP	Generic Access	SNMP	TLS, ETSI ITS-S Security Architecture	Figure 197 of D3.3
CPBO-PID_EVW	CPBO	PID	-	ETSI ITS CAM, ETSI ITS DENM, MQTT	IPv4, IPv6, TCP	3GPP 4G Suite, 3GPP 3G Suite	SNMP	TLS, ETSI ITS-S Security Architecture	Figure 190 of D3.3
CPBO-RSU_EVW	CPBO	RSU	-	ETSI ITS CAM, ETSI ITS DENM, MQTT	IPv4, IPv6, TCP	Generic Access	SNMP	TLS, ETSI ITS-S Security Architecture	Figure 191 of D3.3
PID-SPBO_EVW	PID	SPBO	HTTPS	ETSI ITS CAM	IPv4, IPv6, TCP	3GPP 4G Suite, 3GPP 3G Suite	SNMP	TLS	Figure 194 of D3.3
OBU-OBU_EVW	OBU	OBU	ETSI ITS BSA	ETSI ITS CAM	GeoNetworking	ETSI ITS G5	TBD	ETSI ITS-S Security Architecture	Figure 192 of D3.3
OBU-RSU_EVW	OBU	RSU	ETSI ITS BSA	ETSI ITS CAM	GeoNetworking	ETSI ITS G5	TBD	ETSI ITS-S Security Architecture	Figure 193 of D3.3
RSU-OBU_EVW	RSU	OBU	ETSI ITS BSA	ETSI ITS DENM	GeoNetworking	ETSI ITS G5	TBD	ETSI ITS-S Security Architecture	Figure 196 of D3.3
RSU-CPBO_EVW	RSU	CPBO	-	ETSI ITS CAM, ETSI ITS DENM, MQTT	IPv4, IPv6, TCP	Generic Access	TBD	TLS, ETSI ITS-S Security Architecture	Figure 195 of D3.3

The table above shows the protocols which shall be used for the respective layer. Those listings may also contain alternatives, e.g. IPv4 or IPv6. The specific reference for the used protocols is listed in Appendix B of D3.3.

The protocol layers used follow the protocol stack as defined by ETSI. See ETSI EN 302 665 for details.

2.5.7. S07 - SVW (Signal Violation Warning)

Signal Violation Warning aims to reduce the number and severity of collisions at signalised intersections. Within C-MobILE the service provides a warning to drivers who are likely - due to high speed - to violate a red light. Warning other road users about a vehicle likely to make a red-light violation is not implemented.

This service is also known as "Signal violation / Intersection Safety" or "Red Light Violation Warning".

The objectives of this service are providing timely in-vehicle driving assistance information on a signal violation downstream of the current position and in the driving direction of the vehicle.[3]

The update of the architecture reflects that this service will only be provided using cellular technologies and that it is used in conjunction with GLOSA.

2.5.7.1. Involved Components

This section shows which components are involved in this service. Furthermore, it lists the different sequence diagrams for each use case and communication protocol, which have been created to describe the service. The foundation of the service description is the component diagram, as shown below.

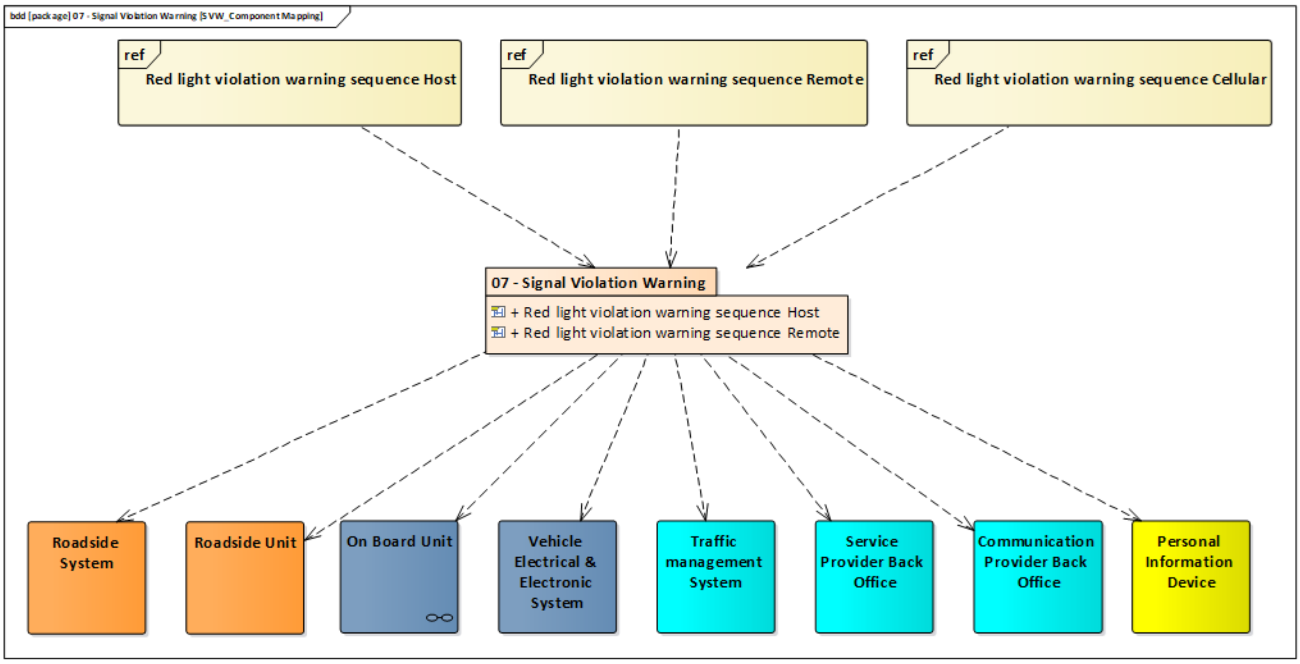

Figure 19: Signal Violation Warning - Components involved in service

To implement this service, the following components are necessary.

- / Roadside System (see section 4.2.3.2.1 of D3.3 for details.)
- / Roadside Unit (see section 4.2.3.2.2 of D3.3 for details.)
- / On Board Unit (see section 4.2.4.2.1 of D3.3 for details.)
- / Vehicle Electrical & Electronic System (see section 4.2.4.2.2 of D3.3 for details.)
- / Traffic Management System (See section 4.2.2.2.5 of D3.3 for details)
- / Service Provider Back Office (See section 4.2.2.2.3 of D3.3 for details)
- / Communication Provider Back Office (See section 4.2.2.2.1 of D3.3 for details)
- / Personal Information Device (See section 4.2.5.2.1 of D3.3 for details)

The relations between those components are described in the section 2.5.7.2, below. The general functionality of these services, as well as more detailed interactions of the involved components is further described in UML Sequence Diagrams for the different use cases on which this service is based. These are in particular:

- / UC07.1 Red light violation warning sequence Host as shown in Figure 133 of D3.3
- / UC07.1 Red light violation warning sequence Remote as shown in Figure 199 of D3.3

2.5.7.2. Component Connections

The following section describes the relations between the components. In Figure 20 all the involved components and the connections between them are listed for all use cases of the service.

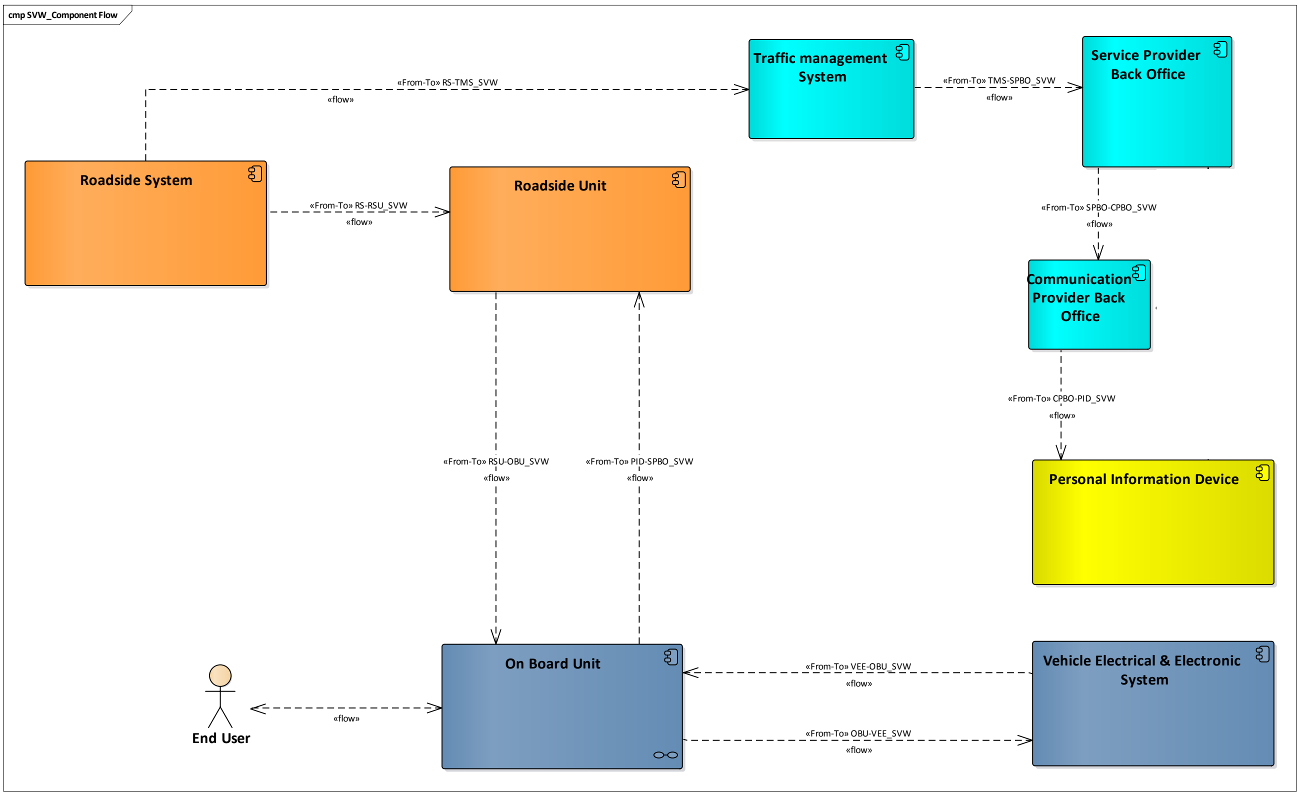

Figure 20: Signal Violation Warning – Components and communication flows

For SVW the Roadside Unit (RSU) receives information about the intersection state and layout through the RS-RSU_SVW connection by a Roadside System (RS).

This information is distributed to the On Board Unit (OBU) over the RSU-OBU_SVW relation in form a SPATEM and MAPEM messages, which can then determine a possible violation and warn the driver (UC07.1). Alternatively, the OBU shares the vehicle state to the RSU through the OBU-RSU_SVW connection using CAM messages, then the RSU can determine the violation and distribute the warning to other vehicles (UC07.2). This is however not implemented.

The vehicle state information can be read from the Vehicle Electrical & Electronic System (VEE). Therefore, the connections VEE-OBU_SVW and OBU-VEE_SVW are used. Those connections are out of scope in C-MobILE and are highly dependent on the Deployment Sites.

Some cities have red light violation detectors (e.g. cameras) in the road infrastructure (RS), which can determine possible red-light violations and order the RSU to send a DENM messages to the vehicle (OBU) to warn the driver.

For the cellular case, the traffic lights information is sent from the RS to the Traffic Management System (TMS), which provide this data to the Service Provider Back Office (SPBO) using the TMS-SPBO_SVW connection. The SPBO will forward, in form SPATEM and MAPEM messages, this timing and phase information and also the intersection layout to the Personal Information Device (PID) as for the GLOSA service.,The PID can then calculate possible violations of the red light using its location and speed values provided by the GPS. In this case, the calculation responsibility is never given to the SPBO as the latency is too high for an adequate warning to the driver.

Table 7 Signal Violation Warning - Protocols used for connections

Name	From	To	Protocol Layer						Datatypes Reference
			Application	Facilities	Transport & Networking	Access	Management	Security	
RS-RSU_SVW	RS	RSU	UTMC TS004.006	UTMC TS003, ETSI ITS SPATEM, ETSI ITS DENM	IPv4, IPv6, TCP	Generic Access	IETF RFC 1907	IETF RFC 6347	Figure 200 of D3.3
RSU-OBU_SVW	RSU	OBU	SAE J2735, CEN ISO 19091, ETSI 102 894-2	ETSI 103 301, ETSI ITS DENM	GeoNetworking	ETSI ITS G5	G5 Congestion Control Management	ETSI IST-S Security Architecture	Figure 201 of D3.3
OBU-RSU_SVW	OBU	RSU	ETSI 102-894-2, ETSI 102 638	ETSI ITS CAM	GeoNetworking	ETSI ITS G5	ETSI 102 890-1, G5 Congestion Control Management	ETSI ITS-S Security Architecture	Figure 203 of D3.3
OBU-VEE_SVW	OBU	VEE	Out of scope						
VEE-OBU_SVW	VEE	OBU	Out of scope						
RS-TMS_SVW	RS	TMS	DATEX	XML, ETSI ITS SPATEM	IPv4, IPv6, TCP	Generic Access	TBD	TLS, ETSI ITS-S Security Architecture	Not defined yet
TMS-SPBO_SVW	TMS	SPBO	DATEX	XML, ETSI ITS SPATEM	IPv4, IPv6, TCP	Generic Access	TBD	TLS, ETSI ITS-S Security Architecture	Not defined yet
SPBO-CPBO_SVW	SPBO	CPBO	-	ETSI ITS SPATEM , ETSI ITS DENM, MQTT	IPv4, IPv6, TCP	Generic Access	TBD	TLS, ETSI ITS-S Security Architecture	Figure 202 of D3.3
CPBO-PID_SVW	CPBO	PID	-	ETSI ITS SPATEM , ETSI ITS DENM, MQTT	IPv4, IPv6, TCP	3GPP 4G Suite, 3GPP 3G Suite	TBD	TLS, ETSI ITS-S Security Architecture	Not defined yet
PID-SPBO_SVW	PID	SPBO	-	ETSI ITS CAM	IPv4, IPv6, TCP	3GPP 4G Suite, 3GPP 3G Suite	TBD	TLS, ETSI ITS-S Security Architecture	Not defined yet

The table above shows the protocols which shall be used for the respective layer. Those listings may also contain alternatives, e.g. IPv4 or IPv6. The specific reference for the used protocols is listed in Appendix B of D3.3.

The protocol layers used follow the protocol stack as defined by ETSI. See ETSI EN 302 665 for details.

2.5.8. S08 - WSP (Warning System for Pedestrian)

"Warning System for Pedestrians (not limited to crossings)" aims to detect risky situations (e.g. road crossing) involving pedestrians and VRUs, allowing the possibility to warn vehicle drivers or to automatically control the vehicle (e.g. braking).

2.5.8.1. Involved Components

This section shows, which components are involved in this service. Furthermore, it lists the various sequence diagrams, which have been created to describe the service. The foundation of the service description is the component diagram, as shown in Figure 21.

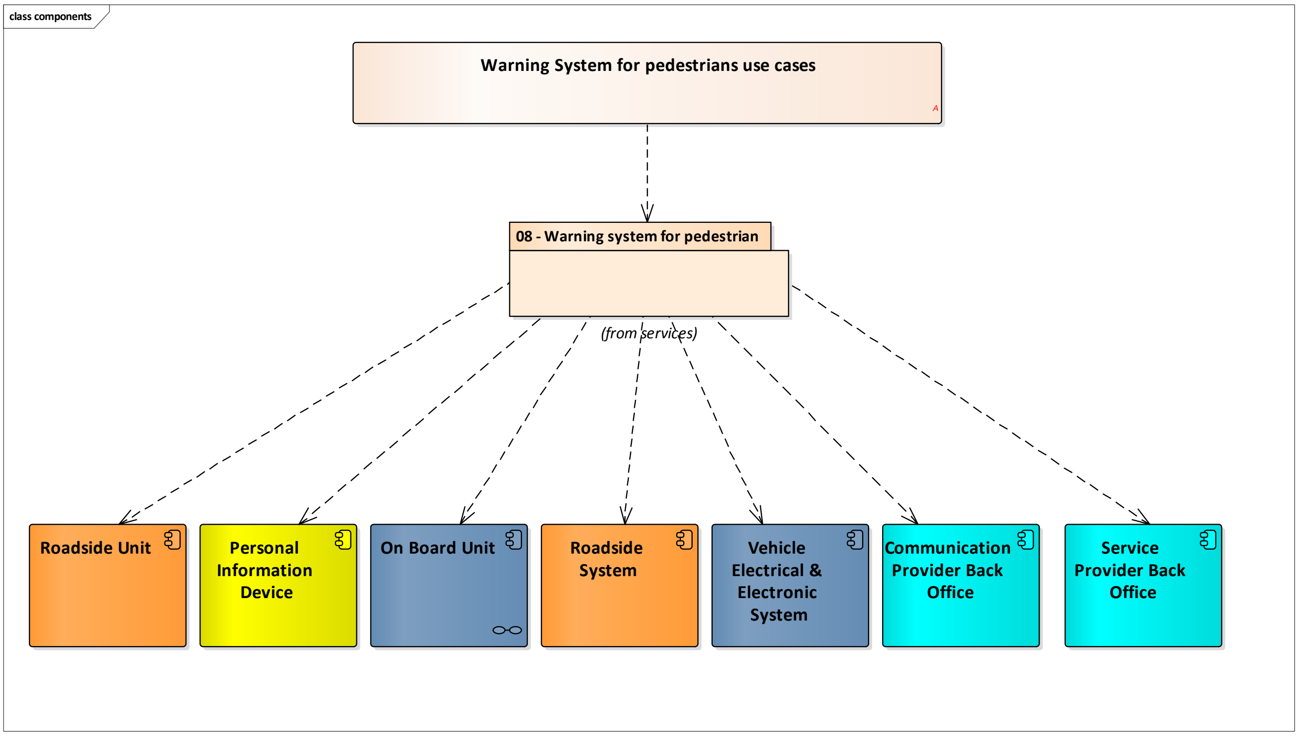

Figure 21: Warning system for pedestrian – Components involved in service

To implement this service, the following components are necessary.

- Roadside Unit (see section 4.2.3.2.2 of D3.3 for details.)
- Personal Information Device (see section 4.2.5.2.1 of D3.3 for details)
- On Board Unit (see section 4.2.4.2.1 of D3.3 for details.)
- Roadside System (see section 4.2.3.2.1 of D3.3 for details). This contains the Road Side Equipment (RSE) such as the Traffic Light Controllers (TLC) and Cameras used to track the Vulnerable Road Users (VRU).
- Vehicle Electrical & Electronic System see section 4.2.4.2.2 of D3.3 for details.)
- Communication Provider Back Office (See section 4.2.2.2.1 of D3.3 for details)
- Service Provider Back Office (See section 4.2.2.2.3 of D3.3 for details)

The relations between those components are described in the section 2.5.8.2, below. The general functionality of these services, as well as more detailed interactions of the involved components is further described in UML Sequence Diagrams for the different use cases on which this service is based. These are in particular:

- Warning system for pedestrians without RSE for detection or traffic lights shown in Figure 204 of D3.3
- Warning system for pedestrians with RSE for VRU detection as shown in Figure 205 of D3.3

/ Warning system for pedestrians Signalled crossing without RSE for VRU detection as shown in Figure 206 of D3.3

/ Warning system for pedestrians Signalled crossing with RSE for VRU detection as shown in Figure 207 of D3.3

/ Warning system for pedestrians Signalled crossing with RSE for VRU detection with cellular communication to the OBU as shown in Figure 208 of D3.3

Use Case	RSE for VRU detection	RSE TLC	RSU	Cellular
1	-	-	-	-
2	X	X	X	-
3	-	-	X	-
4	X	X	X	-
5,6*	X	X	-	X

*Only with cellular communications (PID, CPBO and SPBO involved), without RSE.

2.5.8.2. Component Connections

The following section describes the relations between the components. In the following figures all the involved components and the connections between them are listed for all use cases of the service.

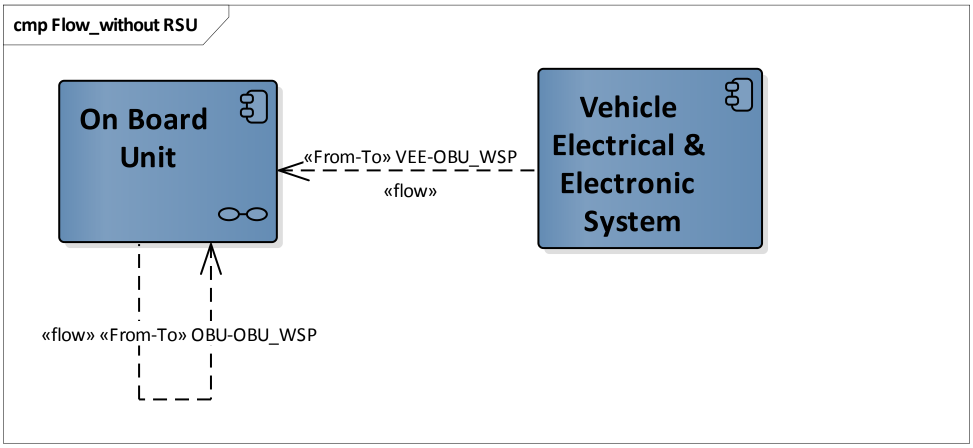

Figure 22: Warning system for pedestrians without RSU or RSE – Components and communication flows UC1

The first use case of the Warning System for Pedestrians (WSP) is that where there are no Road Side Units (RSU), vehicles are communicating via ETSI ITS G5. There are two instances of the OBU component. One is detecting the pedestrian and transmitting the information to the other one whose trajectory possibly collides with the VRU. There is the singularity case where both instances are the same and the OBU detects itself there is an VRU on its trajectory but that is not considered as C-ITS.

The OBU(VRU)-OBU communication consists of a DENM message (See requirement R/S08-WSP-10) with cause code people on the road. The receiving OBU calculates if there is a possible collision with the VRU. If so the OBU informs the driver via the cars HMI. The OBU expects a reaction from the driver such as slow down, take a turn or acknowledge the message. It after a time-out no reaction is detected the safety protocol of the OBU is activated. The OBU-HMI communication and the safety protocol are proprietary car specific implementations.

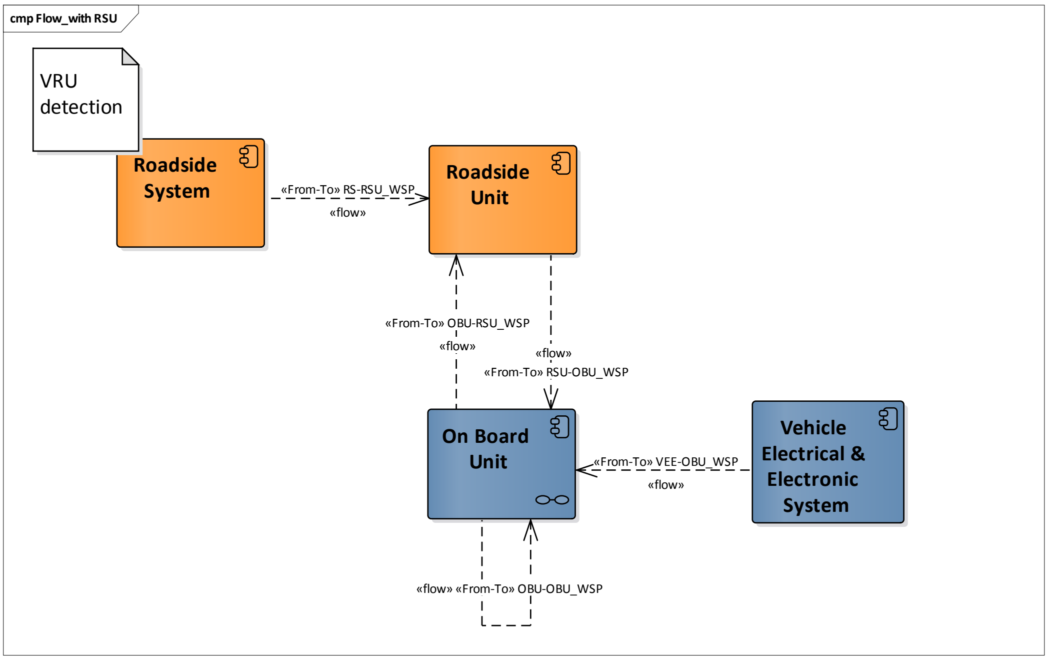

Figure 23: Warning system for pedestrians with RSU and RSE for VRU detection – Components and communication flows UC2

In the case of a unsignalled pedestrian crossing (zebra but no traffic lights) RSE with VRU detection capabilities can be installed. The RSE will monitor the trajectories of the VRU with its detection system. The connected cars indicate their presence with broadcasted CAM messages that are used in the OBU-RSU(VRU) communication flow. The RSE calculates the trajectories of both car and VRU. In case of a conflict the RSE(VRU)-RSU-OBU communication flow uses a DENM message indicating VRU on the road.

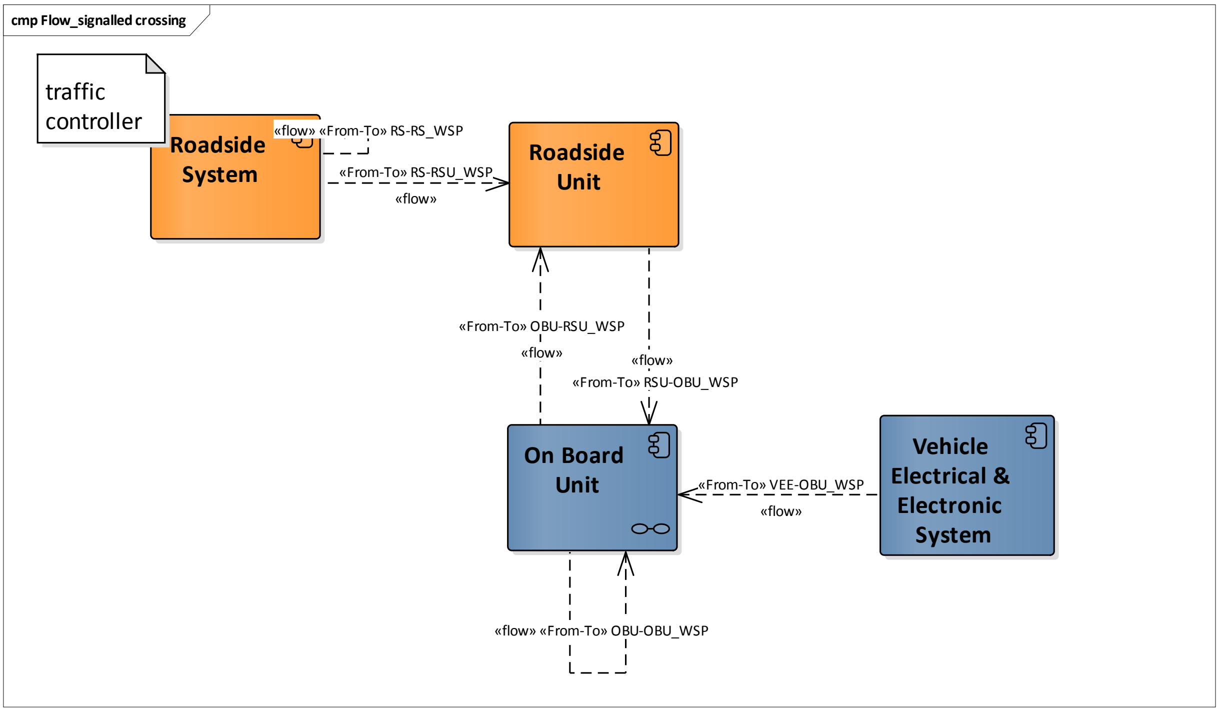

Figure 24: Warning system for pedestrians Signalled crossing with RSU, no RSE for VRU detection – Components and communication flows UC3

In the case of a signalled crossing with an RSU with C-ITS capabilities the RSE controlling the traffic lights sends a SPATSPATEM message. In the WSP service the RSU(TLC)-OBU only goes from the TLC to the car. For other services there could also be messages from the OBU to the TLC that are used to optimize the scheduling of the lights. The OBU uses the information in the SPAT message to decide if the VRU has priority because of the green light. In that case no warning is issued through the HMI because the driver already is informed via the status of the traffic lights on its own lane. If the VRU violates the lights than a warning is issued. If the driver does not react the safety protocol is activated. The detection of the VRU can come from another OBU that sends a DENM message (OBU(VRU)-OBU).

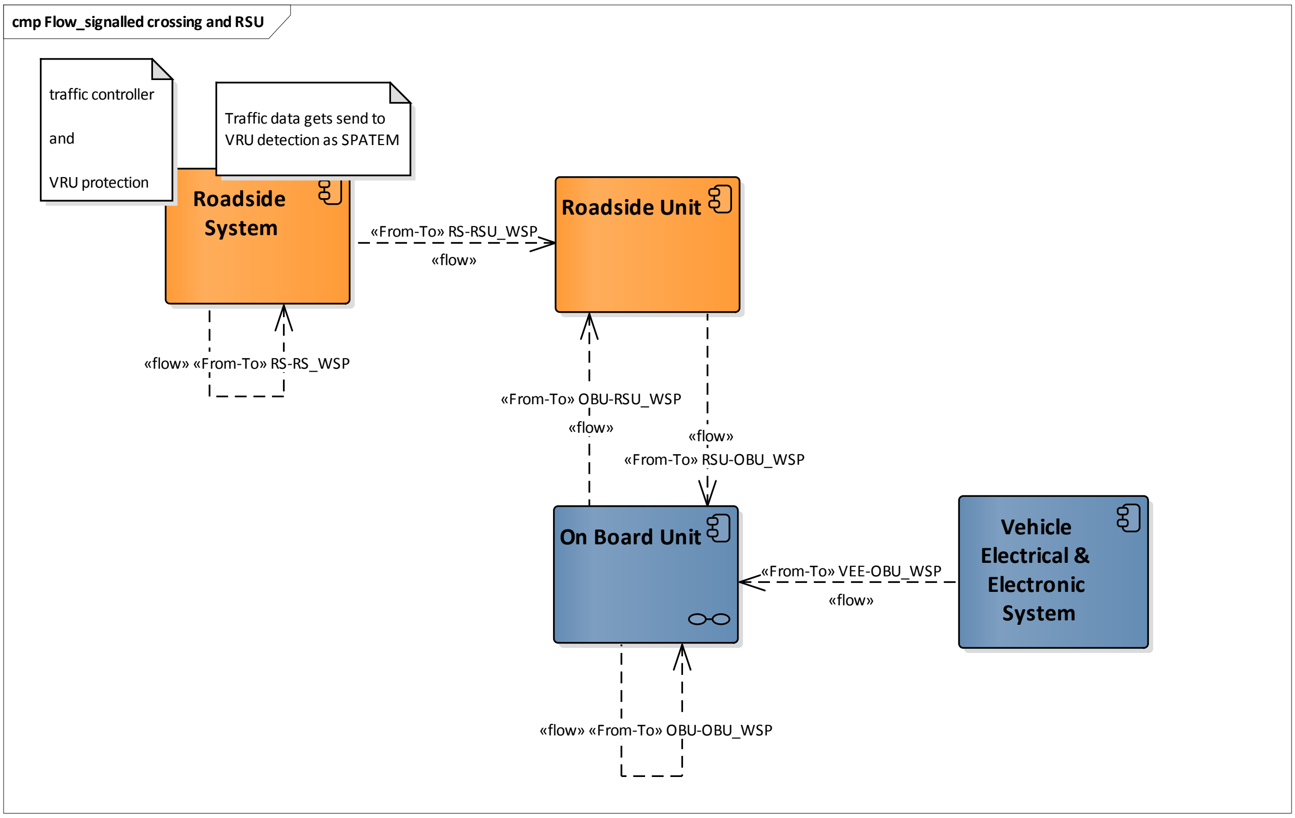

Figure 25: Warning system for pedestrians Signalled crossing with RSU for VRU detection – Components and communication flows UC4

The uses case of a signalled crossing with an RSU, RSE TLC and a RSE with VRU detection is a combination of the previous two use cases. Here we consider the case where the TLC does not use DSRC communication. The RSE with VRU detection receives the traffic light status via a wired RSE(TLC)-RSE(VRU) connection. The vehicles OBU sends CAM messages to inform about its trajectory that are interpreted by the RSE. In the RSE(VRU)-OBU communication flow the RSU sends a DENM message if there is a conflict in the trajectories and the VRU does not have a green light. The OBU combines the DENM info with its own information to decide if it is necessary to warn the driver through the HMI. If so, and if the driver does not react, the safety protocol is activated.

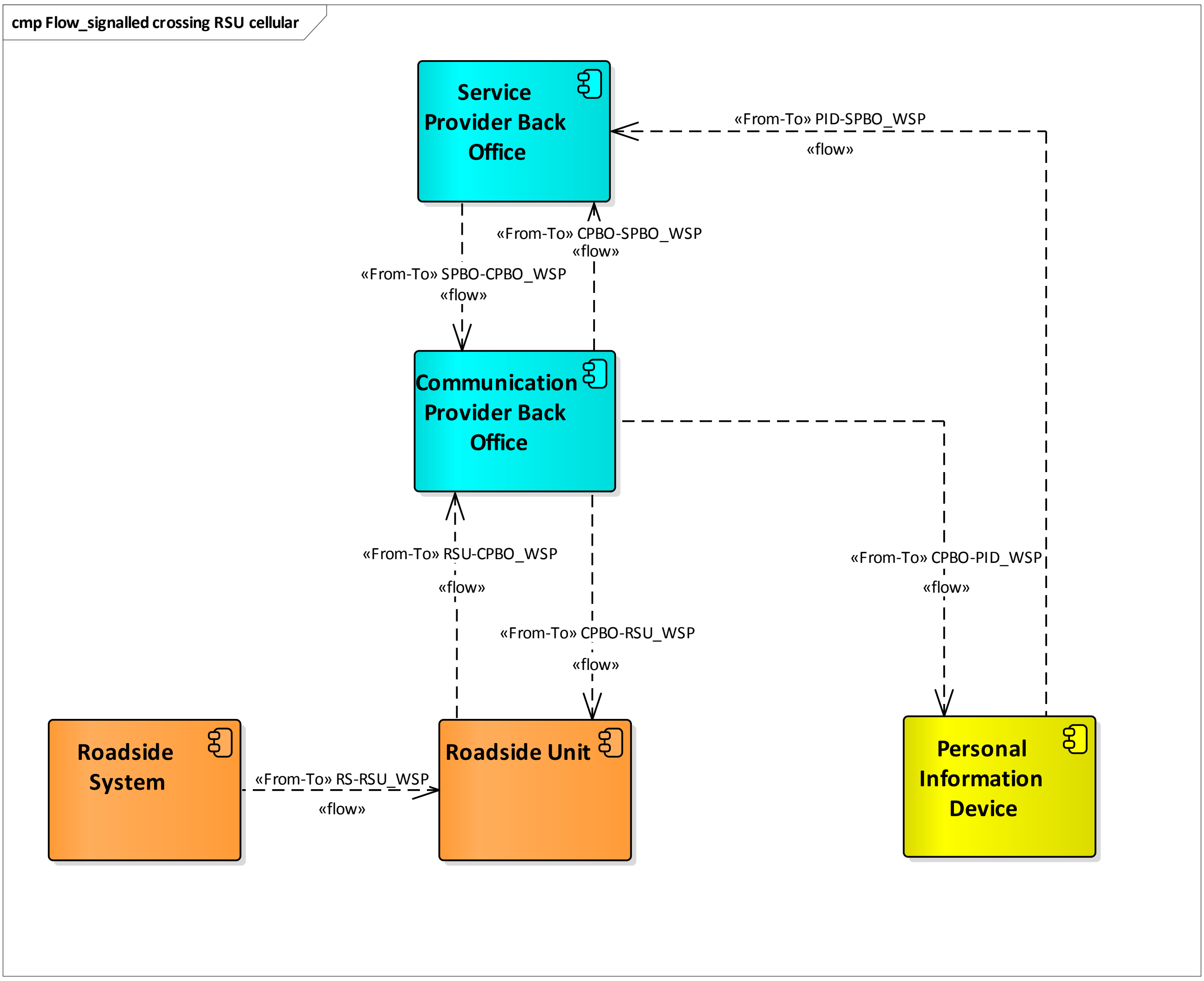

Figure 26: Warning system for pedestrians Signalled crossing with RSE for VRU detection Cellular communication with OBU – Components and communication flows UC5

With the OBU the driver activates the WSP service at his service provider. The service provider's data centre allocates a distributed data centre local to the vehicles position that will monitor the vehicle. If the vehicles move away from this distributed data centre another distributed data centre is allocated.

The distributed data centre receives frequent updates of the vehicle position. This position is sent to RSE with VRU detection that are nearby. The RSE combines the traffic light status with the detection of VRUs and the vehicle position. If the light is red for the VRU and there is a possible conflict with the vehicle trajectory the RSU sends a message to the distributed data centre. The distributed data centre sends a message to the OBU via the cellular transport network. Finally, the OBU receives the message that a VRU is detection on his trajectory. The OBU warns the driver via the HMI. If no reaction is detected the OBU activates the safety procedure.

UC6 is very similar, but the RSE is not involved, i.e. the VRUs are detected while using a PID (which sends the position to the CPBO), instead of using hardware in the infrastructure.

Table 8 Warning system for pedestrian - Protocols used for connections

Name	From	To	Protocol Layer						Datatypes Reference
			Application	Facilities	Transport & Networking	Access	Management	Security	
OBU(VRU)-OBU	OBU	OBU	-	ETSI ITS DENM	GeoNetworking	ETSI ITS G5	-	ETSI ITS-S Security Architecture	Not defined yet
RSU(TLC)-RSU(VRU)	RSU	RSU	-	ETSI ITS SPAT	IPv4, IPv6, TCP	Generic Access	-	TLS, ETSI ITS-S Security Architecture	Not defined yet
RSU(VRU)-OBU	RSU	OBU	-	ETSI ITS DENM	GeoNetworking	ETSI ITS G5	-	ETSI ITS-S Security Architecture	Not defined yet
RSU(TLC)-OBU	RSU	OBU	-	ETSI ITS SPAT	GeoNetworking	ETSI ITS G5	-	ETSI ITS-S Security Architecture	Not defined yet
OBU-RSU(VRU)	OBU	RSU	-	ETSI ITS CAM	GeoNetworking	ETSI ITS G5	-	ETSI ITS-S Security Architecture	Not defined yet

The table above shows the protocols which shall be used for the respective layer. Those listings may also contain alternatives, e.g. IPv4 or IPv6. The specific reference for the used protocols is listed in Appendix B of D3.3.

The protocol layers used follow the protocol stack as defined by ETSI. See ETSI EN 302 665 for details.

2.5.9. S09 - GP (Green Priority)

The Green Priority service aims to provide vehicles with priority in intersections via fast G5 communication where roadside equipment is installed and via cloud-based internet communication, where roadside equipment is cumbersome to install or where fast speed communication is not necessary.

Providing Green Priority, a road authority can reduce the number of stops for e.g. public transport buses, emergency vehicles or heavy good vehicles by extending the intersection green time upon arrival of the vehicles. on a more strategic level, priority, if only provided for certain times a day e.g. outside congestion hours, can form an incentive for certain companies to schedule their transport within specific times of the day where capacity is freed up.

2.5.9.1. Involved components

To implement GP, a number of components are necessary. But the GP services can be implemented in two different ways. One way of implementing GP is via roadside equipment, while another way of implementing the services is through the cellular or cloud approach. Figure 27 shows all components necessary for both approaches.

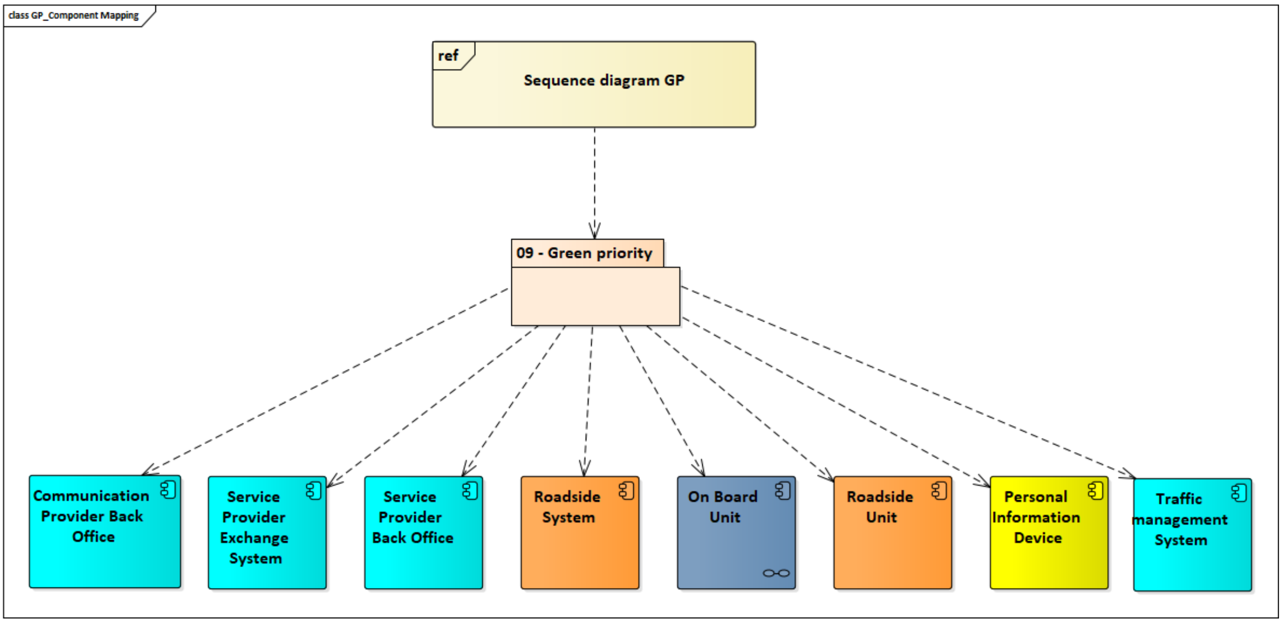

Figure 27: Green Priority - Components involved in service

To implement the roadside based approach, all that is needed is the roadside unit connected to the roadside system, in this case a traffic light controller for a signalled intersection, and a corresponding on-board unit in the relevant vehicles. The components as mentioned as well as references to detailed descriptions can be found below:

- Roadside System (see section 4.2.3.2.1 of D3.3 for details)
- Roadside Unit (see section 4.2.3.2.2 of D3.3 for details)
- On-Board Unit (see section 4.2.4.2.1 of D3.3 for details)

Implementing the cellular approach is somewhat more complicated but is not dependent on sometimes expensive equipment and installation and this approach can be scaled more easily. The components necessary for this approach are the following.

- Traffic Management System (See section 4.2.2.2.5 of D3.3 for details)
- Service Provider Back Office (see section 4.2.2.2.3 of D3.3 for details.)
- Communication Provider Back Office (see section 4.2.2.2.1 of D3.3 for details.)
- Service Provider Exchange System (see section 4.2.2.2.2 of D3.3 for details)
- Personal Information Device (see section 4.2.5.2.1 of D3.3 for details)

The relations between those components are described in the next section. The general functionality of these services, as well as more detailed interactions of the involved components is further described in UML Sequence Diagrams for the different use cases on which this service is based. In particular:

- Green Priority Sequence (see section 7.1.9.1.1 in D3.3 for details)

1.1.9.2 Component Connections

The following section describes the relations between the several components. In all the involved components and the connections between them are listed for all use cases of the service.

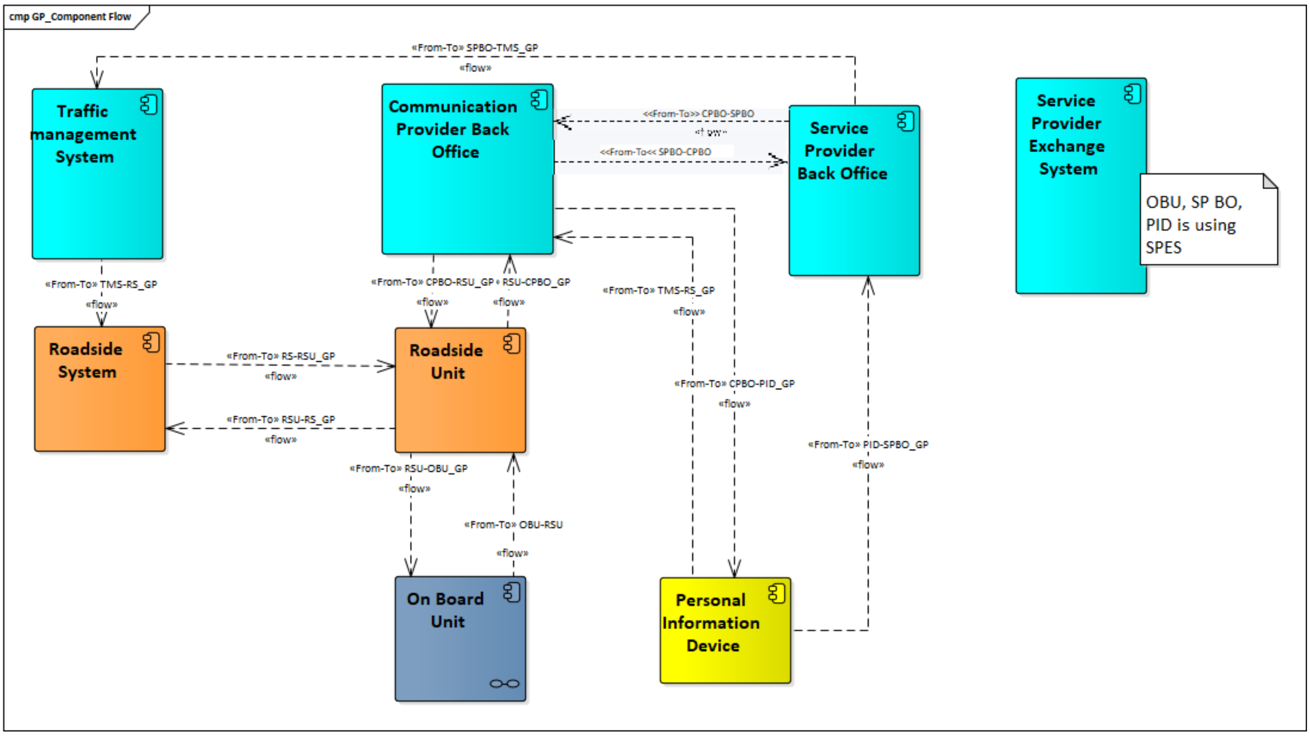

Figure 28: Green Priority – Components and communication flows

In most cases of the Green Priority deployment, communication is between the On-Board Unit and the Road side Unit using the OBU-RSU connection defined in ITS G5standard. The Road Side Unit receives an SRM priority request from the vehicle, verifies the authorization and communicates it to the Road Side System, in this case a traffic light controller, using the RS-RSU_GP connection. The TLC sends feedback whether the priority can be granted again via the RS-RSU_GP connection, which is then encoded in an SSM message sent back to the On-Board Unit via the OBU-RSU connection.

In Bordeaux, on the other hand, the messages from the emergency vehicle OBUs are sent as CAM not as SRM as stated above, with the following emergency profiles:

vehicleRole = emergency

specialVehicleContainer = EmergencyVehicleContainer

lightBarInUse = true

The Road Side Unit then receives the CAM messages and forwards them to the Communication Provider Back Office and from there to the Service Provider Back Office that manages the deployed RSUs. The Service Provider Back Office matches the Emergency Vehicle on approach lanes and generates Frames (DIASER) that are sent to the Traffic Management System via the SPBO-TMS_GP connection. Gertrude receives the frames and decide to grant priority or not, which is communicated to the Roadside System via the TMS-RS_GP connection.

Table 9: Green Priority - Protocols used for connections

Name	From	To	Protocol Layer						Datatypes Reference
			Application	Facilities	Transport & Networking	Access	Management	Security	
RSU-RS_GP	RSU	RS	local	local	any	Generic Access	any	any	iVERA, RSMP+, etc.
SPBO-CPBO_RHW	RS	RSU	local	local	any	Generic Access	any	any	iVERA, RSMP+, etc.
CPBO-PID_GP	CPBO	PID	-	ETSI ITS SSM, ETSI ITS SPAT, MQTT	IPv4, IPv6, TCP	3GPP 4G Suite, 3GPP 3G Suite	SNMP	TLS, ETSI ITS-S Security Architecture	Not defined yet
PID-CPBO_GP	PID	CPBO	-	ETSI ITS SRM, ETSI ITS CAM, MQTT	IPv4, IPv6, TCP	3GPP 4G Suite, 3GPP 3G Suite	SNMP	TLS, ETSI ITS-S Security Architecture	Not defined yet
CPBO-RSU_GP	CPBO	RSU	-	SRM, ETSI ITS CAM, MQTT	IPv4, IPv6, TCP	Generic Access	SNMP	TLS, ETSI ITS-S Security Architecture	Not defined yet
RSU-CPBO_GP	RSU	CPBO	-	SSM, ETSI ITS SPAT, MQTT	IPv4, IPv6, TCP	Generic Access	SNMP	TLS, ETSI ITS-S Security Architecture	Not defined yet
RSU-OBU_GP	RSU	OBU	-	SSM, ETSI ITS SPAT	GeoNetworking	ETSI ITS G5	GeoNetworking	ETSI ITS-S Security Architecture	Not defined yet
OBU-RSU_GP	OBU	RSU	-	SRM, ETSI ITS CAM	GeoNetworking	ETSI ITS G5	GeoNetworking	ETSI ITS-S Security Architecture	Not defined yet
SPBO-TMS_GP	SPBO	TMS	HTTPS	JSON	IPv4, IPv6, TCP	Generic Access	SNMP	TLS	Not defined yet

The table above shows the protocols which shall be used for the respective layer. Those listings may also contain alternatives, e.g. IPv4 or IPv6. The specific reference for the used protocols is listed in Appendix B of D3.3.

The protocol layers used follow the protocol stack as defined by ETSI. See ETSI EN 302 665 for details.

2.5.10. S10 - GLOSA (Green Light Optimal Speed Advisory)

GLOSA provides vehicle drivers an optimal speed advice when they approach a controlled intersection equipped with traffic lights.

The "Green Light Optimal Speed Advisory (GLOSA)" service aims at creating an eco-friendlier and energy-efficient driving experience for vehicle drivers by providing speed advice, traffic light information and countdown to green/red, aiming to reduce energy consumption and lower the number of stops.

2.5.10.1. Involved Components

This section shows, which components are involved in this service. Furthermore, it lists the various sequence diagrams, which have been created to describe the service. The foundation of the service description is the component diagram, as shown below in.

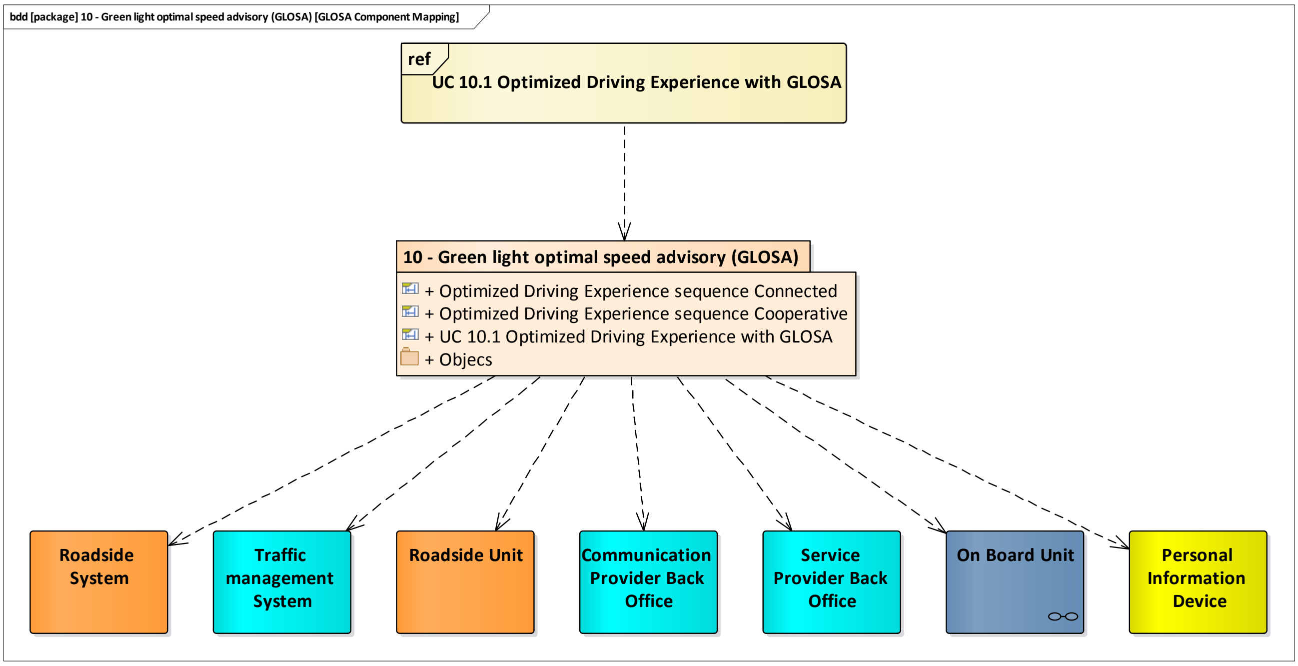

Figure 29: Green Light Optimal Speed Advisory - Components involved in service

To implement this service, the following components are necessary.

- / Roadside System (see section 4.2.3.2.1 of D3.3 for details.)
- / Traffic Management System (See section 4.2.2.2.5 of D3.3 for details)
- / Roadside Unit (see section 4.2.3.2.2 of D3.3 for details)
- / Communication Provider Back Office (see section 4.2.2.2.1 of D3.3for details.)
- / Service Provider Back Office (See section 4.2.2.2.3 of D3.3 for details)
- / On Board Unit (see section 4.2.4.2.1 of D3.3 for details.)
- / Personal Information Device (See section 4.2.5.2.1 of D3.3 for details)

The relations between those components are described in the section 2.5.10.2, below. The general functionality of these services, as well as more detailed interactions of the involved components is further described in UML Sequence Diagrams for the different use cases on which this service is based. This are in particular:

- / "UC 10.1 Optimized Driving Experience with GLOSA" as shown in Appendix A of D3.3

2.5.10.2. Component Connections

The following section describes the relations between the several components. In Figure 30 all the involved components and the connections between them are listed for all use cases of the service.

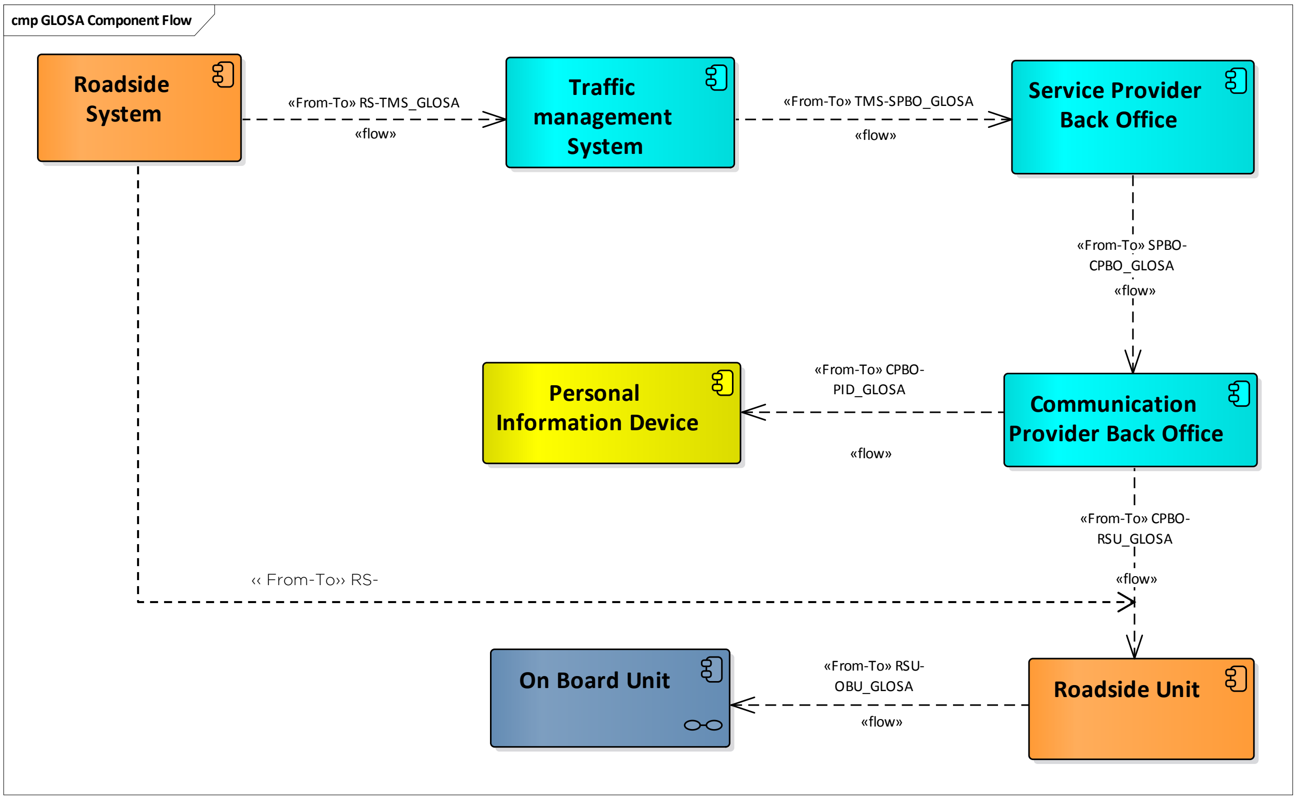

Figure 30: GLOSA – Components and communication flows

The Roadside System (RS) uses RS-TMS_GLOSA connection to broadcast the signal states and the time for the next signal to the Traffic Management System (TMS) that are forwarded to the Service Provider Back Office (SPBO) via the TMS-SPBO_GLOSA connection. The SPBO generates the standards SPATEM (and MAPEM messages if not done yet) and transmits them to the Communication Provider Back Office (CPBO) via the SPBO-CPBO_GLOSA connection. According to the HMI selected, there are two flows. If the Personal Information Device (PID) is used for the service, the CPBO uses the CPBO-PID_GLOSA connection to transmit the GLOSA messages (SPATEM and MAPEM) and the PID will calculate the corresponding speed advice and display it to the user. If the On-Board Unit (OBU) is used for the service, the CPBO uses the CPBO-RSU_GLOSA connection to transmit the optimal speed profiles to the Roadside Unit (RSU), which in turn forwards the speed profiles to the OBU via the RSU-OBU_GLOSA connection. At the OBU, the speed advice is calculated and displayed to the user.

Alternatively, the Roadside System (RS) can use RS-RSU_GLOSA connection to connect directly to the RSU, which will receive the signal phase and timings from the traffic lights and will generate the SPATEM messages to be sent to the Service Provider Back-Office (SPBO) for the cellular case and to the nearby On-board Units (OBU) for the ITS G5 case.

Table 10: Green Light Optimal Speed Advisory - Protocols used for connections

Name	From	To	Protocol Layer						Datatypes Reference
			Application	Facilities	Transport & Networking	Access	Management	Security	
RS-TMS_GLOSA	RS	TMS	-	ETSI ITS SPATEM, DATEX II or proprietary format	IPv6, IPv4, TCP	Generic Access	SNMP	TLS	Figure 211 of D3.3 for SPATEM
TMS-SPBO_GLOSA	TMS	SPBO	-	DATEX II or proprietary format	IPv6, IPv4, TCP	Generic Access	SNMP	TLS	Not defined
SPBO-CPBO_GLOSA	SPBO	CPBO	-	ETSI ITS SPATEM/MAPEM	IPv6, IPv4, TCP	Generic Access	SNMP	TLS	Figure 212 of D3.3
CPBO-PID_GLOSA	CPBO	PID		ETSI ITS SPATEM/MAPEM, MQTT	IPv4, IPv6, TCP	3GPP 4G Suite, 3GPP 3G Suite	SNMP	TLS	Figure 212 of D3.3
CPBO-RSU_GLOSA	CPBO	RSU	-	ETSI ITS SPATEM/MAPEM	IPv4, IPv6, TCP	Generic Access	SNMP	TLS	Figure 212 of D3.3
RSU-OBU_GLOSA	RSU	OBU	-	ETSI ITS SPATEM/MAPEM	GeoNetworking	ETSI ITS G5	ETSI 102 890-1, G5 Congestion Control Mgmt.	ETSI ITS-S Security Arch.	Figure 213 of D3.3

The table above shows the protocols which shall be used for the respective layer. Those listings may also contain alternatives, e.g. IPv4 or IPv6. The specific reference for the used protocols is listed in Appendix B of D3.3.

The protocol layers used follow the protocol stack as defined by ETSI. See ETSI EN 302 665 for details.

2.5.11. S11 - CTLV (Cooperative Traffic Light for VRU)

An Employer (an organization or a business/industrial zone) endorses cycling as the choice of commuting for its employees. This is with the aim to reduce the traffic around and within its premises and reduce the need for parking spaces for cars. To foster this, a Service Provider offers a priority crossing for cyclists via a smartphone application. The Provider delivers software activation codes to the Employer, which distributes to its Employees that commute by bike.

The service should be available to all. However, user recruitment will be done by approaching large employers, educational institutions, and certain groups of more-vulnerable VRUs, all of which may be able to further benefit by making this service available to their members.

The operation of the service will vary based on VRU-demand and traffic conditions for other phases. Operation during peak hour, for instance, may only adjust signal timing when large numbers of pedestrians are waiting, whilst during non-peak, the service could be used to provide priority for only a small number of VRUs.

The service could optionally be activated only during certain time periods (e.g., rush hours).

This use case is differentiating from Use Case 2 as it only operates based on detection of (self-)selected VRUs using active sensor technology.

"Traffic Light Prioritisation for Designated VRUs (Vulnerable Road Users)" aims at increasing comfort and safety of VRUs in traffic by adjusting traffic signal timing and/or assigning priority based on VRU-data collected through an app or tag carried by individual VRUs. [3]

2.5.11.1. Involved Components

This section shows, which components are involved in this service. Furthermore, it lists the various sequence diagrams, which have been created to describe the service. The foundation of the service description is the component diagram, as shown below in Figure 31.

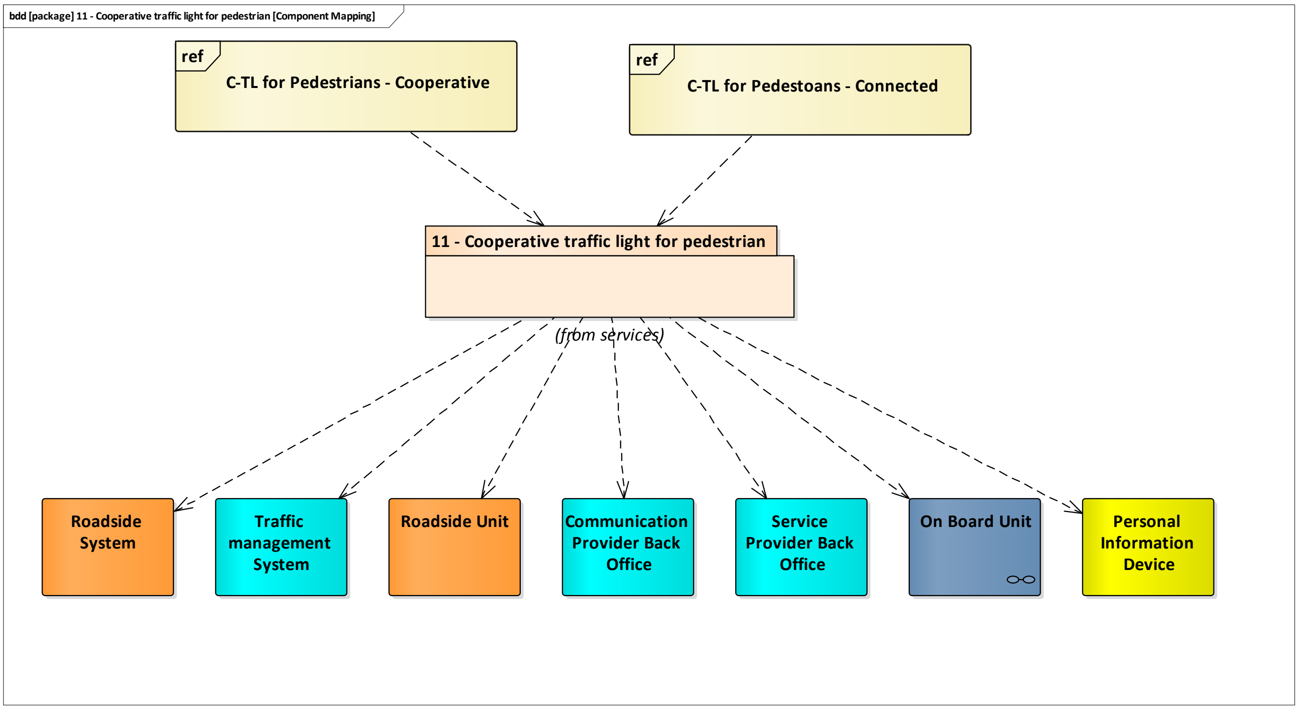

Figure 31: Cooperative Traffic Light for Pedestrians - Components involved in service

To implement this service, the following components are necessary.

- / Roadside System (see section 4.2.3.2.1 of D3.3 for details.)
- / Traffic management system (see section 4.2.2.2.5 of D3.3 for details.)
- / Roadside Unit ((see section 4.2.3.2.2 of D3.3 for details.)
- / Communication Provider Back Office (See section 4.2.2.2.1 of D3.3 for details)
- / Service Provider Back Office (See section 4.2.2.2.3 of D3.3 for details)

- On Board Unit (see section 4.2.4.2.1 of D3.3 for details.)
- Personal Information Device (See section 4.2.5.2.1 of D3.3 for details)

The relations between those components are described in the section 2.5.11.2, below. The general functionality of these services, as well as more detailed interactions of the involved components is further described in UML Sequence Diagrams for the different use cases on which this service is based. This are in particular:

- UC11.1 “Traffic Light for VRU cooperative” as shown in Appendix A of D3.3
- UC11.2 “Traffic Light for VRU Connected” as shown in Appendix A of D3.3
- UC11.3 “Traffic Light for VRU Counting and/or tracking VRUs

2.5.11.2. Component Connections

The following section describes the relations between the several components. In Figure 32 all the involved components and the connections between them are listed for all use cases of the service.

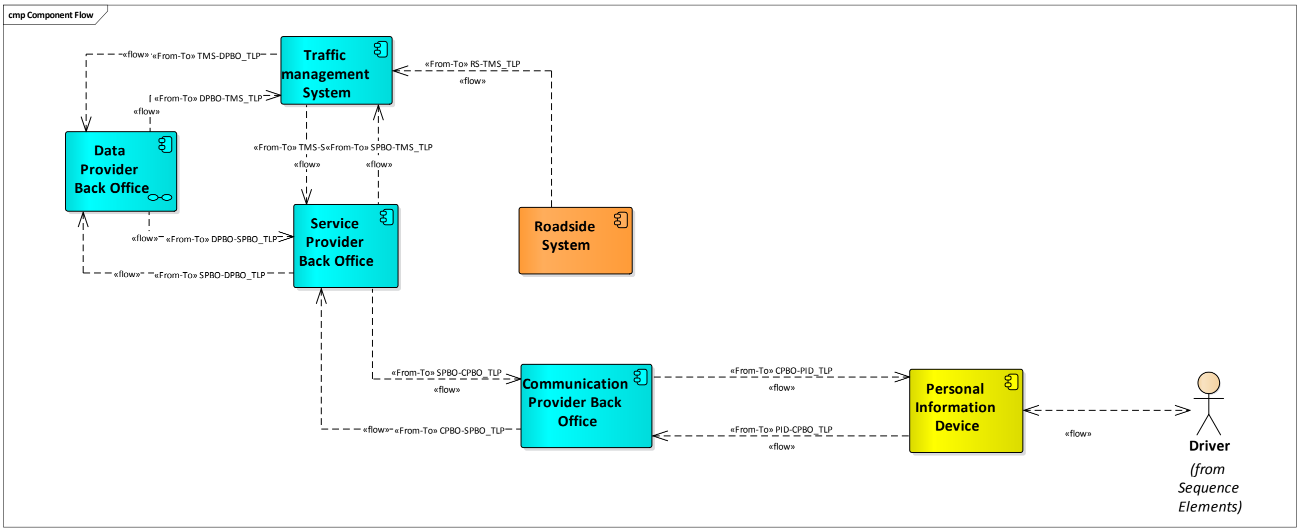

Figure 32: Cooperative Traffic Light for pedestrians – Components and communication flows

In the defined use cases the Traffic Management System (TMS) uses the Back-Office Communication Provider (CPBO) relationship to provide information to the Service Provider in order to provide the information to the vehicle communication system (VCS). The information shared to the VCS is obtained via the VRU sensor and pushed to the Traffic Signal controller. The road side unit is able to handle SPATSPATEM/MAPEM and CAM messages in order to obtain and provide information the On-Board Unit (OBU).

Table 11: Cooperative traffic light for pedestrian - Protocols used for connections

Name	From	To	Protocol Layer						Datatypes Reference
			Application	Facilities	Transport & Networking	Access	Management	Security	
TMS-SPBO_TLP	TMS	CPBO	HTTPS	JSON	IPv4, IPv6, TCP			TLS	Not defined yet
SPBO-TMS_TLP	SPBO	TMS	HTTPS	JSON	IPv4, IPv6, TCP	Generic Access	SNMP	TLS	Not defined yet
SPBO-CPBO_TLP	SPBO	CPBO	TBD	JSON, MQTT	IPv4, IPv6, TCP	Generic Access	SNMP	TLS	Not defined yet
CPBOCPBO-PID_TLP	CPBO	PID	TBD	JSON, MQTT	GeoNetworking	3GPP 4G Suite, 3GPP 3G Suite	SNMP	TLS	Not defined yet
RS-TMS_TLP	RS	TMS	HTTPS	JSON	IPv4, IPv6, TCP	Generic Access	SNMP	TLS	Not defined yet
TMS-DPBO_TLP	TMS	DPBO	DATEX II	-	IPv4, TCP	Generic Access	SNMP	TLS	Not defined yet
DPBO-TMS_TLP	DBPO	TMS							
DPBO-SPBO_TLP	DPBO	SPBO	HTTP, DATEX,	XML, JSON	IPv4, IPv6, TCP	3GPP 4G Suite, 3GPP 3G SuiteGeneric Access	SNMP	TLS	Not defined yet
SPBO-DPBO_TLP	SPBO	DPBO		AMQP	IPv4, IPv6, TCP	Generic Access			
PID-CPBO_TLP	PID	CPBO				3GPP 4G Suite, 3GPP 3G Suite			
CPBO-SPBO_TLP	CPBO	SPBO			IPv4, IPv6, TCP				

The table above shows the protocols which shall be used for the respective layer. Those listings may also contain alternatives, e.g. IPv4 or IPv6. The specific reference for the used protocols is listed in Appendix B of D3.3.

The protocol layers used follow the protocol stack as defined by ETSI. See ETSI EN 302 665 for details.

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2.5.12. S12 - FI (Flexible Infrastructure)

Flexible infrastructure aims to interchange information about the lanes provided to the traffic users according to the time of the day. It includes solutions such as reserved lane.

Objectives of FI are informing traffic users about the lanes provided downstream of the current position and in the driving direction of the vehicle. [3]

2.5.12.1. Involved Components

This section shows, which components are involved in this service. Furthermore, it lists the various sequence diagrams, which have been created to describe the service. The foundation of the service description is the component diagram, as shown below in Figure 33.

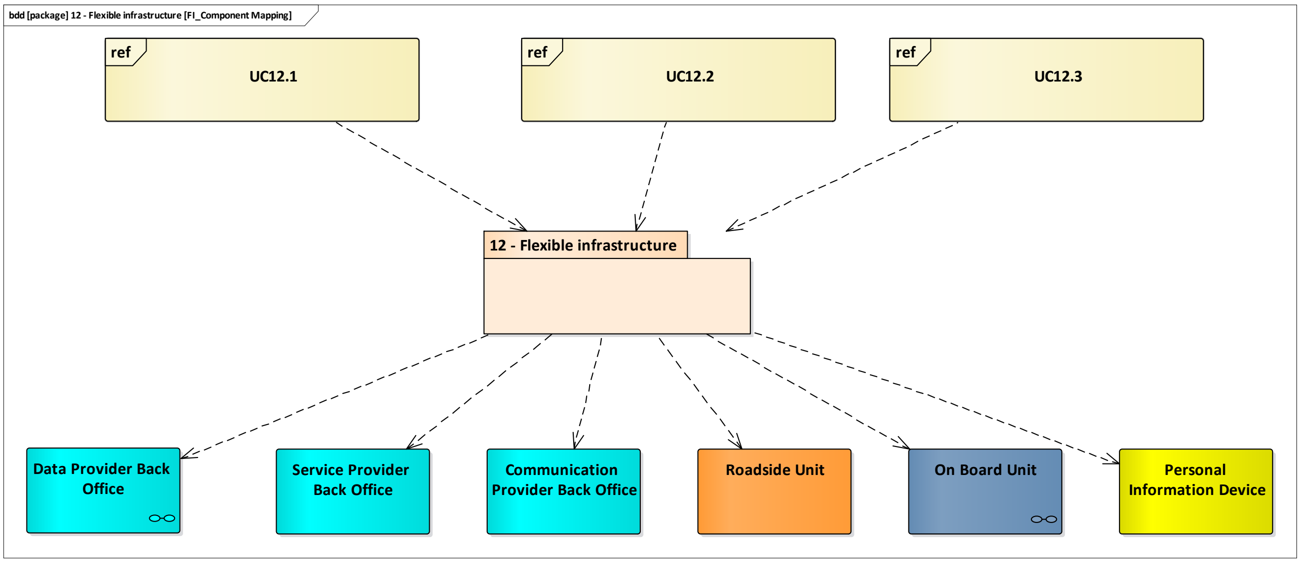

Figure 33: Flexible Infrastructure - Components involved in service

To implement this service, the following components are necessary.

- Data Provider Back Office (see section 4.2.2.2.4 of D3.3 for details.)
- Service Provider Back Office (See section 4.2.2.2.3 of D3.3 for details)
- Communication Provider Back Office (See section 4.2.2.2.1 of D3.3 for details)
- Roadside Unit (see section 4.2.3.2.2 of D3.3 for details.)
- On Board Unit (see section 4.2.4.2.1 of D3.3 for details.)
- Personal Information Device (See section 4.2.5.2.1 of D3.3 for details)

The relations between those components are described in the section 5.2.12.2, below. The general functionality of these services, as well as more detailed interactions of the involved components is further described in UML Sequence Diagrams for the different use cases on which this service is based. This are in particular:

- 12.1 - Dynamic Lane Management – Lane Status Information as shown in Appendix A of D3.3
- 12.2 - Dynamic Lane Management – Reserved Lane (with probe vehicle data) as shown in Appendix A of D3.3
- 12.3 - Dynamic Lane Management – Reserved Lane (without probe vehicle data) as shown in Appendix A of D3.3

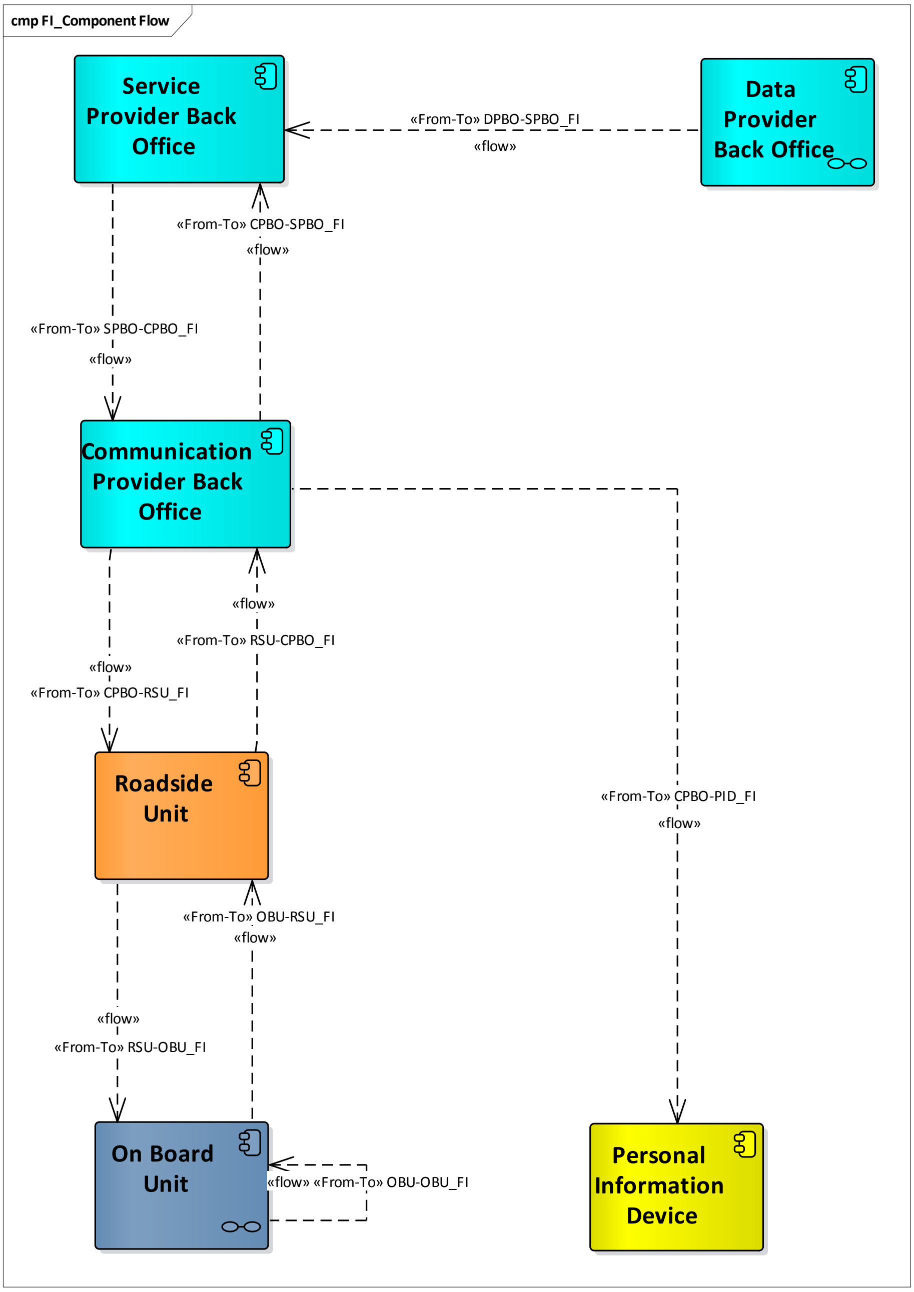

Figure 34: Flexible Infrastructure – Components and communication flows

The sources are the following:

- Static messages: Sometimes the messages never change. In that case we have a static IVI message that we leave active 100% of the time:
  - ex: when traffic is allowed on the hard shoulder for buses.
  - ex: when traffic is allowed on bus lanes for cars with more than 2 people on board.
- Dynamic messages: We receive “Dynamic Lane Management” data from the TMS. In that case the location is static (e.g. Pont d’Aquitaine in Bordeaux) and the data is dynamic.

Table 12 Flexible Infrastructure - Protocols used for connections

Name	From	To	Protocol Layer						Datatypes Reference
			Application	Facilities	Transport & Networking	Access	Management	Security	
DPBO-SPBO_FI	DPBO	SPBO	DATEX II XML CSV	TBD	IPv6, IPv4, TCP	Generic Access		TLS	Not defined yet
SPBO-CPBO_FI	SPBO	CPBO		IVIM	IPv4, IPv6, TCP	Generic Access		TLS, ETSI ITS-S Security Architecture	Not defined yet
CPBO-RSU_FI	CPBO	RSU	TBD	MQTT, ETSI ITS IVIM	IPv4, IPv6, TCP	Generic Access, 3GPP 4G Suite, 3GPP 3G Suite		TLS, ETSI ITS-S Security Architecture	Not defined yet
RSU-OBU-FI	RSU	OBU	TBD	ETSI ITS IVIM	GeoNetworking	ETSI ITS G5	TBD	ETSI ITS-S Security Architecture	Not defined yet
OBU-OBU_FI	OBU	OBU	TBD	ETSI ITS IVIM	GeoNetworking	ETSI ITS G5	TPEG2-MMC ISO 21219-6	ETSI ITS-S Security Architecture	Not defined yet
OBU-RSU_FI	OBU	RSU	TBD	ETSI ITS IVIM	GeoNetworking	ETSI ITS G5	TBD	ETSI ITS-S Security Architecture	Not defined yet
RSU-CPBO_FI	RSU	CPBO	TBD	MQTT, ETSI ITS IVIM	IPv4, IPv6, TCP	Generic Access, 3GPP 4G Suite, 3GPP 3G Suite		TLS, ETSI ITS-S Security Architecture	Not defined yet
CPBO-SPBO_FI	CPBO	SPBO	TBD	MQTT, ETSI ITS CAM	IPv4, IPv6, TCP	Generic Access		TLS	Not defined yet
SPBO-PID_FI	CPBO	PID	TBD	ETSI ITS MAPEM, MQTT	IPv4, IPv6, TCP	3GPP 4G Suite, 3GPP 3G Suite		TLS, ETSI ITS-S Security Architecture	Not defined yet

The table above shows the protocols which shall be used for the respective layer. Those listings may also contain alternatives, e.g. IPv4 or IPv6. The specific reference for the used protocols is listed in Appendix B of D3.3.

The protocol layers used follow the protocol stack as defined by ETSI. See ETSI EN 302 665 for details.

2.5.13. S13 - IVS (In-Vehicle Signage)

In-Vehicle Signage (IVS) shows both static and dynamic information of road signs inside the vehicle.

In scope of IVS. the IVS information is retrieved by means of Infrastructure-to-Vehicle (I2V) communication. IVS shows both static and dynamic information of road signs. [3]

The service contains actual and continuous information on:

- Speed limits: in-vehicle information on actual speed limit.
  - Standard speed limit (incl. time-of-the-day windows).
  - Dynamic speed limit during incidents, traffic jams, etc.
  - Adjusted speed limits during road works.
- Overtaking prohibition: in-car information on actual overtaking prohibition, especially for trucks.
- Actual travel times and other traffic information.

2.5.13.1. Involved Components

This section shows which components are involved in this service. Furthermore, it lists the various sequence diagrams, which have been created to describe the service. The foundation of the service description is the component diagram, as shown below in Figure 35.

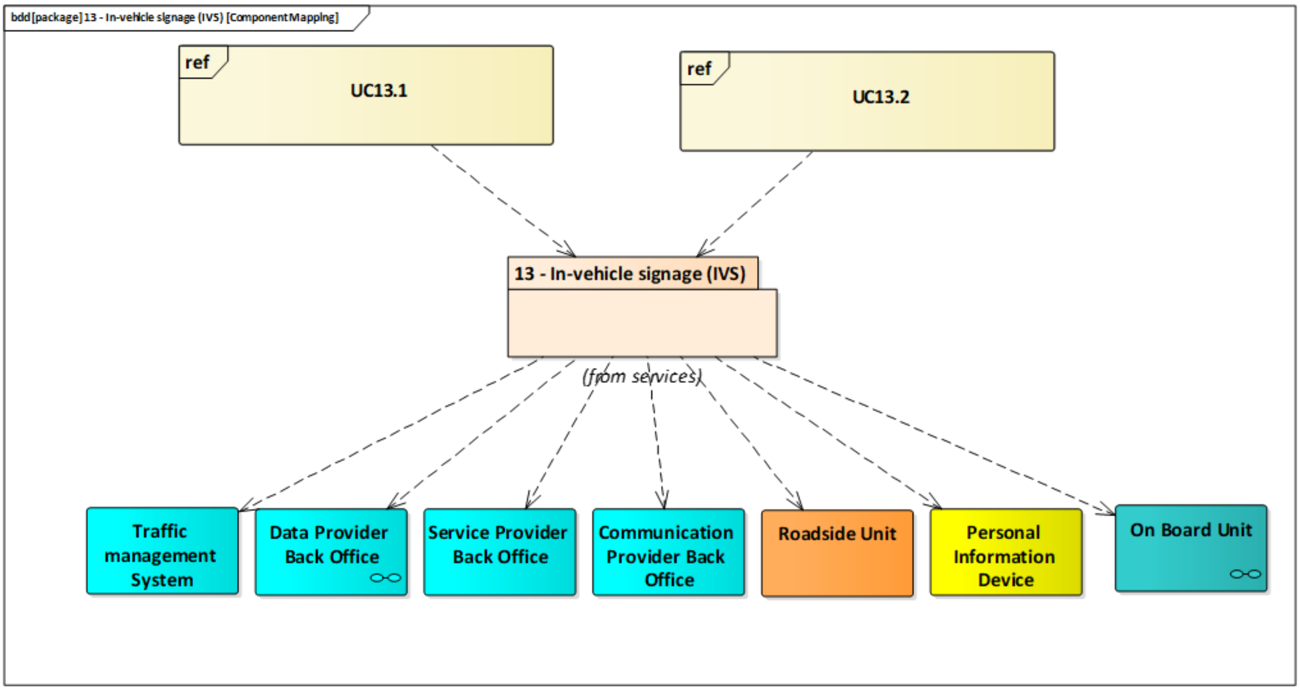

Figure 35: In-Vehicle Signage - Components involved in service

This service comprises two use cases which share the same architecture and can be implemented with both communication protocols (ITS G5 and cellular). Therefore, different architecture components are involved in each one. In general, in order to implement this service, the following components are necessary:

- Traffic management system (see section 4.2.2.2.5 for details.)
- Data Provider Back Office (see section 4.2.2.2.4 for details.)
- Service Provider Back Office (See section 4.2.2.2.3 for details)
- Communication Provider Back Office (See section 4.2.2.2.1 for details)
- Roadside Unit (see section 4.2.3.2.2 for details.)

/ Personal Information Device (See section 4.2.5.2.1 for details)

/ On Board Unit (see section 4.2.4.2.1 for details.)

The relations among those components are described in the section Component Connections, below. The general functionality of this service, as well as more detailed interactions of the involved components are further described in UML Sequence Diagrams for the unique use case on which this service is based:

/ UC13.1 “In-Vehicle Signage, dynamic traffic signs”

/ UC13.2 “In-Vehicle Signage, static traffic signs”

2.5.13.2. Component Connection

The components of the service along with the communication flows among them are described in the diagram below.

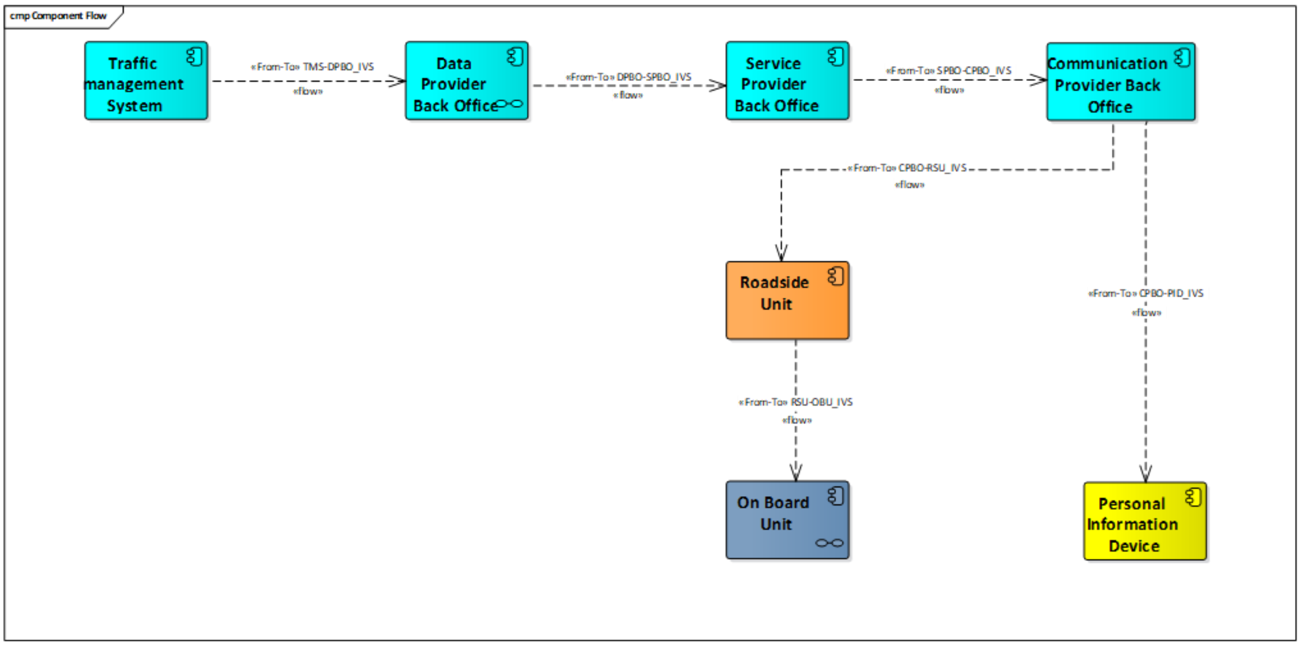

Figure 36: In-Vehicle Signage – Components and communication flows

The main scope of the In-Vehicle Signage (IVS) service is to provide drivers with information about dynamic and static road signs, as well as travel time and other traffic information. Provision of information is achieved through Vehicle-to-Infrastructure (V2I) communications, either ITS G5 or cellular.

As an example, in Thessaloniki IVS is implemented based in cellular communications. The main components for the operation of the service are comprised of the back-office systems (Communication Provider Back-Office and Service Provider Back-Office), i.e. CERTH GeoMessaging Platform and local database, and an application (App) developed by CERTH for the Personal Information Devices (PIDs), i.e. smartphones and tablets.

Concerning raw data used for the IVI messages, data sources comprise of a digital map including static and virtual road signs for the network of Thessaloniki, where sign codes are compatible with the ETSI standard. Travel time and other traffic information, provided as dynamic/ virtual IVI messages, are extracted from the content of Virtual Message Signs (VMSs), through a web service operated by CERTH. All these raw data are received from the Back-Office where ASN.1 messages are produced based on the ETSI/ISO IVIM standard. These messages are published, through the CERTH GeoMessaging Server, every 10 minutes to relevant topics (which include the quadtree).

Regarding the App, access to the Back-Office systems is provided through the Registration Server included in the CERTH GeoMessaging Platform. More specifically, the Registration Server provides a JSON Web Token (JWT) to the PID which acts as the password and includes all the necessary information in its claims (username, endpoint, topics). Once a PID has access to the server, it determines the relevance of a message based on the current location of the vehicle and then receives the relative IVI messages.

Table 13 In-Vehicle Signage - Protocols used for connections

Name	From	To	Protocol Layer						Datatypes Reference
			Application	Facilities	Transport & Networking	Access	Management	Security	
TMS-DPBO_IVS	TMS	DP BO	HTTPS	DATEX, JSON	IPv4, IPv6, TCP	Generic Access	SNMP	TLS	Not defined yet
DPBO-SPBO_IVS	DP BO	SPBO	HTTPS	DATEX, JSON	IPv4, IPv6, TCP	Generic Access	SNMP	TLS	Not defined yet
SPBO-CPBO_IVS	SPBO	CPBO	-	MQTT, ETSI ITS IVIM	IPv4, IPv6, TCP	Generic Access	SNMP	TLS, ETSI ITS-S Security Architecture	Not defined yet
CPBO-RSU_IVS	CPBO	RSU	-	MQTT, ETSI ITS IVIM	IPv4, IPv6, TCP	Generic Access	SNMP	TLS, ETSI ITS-S Security Architecture	Not defined yet
RSU-OBU_IVS	RSU	OBU	ETSI ITS BSA	ETSI ITS IVIM	GeoNetworking	ETSI ITS G5	TBD	ETSI ITS-S Security Architecture	Not defined yet
CPBO-PID_IVS	CPBO	PID	ETSI ITS BSA	ETSI ITS IVIM	GeoNetworking	ETSI ITS G5	TBD	ETSI ITS-S Security Architecture	Not defined yet

The table above shows the protocols which shall be used for the respective layer. Those listings may also contain alternatives, e.g. IPv4 or IPv6. The specific reference for the used protocols is listed in Appendix B of D3.3.

The protocol layers used follow the protocol stack as defined by ETSI. See ETSI EN 302 665 for details.

2.5.14. S14 - MTTA (Mode & Trip Time Advice)

The service Mode & Trip Time Advice (MTTA) aims to provide travelers with an itinerary for a multimodal transport journey, taking into account real-time and/ or static multimodal journey information. The information provided include alternative modes of transport, as well as time and cost-efficient routes.

2.5.14.1. Involved Components

This section shows, which components are involved in this service. Furthermore, it lists the various sequence diagrams, which have been created to describe the service. The foundation of the service description is the component diagram, as shown below in Figure 37.

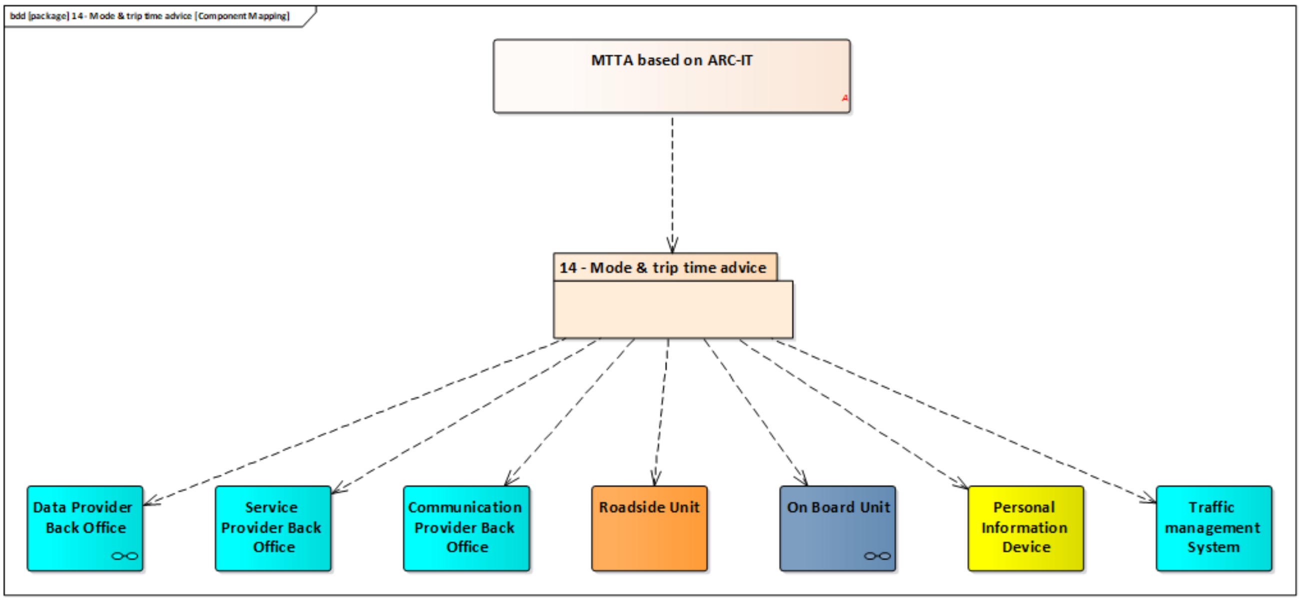

Figure 37 Mode & Trip Time Advice - Components involved in service

To implement this service, the following components are necessary:

- / Data Provider Back Office (see section 4.2.2.2.4 of D3.3 for details.)
- / Service Provider Back Office (See section 4.2.2.2.3 of D3.3 for details)
- / Communication Provider Back Office (See section 4.2.2.2.1 of D3.3 for details)
- / Roadside Unit, optional required for 802.11p communication only (see section 4.2.3.2.2 of D3.3 for details.)
- / On Board Unit (see section 4.2.4.2.1 of D3.3 for details.)
- / Personal Information Device (See section 4.2.5.2.1 of D3.3 for details)
- / Traffic management system (see section 4.2.2.2.5 of D3.3 for details.)

The relations between those components are described in the section 2.5.14.2, below. The general functionality of this service is based on the ARC-IT reference architecture. Therefore, an adapted Version for C-MobILE was created and can be found in Appendix A of D3.3.

2.5.14.2. Component Connections

The components of the service along with the communication flows among them are described in the diagram below.

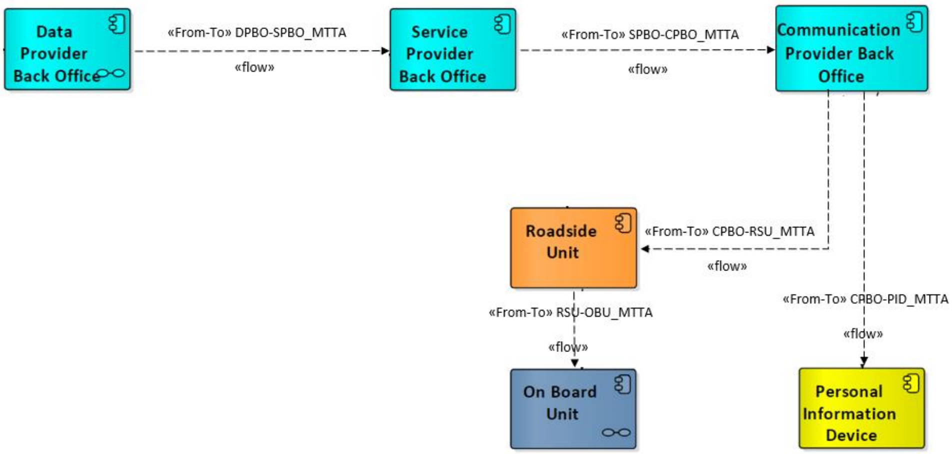

Figure 38: Mode & Trip Time Advice – Components and communication flows

As an explanatory example, MTTA is implemented in Thessaloniki based in cellular communications. The main components for the operation of the service are comprised of the back-office systems (Communication Provider Back-Office and Service Provider Back-Office), i.e. CERTH GeoMessaging Platform and local database, and an application (App) developed by CERTH for the Personal Information Devices (PIDs), i.e. smartphones and tablets.

The current implementation of MTTA includes the provision of travel time information. Initial data about travel times for several routes in the road network of Thessaloniki are extracted from VMSs content. Travel times are estimated based on Floating Car Data (FCD). These raw are received from the Back-Office where ASN.1 messages are produced based on the ETSI/ISO IVIM standard. These messages are published, through the CERTH GeoMessaging Server, every 10 minutes to relevant topics (which include the quad tree).

Regarding the App, access to the Back-Office systems is provided through the Registration Server included in the CERTH GeoMessaging Platform. More specifically, the registration server provides a JSON Web Token (JWT) to the PID which acts as the password and includes all the necessary information in its claims (username, endpoint, topics). Once a PID has access to the server, it determines the relevance of a message based on the current location of the vehicle and then receives the relative IVI messages.

Table 14 Mode & Trip Time Advice - Protocols used for connections

Name	From	To	Protocol Layer						Datatypes Reference
			Application	Facilities	Transport & Networking	Access	Management	Security	
CPBO-RSU_MTTA	CPBO	RSU	TBD	MQTT, ETSI ITS DENM	IPv4, IPv6, TCP	Generic Access	SNMPv3 MIB	TLS, ETSI ITS-S Security Architecture	Not defined yet
DPBO-SPBO_MTTA	DPBO	SPBO	TBD	AMQP	IPv6, IPv4, TCP	Generic Access	SNMPv3 MIB	TLS, ETSI ITS-S Security Architecture	Not defined yet
RSU-OBU_MTTA	RSU	OBU	TBD	TBD	IPv6, TCP, UDP	ETSI ITS G5	SNMPv3 MIB	TLS, IETF RFC 6071	Not defined yet
SPBO-CPBO_MTTA	SPBO	CPBO	TBD	TBD	IPv6, IPv4, TCP	Generic Access	SNMPv3 MIB	TLS,	Not defined yet
SPBO-PID_MTTA	SPBO	PID	TBD	TBD	IPv4, IPv6, TCP, UDP	3GPP 3G Suite, 3GPP 4G Suite	SNMPv3 MIB	TLS, IETF RFC 6071	Not defined yet
TMS-SPBO_MTTA	TMS	SPBO	TBD	AMQP	IPv6, IPv4, TCP	Generic Access	SNMPv3 MIB	TLS	Not defined yet

The table above shows the protocols which shall be used for the respective layer. Those listings may also contain alternatives, e.g. IPv4 or IPv6. The specific reference for the used protocols is listed in Appendix B of D3.3.

The protocol layers used follow the protocol stack as defined by ETSI. See ETSI EN 302 665 for details.

2.5.15. S15 - PVD (Probe Vehicle Data)

Probe Vehicle Data is data generated by vehicles. The collected traffic data can be used as input for operational traffic management (e.g., to determine the traffic speed, manage traffic flows by - for instance- alerting users in hot spots, where the danger of accidents accumulates), long term tactical/strategic purposes (e.g. road maintenance planning) and for traveller information services. Also known as Floating Car Data (FCD).

This service aims to collect data about traffic conditions, road surface conditions and the surroundings. [3]

2.5.15.1. Involved Components

This section shows which components are involved in this service. Furthermore, it lists the various sequence diagrams, which have been created to describe the service. The foundation of the service description is the component diagram, as shown below in Figure 39.

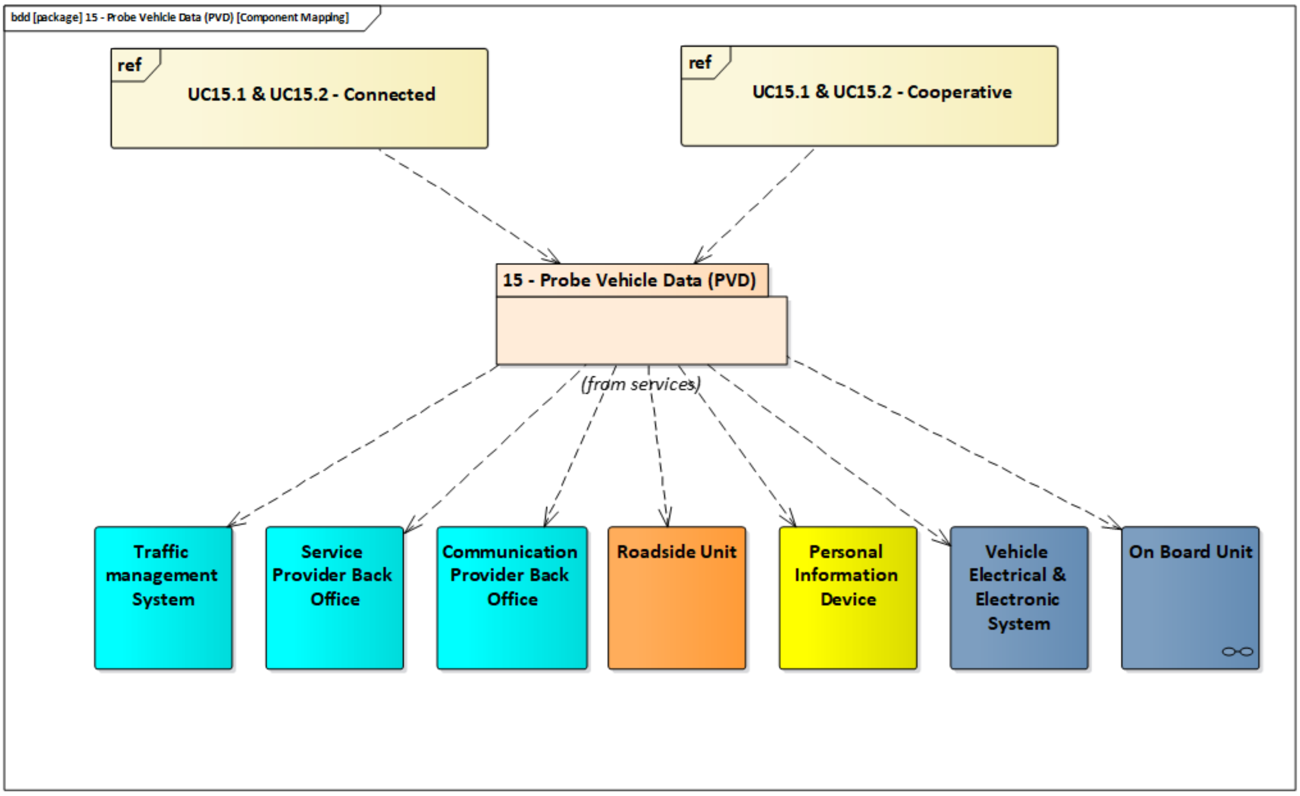

Figure 39: Probe Vehicle Data - Components involved in service

This service comprises two use cases which share the same architecture and can be implemented with both communication protocols (cooperative and connected). Therefore, different architecture components are involved in each one. In general, in order to implement this service, the following components are necessary:

/ Traffic management system (see section 4.2.2.2.5 of D3.3 for details.)
/ Service Provider Back Office (See section 4.2.2.2.3 of D3.3 for details)
/ Communication Provider Back Office (See section 4.2.2.2.1 of D3.3 for details)
/ Roadside Unit (see section 4.2.3.2.2 of D3.3 for details.)
/ Personal Information Device (See section 4.2.5.2.1 of D3.3 for details)
/ Vehicle Electrical & Electronic system, (see section 4.2.4.2.2 of D3.3 for details.)
/ On Board Unit (see section 4.2.4.2.1 of D3.3 for details.)

The relations among those components are described in the section Component Connections, below. The general functionality of this service, as well as more detailed interactions of the involved components are further described in UML Sequence Diagrams for the unique use case on which this service is based:

- UC15.1 “Basic probe vehicle data”
- UC15.2 “Extended probe vehicle data”

2.5.15.2. Component Connections

The following section describes the relations between the components. In Figure 40 all the involved components and the connections among them are listed for all use cases of the service.

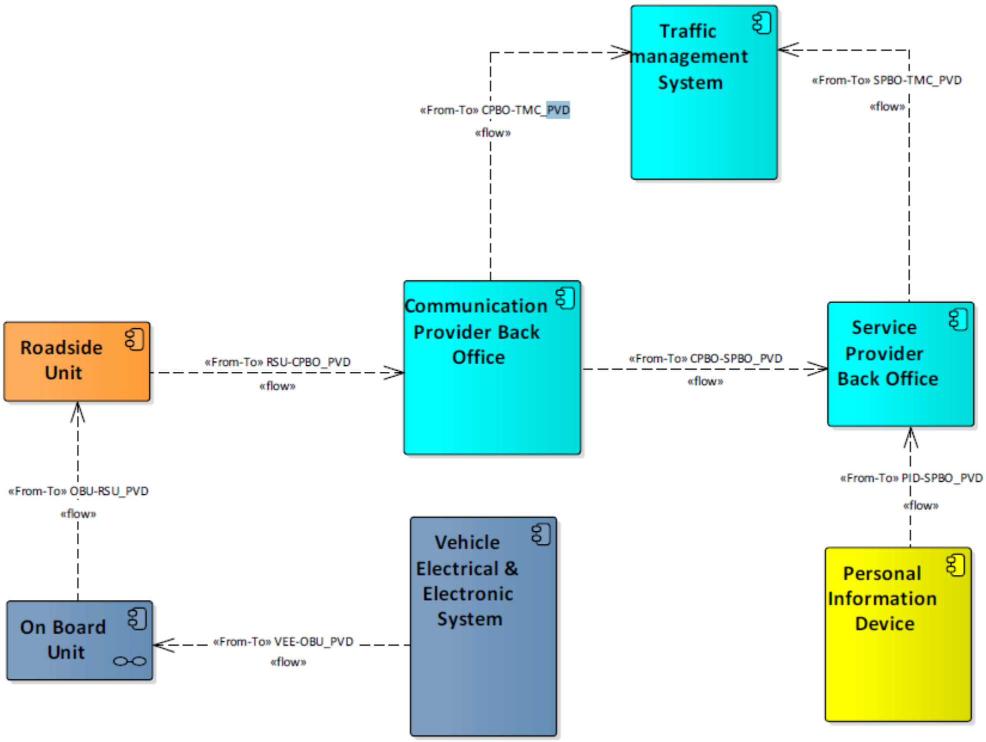

Figure 40: Probe Vehicle Data – Components and communication flows

The sequence diagram above shows the communication actors in Vigo DS. The information originated at the Data Provider Back Office (DPBO), which could be a Traffic Management system (TMS), is originated after analysing the data collected from the PIDs connected (e.g. speed, position, windscreen wiper status, ABS , ESP, collision sensors, etc.) every certain time. This data is processed in such a way that traffic events not detected by conventional sensors due to its limited coverage can be inferred. The Service Provider Back Office (SPBO) then reads this inferred information and transforms it to C-MobILE standards, which means encapsulating the information in DENM messages. The SPBO pushes the data into the CPBO. At this point there are two possible paths, either the information gets directly forwarded to Personal Information Devices (PIDs) in the relevant area, or 802.11p communication is used. In the latter case a Road Side Unit (RSU) in the relevant area receives the information and broadcasts the messages. These messages will be picked up by On Board Units (OBUs) and they forward them to PIDs to display to the end-users.

Table 15 Probe Vehicle Data - Protocols used for connections

Name	From	To	Protocol Layer						Datatypes Reference
			Application	Facilities	Transport & Networking	Access	Management	Security	
VEE-OBU_PVD	VEE	OBU							
OBU-RSU_PVD	OBU	RSU	ETSI ITS BSA	ProbeVehicleData_Msg (SAE J2735), ETSI ITS CAM	GeoNetworking	ETSI ITS G5	TBD	TBD	Not defined yet
RSU-CPBO_PVD	RSU	CPBO	-	(Aggregated) ProbeVehicleData_Msg (SAE J2735), ETSI ITS CAM*, MQTT	IPv4, IPv6, TCP	Generic Access	SNMP	TLS, ETSI ITS-S Security Architecture	Not defined yet
CPBO-SPBO_PVD	CPBO	SPBO	-	(Aggregated) ProbeVehicleData_Msg (SAE J2735), ETSI ITS CAM*, MQTT	IPv4, IPv6, TCP	Generic Access	SNMP	TLS, ETSI ITS-S Security Architecture	Not defined yet
CPBO-TMS_PVD	CPBO	TMS	HTTPS	(Aggregated) ProbeVehicleData_Msg (SAE J2735), ETSI ITS CAM*	IPv4, IPv6, TCP	Generic Access	SNMP	TLS, ETSI ITS-S Security Architecture	Not defined yet
SPBO-TMS_PVD	SPBO	TMS	HTTPS	(Aggregated) ProbeVehicleData_Msg (SAE J2735), ETSI ITS CAM*	IPv4, IPv6, TCP	Generic Access	SNMP	TLS, ETSI ITS-S Security Architecture	Not defined yet
PID-SPBO_PVD	PID	SPBO	HTTPS	(Aggregated) ProbeVehicleData_Msg (SAE J2735), ETSI ITS CAM*	IPv4, IPv6, TCP	3GPP 4G Suite, 3GPP 3G Suite	SNMP	TLS, ETSI ITS-S Security Architecture	Not defined yet

The table above shows the protocols which shall be used for the respective layer. Those listings may also contain alternatives, e.g. IPv4 or IPv6. The specific reference for the used protocols is listed in Appendix B of D3.3.

The protocol layers used follow the protocol stack as defined by ETSI. See ETSI EN 302 665 for details.

2.5.16. S16 - EBL (Emergency Brake Light)

Emergency Brake Light aims to avoid (fatal) rear end collisions, which can occur if a vehicle ahead suddenly brakes, especially in dense driving situations or in situations with decreased visibility. The driver is warned before s/he is able to realize that the vehicle ahead is braking hard, especially if s/he does not see the vehicle directly (vehicles in between).

This service addresses the situation that occurs when any vehicle abruptly slows down, it switches on emergency electronic brake lights. The service warns the local followers, in due time, so they can adopt their speed to avoid collision with the vehicle. [3]

2.5.16.1. Involved Components

This section shows, which components are involved in this service. Furthermore, it lists the sequence diagrams, which have been created to describe the service. The foundation of the service description is the component diagram, as shown below in Figure 41.

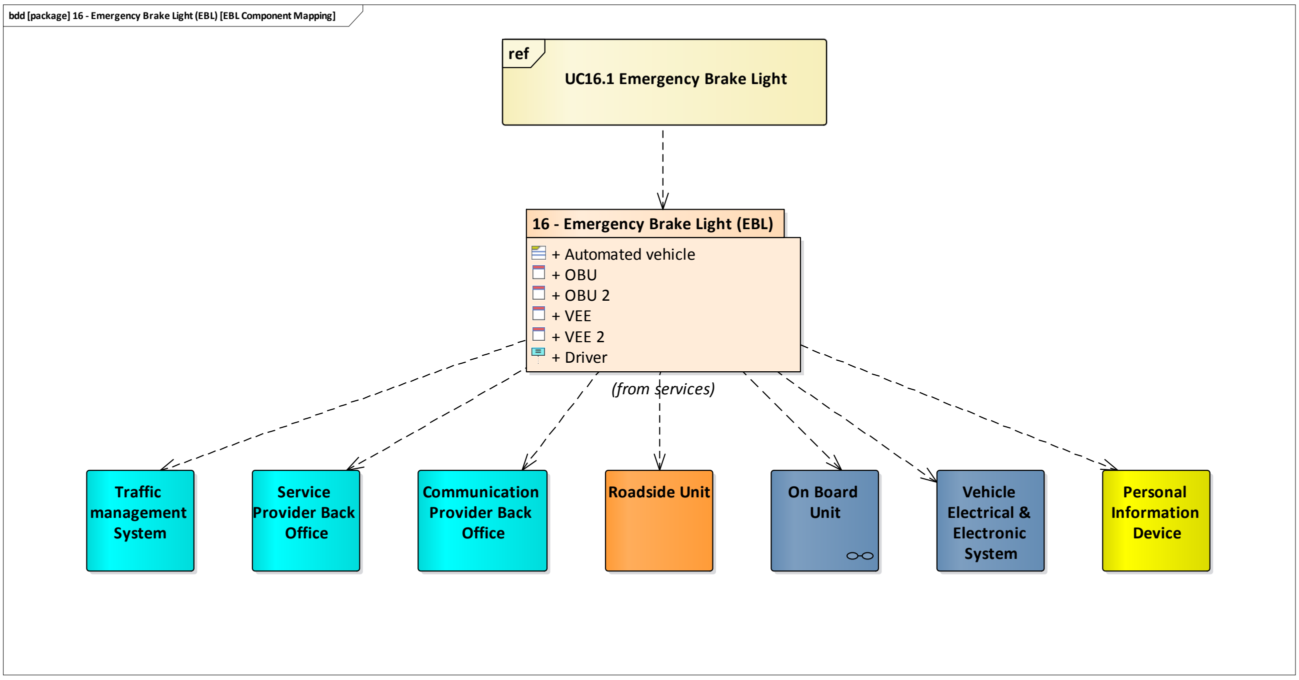

Figure 41: Electronic Brake Light - Components involved in service

To implement this service, the following components are necessary.

- Traffic Management System, for EBL the data is collected at the TMC following the path RSU-> CPBO -> SPBO -> TMC (See section 4.2.2.2.5 of D3.3 for details.)
- Service Provider Back Office (See section 4.2.2.2.3 of D3.3 for details)
- Communication Provider Back Office, for EBL this is the gateway to share the local traffic information to interested Service Providers Back Office/TMC. (See section 4.2.2.2.1 of D3.3 for details)
- Roadside unit, for EBL this is optionally used for sharing local traffic awareness data to a local Traffic Management Centre (TMC). (See section 4.2.3.2.2 of D3.3 for details.)
- On Board Unit, for EBL the minimal requirement is V2V based on ITS G5. Extensions are V2I over ITS G5 using local infrastructure and awareness. (See section 4.2.4.2.1 for of D3.3 details.)
- Vehicle Electrical & Electronic system, for EBL this is the interaction with vehicle control system, sensors and actuators. EBL can be implemented as a warning system with a notification to the driver or as automated driving function with direct vehicle control functions. And providing the information and EBL Messages to be distributed over V2V. (See section 4.2.4.2.2 of D3.3 for details.)
- Personal Information device, for EBL this can be a separate device, but it can also be part of another platform already on-board available like HMI or a communication/control unit. (See section 4.2.5.2.1 of D3.3 for details)

The relations between those components are described in the section Component Connections, below. The general functionality of these services, as well as more detailed interactions of the involved components is further described in UML Sequence Diagrams for the different use cases on which this service is based. This are in particular:

- UC16.1 – Emergency Brake Light: Cooperative communication
- UML sequence diagram for basis EBL as shown in Appendix 7.1.16.1.1 of D3.3
- S16: Emergency Brake Light (EBL) ARC-IT diagrams" as shown in Appendix 7.1.16.1.1 of D3.3

2.5.16.2. Component Connections

The following section describes the relations between the components. In Figure 42 all the involved components and the connections between them are listed for all EBL use cases.

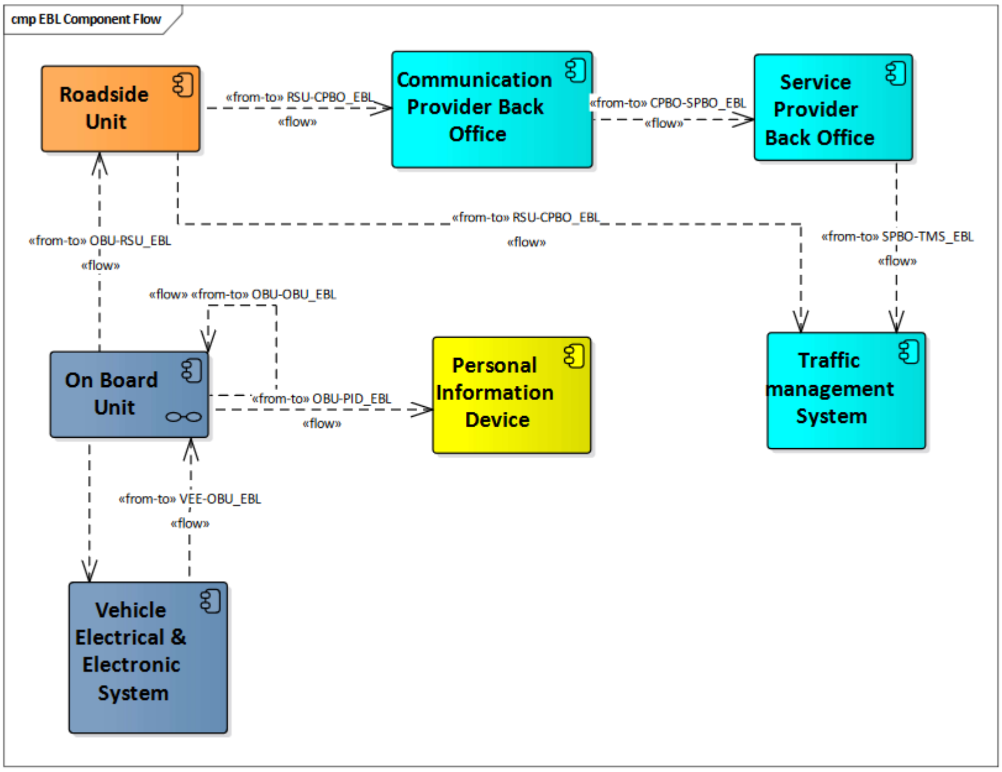

Figure 42: Electronic Break Light – Components and communication flows

This use case is only a V2V ITS G5 use case deployed as a Proof Of Concept (OBUs are not deployed in large-scale). This POC uses the CAN bus of the vehicle to detect a sharp brake press. When this event is detected (sharp brake + warnings lights), a DENM is generated on the position of the car, and the trace corresponds to the path history of the car. The DENM is valid until the vehicle restarts or 10s.

Table 16 Electronic Break Light - Protocols used for connections

Name	From	To	Protocol Layer						Datatypes Reference
			Application	Facilities	Transport & Networking	Access	Management	Security	
VEE-OBU_EBL	VEES	OBU	“EBL”	CAN, propriety vehicle interface	CAN/UDP/TCP	CAN	-	-	Figure 224 of D3.3
OBU-VEE_EBL	OBU	VEES	“EBL”	CAN, propriety vehicle interface	CAN/UDP/TCP	CAN	-	-	Figure 225 of D3.3
OBU-OBU_EBL	OBU	OBU	“EBL”	ETSI ITS CAM, DENM	GeoNetworking	ETSI ITS G5	-	ETSI ITS-S Security Architecture	Figure 226 of D3.3
OBU-RSU_EBL	OBU	RSU	“EBL”	ETSI ITS CAM, DENM	GeoNetworking	ETSI ITS G5	-	ETSI ITS-S Security Architecture	Figure 227 of D3.3
OBU-PID_EBL	OBU	PID	“EBL”	Json, asn.1	IPv6, IPv4, UDP	Generic Access	-	TLS	Figure 228 of D3.3
RSU-CPBO_EBL	RSU	CPBO		Json	IPv4, IPv6, TCP	Generic Access	SNMP	TLS	Figure 229 of D3.3 (Optional)
CPBO-SPBO_EBL	CPBO	SPBO							(Optional, datatype like Figure 229 of D3.3)
SPBO-TMS	SPBO	TMS							(Optional, datatype like Figure 229 of D3.3)

The table above shows the protocols which shall be used for the respective layer. Those listings may also contain alternatives, e.g. IPv4 or IPv6. The specific reference for the used protocols is listed in Appendix B of D3.3.

The protocol layers used follow the protocol stack as defined by ETSI. See ETSI EN 302 665 for details.

2.5.17. S17 - CACC (Cooperative Adaptive Cruise Control)

The service ensures smooth driving of vehicles with enabled Cooperative Adaptive Cruise Control (CACC) function or platooning for driving through a (series of) C-ITS equipped intersection(s). It improves safety, comfort and traffic flow on intersections with V2I communication between CACC and intersection traffic lights (or managed intersections).

The function architectural view of CACC and platooning service is shown in Figure 43. CACC/Platooning vehicles uses the low latency V2V communication over ITS G5 to periodically exchange CACC messages as well as platoon management messages. When approaching an intersection, the vehicles receive MAP and SPAT messages over the hybrid communication channels. They also receive speed advice for GLOSA enabled intersection. For platoons, they use Green Priority service to cross the intersection smoothly. In that case, the leader of the platoon sends an SRM message to the Green Priority service and receives back an SSM message indicating whether the priority is granted or not. The receiving vehicle calculates an optimal speed to cross the traffic light. In the case of a platoon, the platoon leader adjusts its speed in such a way that a smooth speed/acceleration pattern is achieved to efficiently pass through several consecutive intersections.

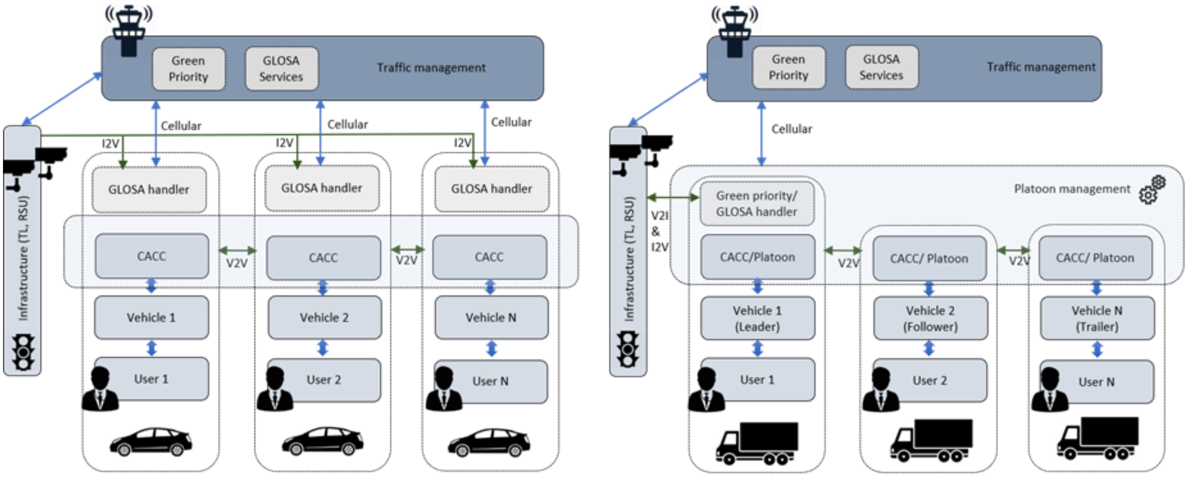

Figure 43: Functional architecture view a) CACC and b) Platooning

2.5.17.1. Involved Components

This section shows, which components are involved in this service. Furthermore, it lists the various sequence diagrams, which have been created to describe the service. The foundation of the service description is the component diagram, as shown below in Figure 44.

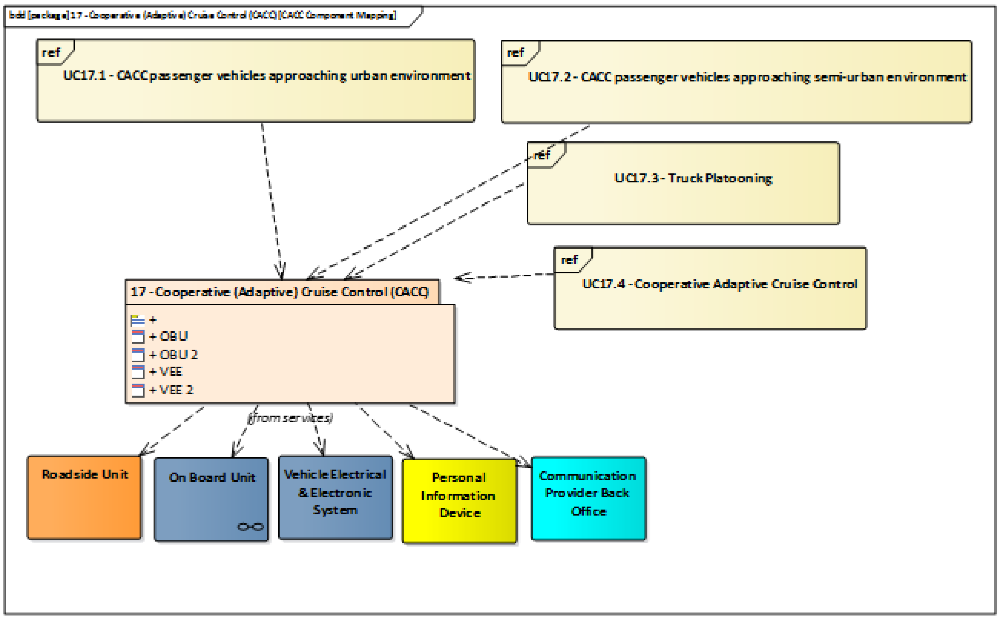

Figure 44: Cooperative Adaptive Cruise Control - Components involved in service

To implement this service, the following components are necessary:

- Roadside unit, for CACC this is used for information related to traffic light information at intersections and/or "priority services".
- On Board Unit, for CACC the minimal requirement is V2V based on ITS G5. Extensions are V2I and I2V over ITS G5 and/or cellular connectivity.
- Vehicle Electrical & Electronic system, for CACC this is the interaction with vehicle control system, sensors and actuators. And providing the information and CACC Messages to be distributed over V2V.
- Personal Information device, for CACC this can be a separate device, but it can also be part of another platform already on-board available like HMI or a communication/control unit.
- Communication Provider Back Office, for CACC this is used for traffic light information at intersections and/or "priority services".

The relations between those components are described in Figure 45.

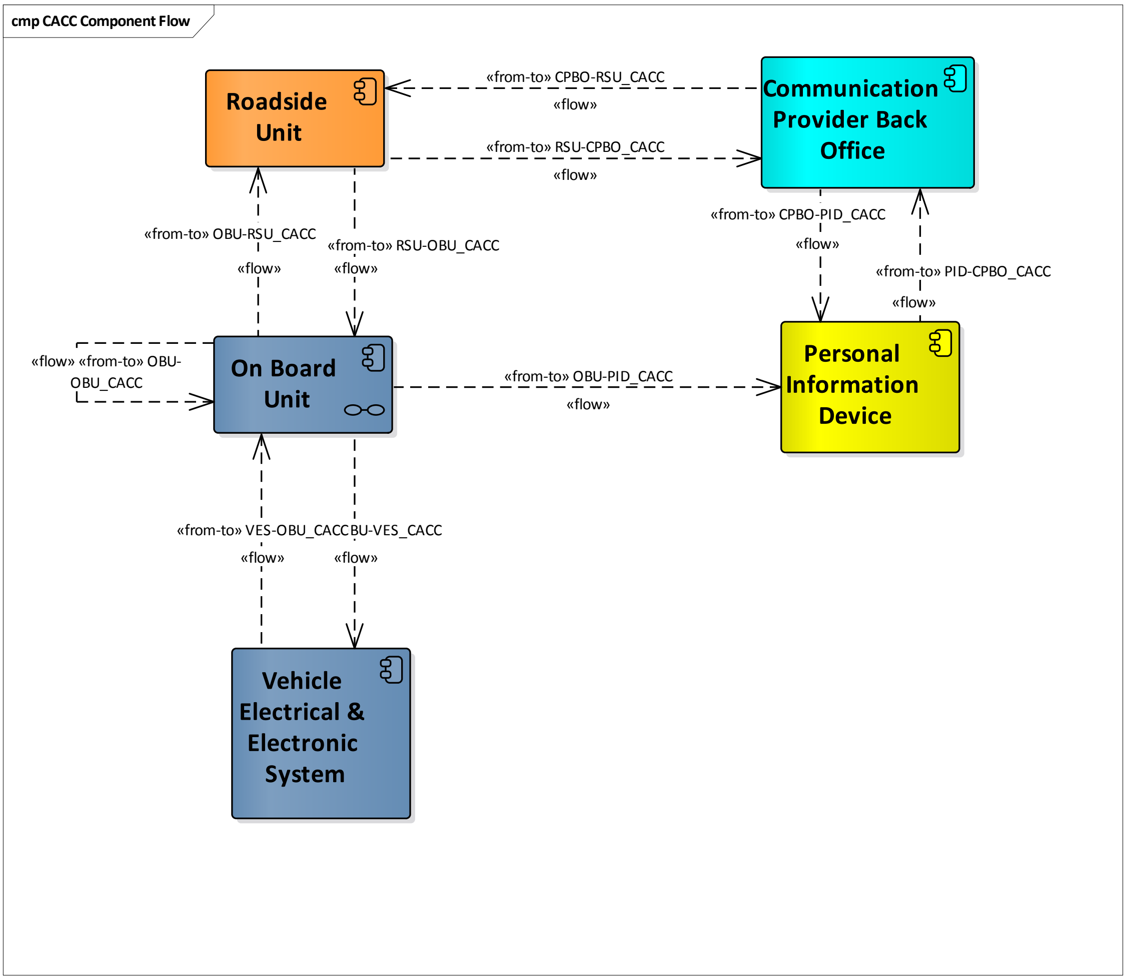

Figure 45: Cooperative Adaptive Cruise Control – Components and communication flows

The ego vehicle's On Board Unit (OBU) broadcasts CACC information needed for vehicle following and/or platooning. The CACC application uses the information from the Vehicle Electrical & Electronic System (VEES) to construct the CACC messages to be broadcasted out of the OBU. The CACC application status is presented on the vehicle HMI and/or Personal Information Device (PID). The PID can also be used for activating/deactivating and configuring the CACC application. The following vehicle uses the received CACC message at its OBU to set the speed set-point via the VEES and its status is presented at the PID. At cooperative intersections vehicles receive information from traffic light controllers (TLC) based on I2V communication with a Roadside unit (RSU). TLC data from RSU is provided to a central Communication Provider Back Office (CPBO). This information is available at vehicle side with hybrid communication units. The OBU uses the TLC data to adapt CACC set points at the VEES. In truck platooning, truck OBU uses a priority request via the RSU or CPBO. More details on the proposed architecture are provided in D3.3 [C-MobILE-D3.3] and the specification of the service in D2.3 [C-MobILE-D3.3]. shows the protocols which shall be used for the respective layer. The datatype references are the figures in D3.3 [C-MobILE-D3.3].

Table 17 Cooperative Adaptive Cruise Control - Protocols used for connections

Name	From	To	Protocol Layer						Datatypes Reference
			Application	Facilities	Transport & Networking	Access	Management	Security	
VES-OBU_CACC	VEES	OBU	"CACC"	CAN, raw bytes	Generic	Generic Access	-	-	Figure 224 of D3.3
OBU-VES_CAC	OBU	VEES	"CACC"	CAN, raw bytes	Generic	Generic Access	-	-	Figure 225 of D3.3
OBU-OBU_CACC	OBU	OBU	"CACC"	CACC, ETSI ITS CAM	GeoNetworking	ETSI ITS G5	-	ETSI ITS-S Security Architecture	Figure 226 of D3.3
OBU-RSU_CACC	OBU	RSU	"CACC	SRM, ETSI ITS CAM	GeoNetworking	ETSI ITS G5	-	ETSI ITS-S Security Architecture	Figure 227 of D3.3
OBU-PID_CACC	OBU	PID	"CACC"	Json, asn.1	IPv6, IPv4, UDP	Generic Access	-	TLS	Figure 228 of D3.3
RSU-OBU_CACC	RSU	OBU	"CACC""	ETSI ITS SPAT, ETSI ITS MAP	GeoNetworking	ETSI ITS G5	-	ETSI ITS-S Security Architecture	Figure 238 of D3.3
RSU-CPBO_CACC	RSU	CPBO		Json, MQTT	IPv4, IPv6, TCP	Generic Access	SNMP	TLS	Figure 229 of D3.3
CPBO-RSU_CACC	CPBO	RSU		Json, MQTT	IPv4, IPv6, TCP	Generic Access	SNMP	TLS	Not defined yet
CPBO-PID_CACC	CPBO	PID		Json, MQTT	IPv4, TCP, UDP	3GPP 4G Suite, 3GPP 3G Suite		TLS	Figure 240 of D3.3
PID-CPBO_CACC	PID	CPBO		Json, MQTT	IPv4, TCP, UDP	3GPP 4G Suite, 3GPP 3G Suite		TLS	Figure 236 of D3.3

The table above shows the protocols which shall be used for the respective layer. Those listings may also contain alternatives, e.g. IPv4 or IPv6. The specific reference for the used protocols is listed in Appendix B of D3.3.

The protocol layers used follow the protocol stack as defined by ETSI. See ETSI EN 302 665 for details.

2.5.18. S18 - SSVW (Slow or Stationary Vehicle Warning)

The slow or stationary vehicle warning system aids drivers to avoid or mitigate rear-end collisions with vehicles in front of driver's own car. The driver will be alerted through a notification or warning of the impending collision on slow vehicles.

The system does not attempt to control the vehicle in order to avoid an impending collision, but warns the vehicles on the potential danger of the slow or stationary vehicle(s) ahead.

This service provides timely in-car driving assistance information on a stationary vehicle(s) downstream of the current position and in the driving direction of the driver's own car.

2.5.18.1. Involved Components

This section shows, which components are involved in this service. Furthermore, it lists the various sequence diagrams, which have been created to describe the service. The foundation of the service description is the component diagram, as shown below in Figure 46.

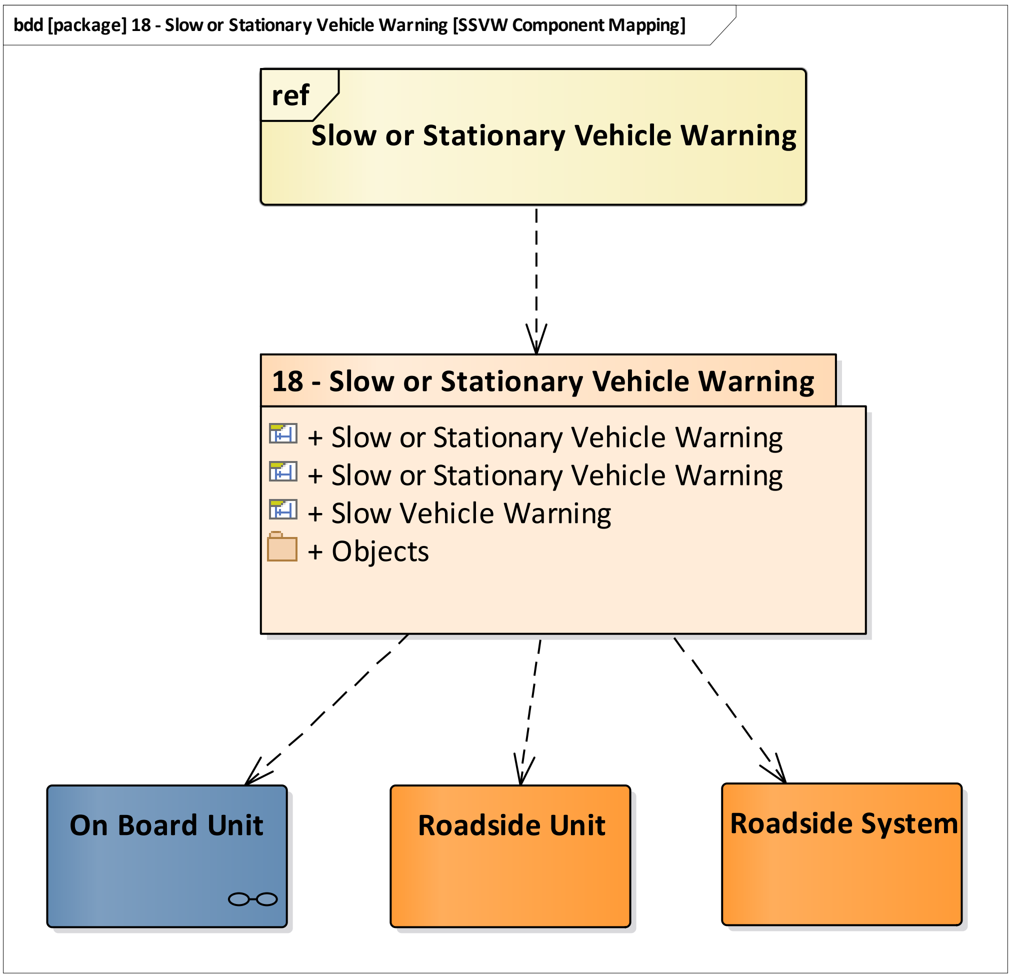

Figure 46: Slow or Stationary Vehicle Warning - Components involved in service

To implement this service, the following components are necessary.

- On Board Unit (see section 4.2.4.2.1 of D3.3 for details.)
- Roadside Unit (see section 4.2.3.2.2 of D3.3 for details.)
- Roadside System (see section 4.2.3.2.1 of D3.3 for details.)
-

The relations between those components are described in the section 2.5.18.2, below. The general functionality of these services, as well as more detailed interactions of the involved components is further described in UML Sequence Diagrams for the different use cases on which this service is based. This are in particular:

- “Slow or Stationary Vehicle Warning” as shown in Appendix A of D3.3.

2.5.18.2. Component Connections

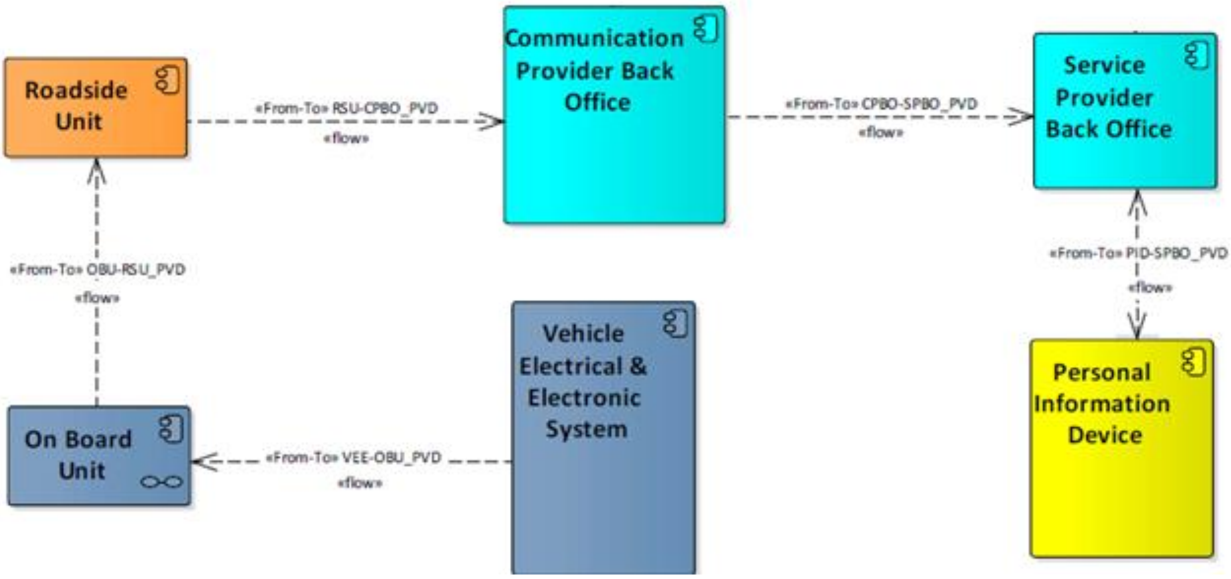

Figure 47: Slow or Stationary Vehicle Warning – Components and communication flows

The sequence diagram above shows the communication actors in Vigo DS as an explanatory example. The Service Provider Back Office (SPBO) is collecting info from PIDS that includes ego-speed. This information is provided to other vehicles at that moment located/entering in the relevance area of the event (relevance area: tile where the event is located and its adjacent ones). Once the message is in the receiver vehicles and not discarded (e.g. due to being too far -it could happen if the zoom is quite low), if the speed is less than a half of the ego vehicle (receiver vehicle) a POI on the position of the SSV is showed on the map available in the HMI.

Same philosophy applies when using ITS G5 technology by using V2V communications.

Table 18: Slow or Stationary Vehicle Warning - Protocols used for connections

Name	From	To	Protocol Layer						Datatypes Reference
			Application	Facilities	Transport & Networking	Access	Management	Security	
OBU-RSU_SSVW	OBU	RSU	-	ETSI ITS CAM	GeoNetworking	ETSI ITS G5		ETSI ITS-S Security Architecture	Figure 242 of D3.3
RSU-OBU_SSVW	RSU	OBU	-	ETSI ITS DENM	GeoNetworking	ETSI ITS G5		ETSI ITS-S Security Architecture	Figure 243 of D3.3
RSU-RS_SSVW	RSU	RS	-	ETSI ITS DENM	IPv4, IPv6, TCP	Generic Access		ETSI ITS-S Security Architecture	Figure 244 of D3.3

The table above shows the protocols which shall be used for the respective layer. Those listings may also contain alternatives, e.g. IPv4 or IPv6. The specific reference for the used protocols is listed in Appendix B of D3.3.

The protocol layers used follow the protocol stack as defined by ETSI. See ETSI EN 302 665 for details.

2.5.19. S19 - MAI (Motorcycle Approaching Indication)

Motorcycle approaching indication (including other VRUs) warns the driver of a vehicle that a motorcycle is approaching/passing (the scope can be extended to cover VRUs, such as pedestrians, cyclists, or moped riders). The motorcycle could be approaching from behind or crossing at an intersection.

European in-depth motorcycle accident analyses highlights that human error, and more specifically not seeing the motorcycle coming or misinterpreting distance and speed is the primary cause of accidents involving motorcycles [3].

2.5.19.1. Involved Components

This section shows, which components are involved in this service. Furthermore, it lists the various sequence diagrams, which have been created to describe the service. The foundation of the service description is the component diagram, as shown below in Figure 48.

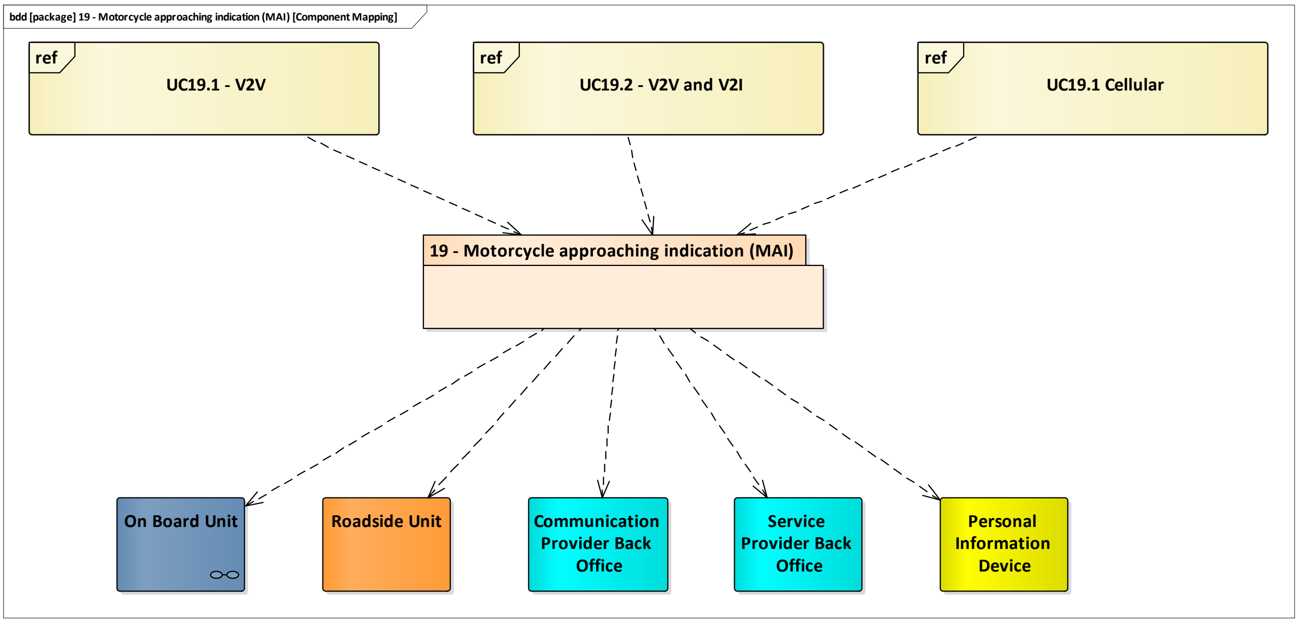

Figure 48: Motorcycle Approaching Indication - Components involved in service

To implement this service, the following components are necessary.

- On Board Unit (see section 4.2.4.2.1 of D3.3 for details.)
- Roadside Unit (see section 4.2.3.2.2 of D3.3 for details.)
- Communication Provider Back Office (See section 4.2.2.2.1 of D3.3 for details)
- Service Provider Back Office (See section 4.2.2.2.3 of D3.3 for details)
- Personal Information Device (See section 4.2.5.2.1 of D3.3 for details)

The relations between those components are described in the section 2.5.19.2, below. The general functionality of this service, as well as more detailed interactions of the involved components are further described in UML Sequence Diagrams for the different use cases on which this service is based. Those are in particular:

- UC19.1 - The approaching two-wheeler warning (V2V) as shown in section 7.1.19.1.1 of D3.3
- UC19.1 – The approaching two-wheeler warning (V2V cellular) as shown in section 7.1.19.1.2 of D3.3
- UC19.2 - The approaching two-wheeler warning (V2V and V2I) as shown in section 7.1.19.1.3 of D3.3

2.5.19.2. Component Connections

The following section describes the relations between the different components. In Figure 49 all the involved components and the connections between them are listed for all use cases of the service.

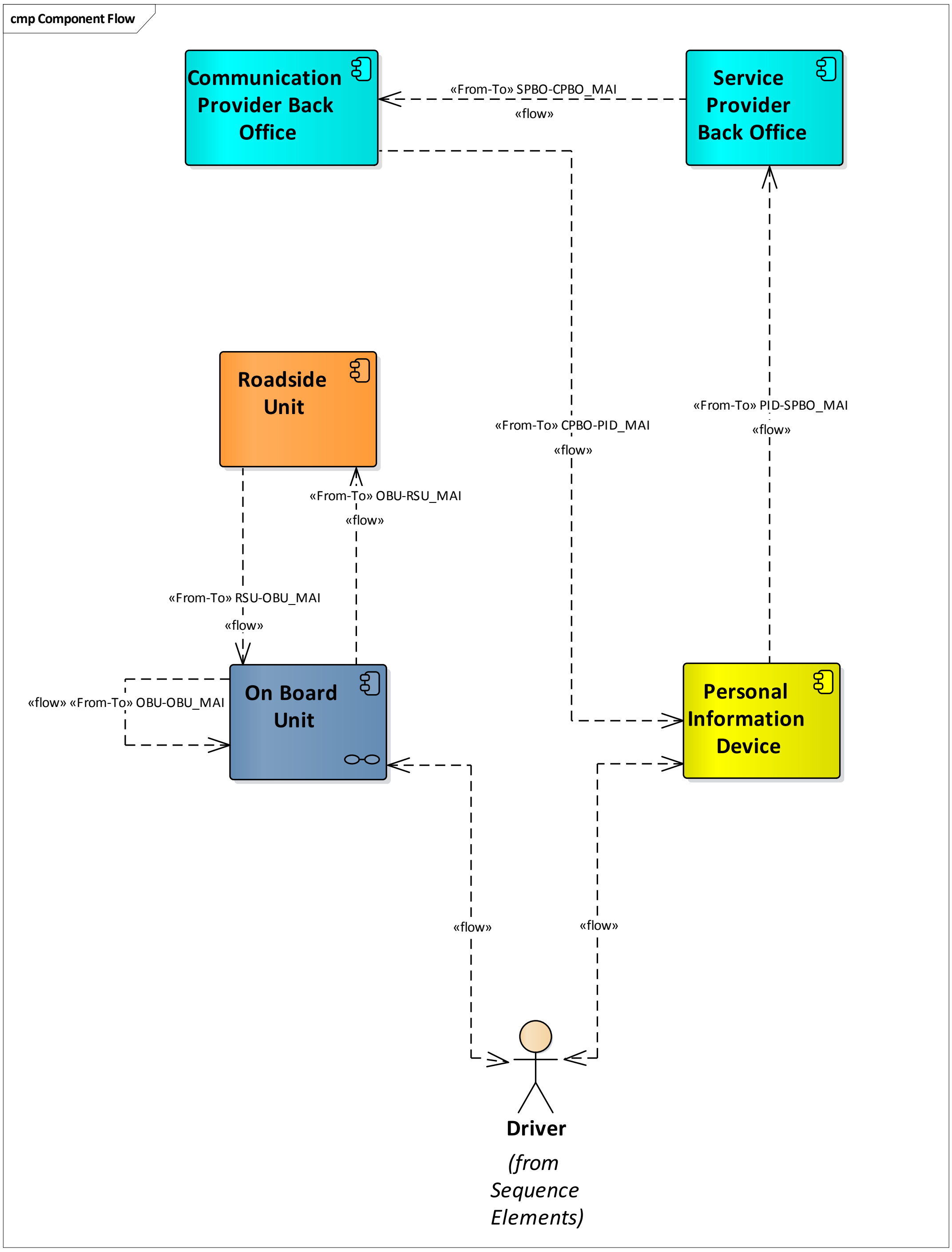

Figure 49: Motorcycle approaching indication – Components and communication flows

For the V2V ETSI ITS G5 case of the approaching two-wheeler warning the On Board Unit (OBU) is periodically sending CAMs to near vehicles. Therefore, the OBU uses the OBU-OBU_MAI relation to provide location data and to calculate a possible crossing. In case of V2I the OBU is sending its location to the Roadside Unit (RSU) using OBU-RSU_MAI as well. If a possible collision is detected the RSU will warn nearby vehicles by sending DENMs to the OBUs using RSU-OBU_MAI.

To implement the approaching two-wheeler warning with cellular communication, the Personal Information Devices (PID) send periodically CAMs to the Service Provider Back Office (SPBO) through the Communication Provider Back Office (CPBO) using PID-CPBO_MAI connection once they enter a specific area.

If the SPBO detect colliding trajectories or any other condition is fulfilled, a trigger is fired to generate a DENM message to be disseminated to the PID using the Communication Provider Back Office (CPBO) through the SPBO-CPBO_MAI relation. To finally send a DENM to the related PIDs, the CPBO-PID_MAI connection is used.

The communication viewpoint for this service is updated as shown in Figure 49.

Table 19: Motorcycle approaching indication- Protocols used for connections

Name	From	To	Protocol Layer						Datatypes Reference
			Application	Facilities	Transport & Networking	Access	Management	Security	
SPBO-CPBO_MAI	SPBO	CPBO	-	ETSI ITS DENM	IPv4, IPv6, TCP	Generic Access	SNMPv3 MIB	TLS	Figure 248 of D3.3
CPBO-PID_MAI	CPBO	PID	-	MQTT, ETSI ITS DENM	IPv4, IPv6, TCP	3GPP 3G Suite, 3GPP 4G Suite	SNMPv3 MIB	TLS	Figure 249 of D3.3
PID-CPBO_MAI	PID	CPBO	HTTPS	ETSI ITS CAM, MQTT	IPv4, IPv6, TCP	3GPP 3G Suite, 3GPP 4G Suite	SNMPv3 MIB	TLS	Figure 252 of D3.3
CPBO-SPBO_MAI	CPBO	SPBO		ETSI ITS CAM	IPv4, IPv6, TCP	Generic Access	SNMPv3 MIB	TLS	New interface
OBU-OBU_MAI	OBU	OBU	-	ETSI ITS DENM, ETSI ITS CAM	GeoNetworking	ETSI ITS G5	ETSI 102 890-1, G5 Congestion Control Management	ETSI ITS-S Security Architecture	Figure 250 of D3.3
OBU-RSU_MAI	OBU	RSU	ETSI 102 638	ETSI ITS CAM	GeoNetworking	ETSI ITS G5	ETSI 102 890-1, G5 Congestion Control Management	ETSI ITS-S Security Architecture	Figure 253 of D3.3
RSU-OBU_MAI	RSU	OBU	ETSI 102 894-2, ETSI 102 638	ETSI ITS DENM	GeoNetworking	ETSI ITS G5	ETSI 102 890-1, G5 Congestion Control Management	ETSI ITS-S Security Architecture	Figure 251 of D3.3

The table above shows the protocols which shall be used for the respective layer. Those listings may also contain alternatives, e.g. IPv4 or IPv6. The specific reference for the used protocols is listed in Appendix B of D3.3.

The protocol layers used follow the protocol stack as defined by ETSI. See ETSI EN 302 665 for details.

2.5.20. S20 - BSD (Blind spot detection / warning)

The blind spot detection aims to detect and warn the drivers about other vehicle of any type locates in predefined blind spot locations. The idea is to provide timely in-car driving assistance information on the presence of a vehicle in a designated blind spot location in the driving direction of the vehicle. The service can be defined on the bases of two diagrams being a cooperative (ITS G5) or connected (cellular) service. Both diagrams are presented below.

2.5.20.1. Involved Components

This section shows, which components are involved in this service. Furthermore, it lists the various sequence diagrams, which have been created to describe the service. The foundation of the service description is the component diagram, as shown below in Figure 50.

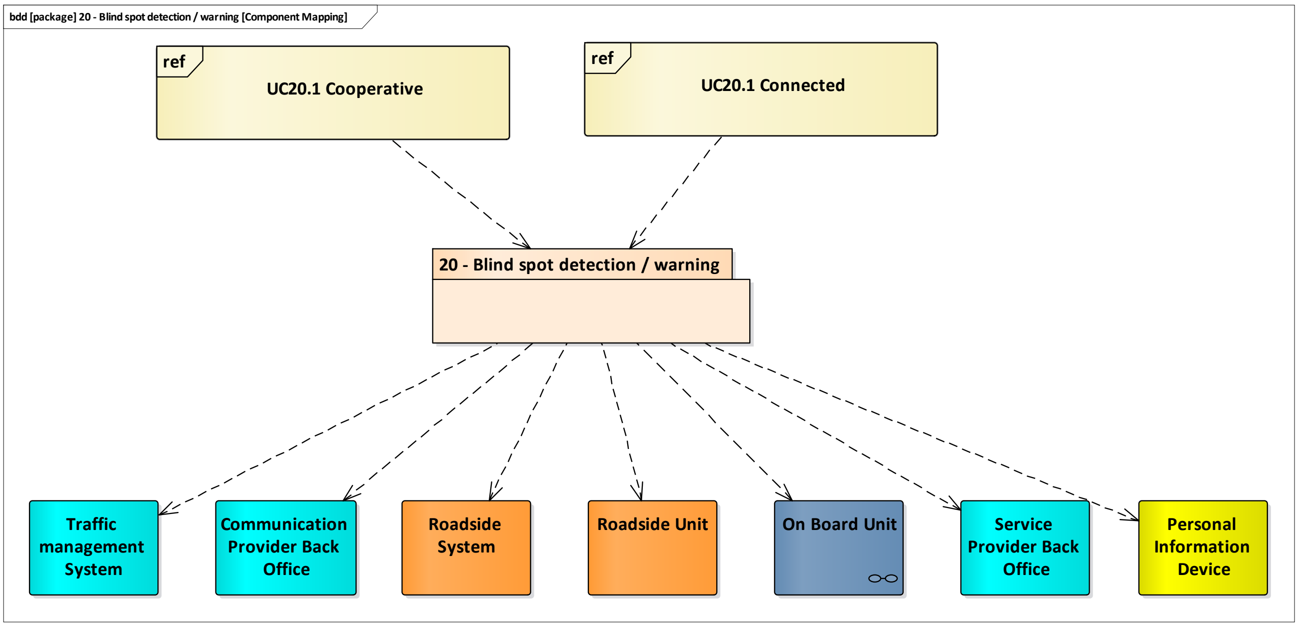

Figure 50: Blind Spot Detection - Components involved in service

To implement this service, the following components are necessary.

- / Traffic management system (see section 4.2.2.2.5 of D3.3 for details.)
- / Communication Provider Back Office (See section 4.2.2.2.1 of D3.3 for details)
- / Roadside System (see section 4.2.3.2.1 of D3.3 for details.)
- / Roadside Unit (see section 4.2.3.2.2 of D3.3 for details.)
- / On Board Unit (see section 4.2.4.2.1 of D3.3 for details.)
- / Service Provider Back Office (See section 4.2.2.2.3 of D3.3 for details)
- / Personal Information Device (See section of D3.3 4.2.5.2.1 for details)

The relations between those components are described in the section 2.5.20.2, below. The general functionality of these services, as well as more detailed interactions of the involved components is further described in UML Sequence Diagrams for the different use cases on which this service is based. This are in particular:

- / UC20.1 “Blind spot detection, cooperative” as shown in Figure 254 of D3.3.
- / UC20.2 “Blind Spot detection, connected” as shown in Figure 255 of D3.3.

2.5.20.2. Component Connections

The following section describes the relations between the components. In Figure 51, all the involved components and the connections between them are listed for all use cases of the service.

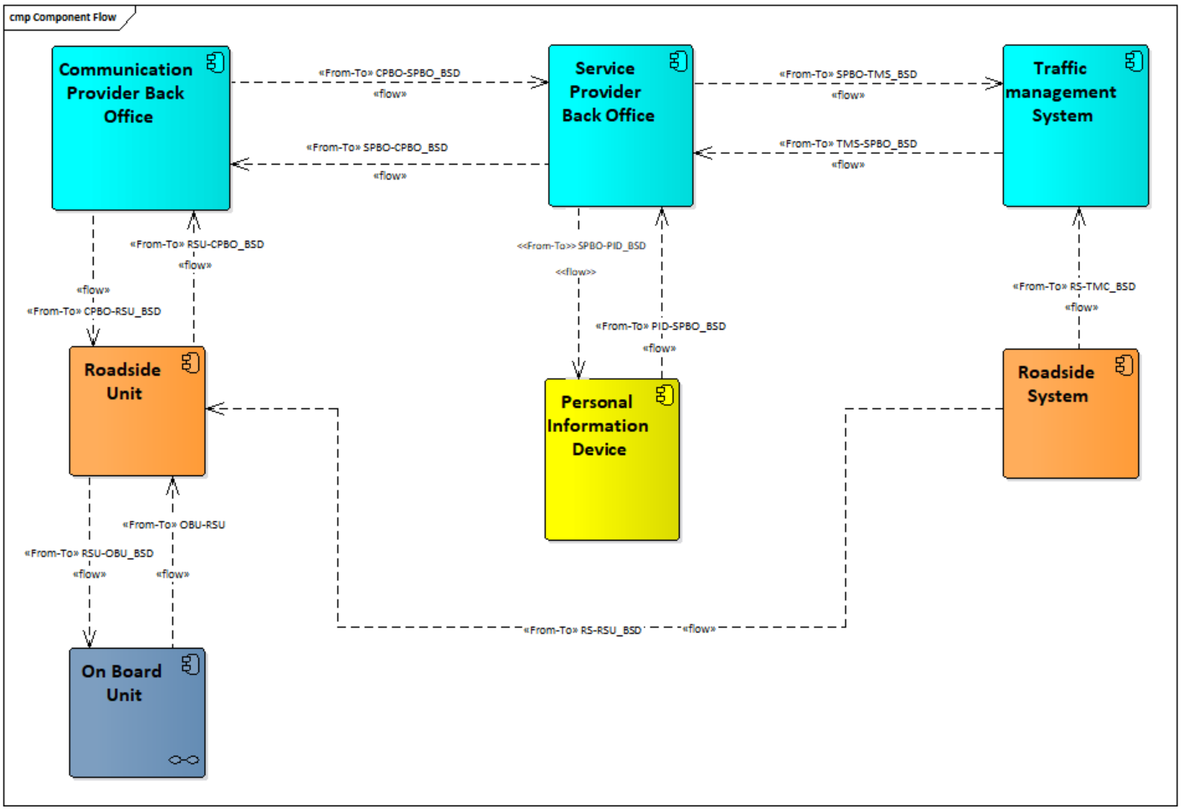

Figure 51: Blind Spot Detection – Components and communication flows

The Roadside System, for that case the RS, e.g. a camera, detects vehicles in a blind spot and provides this information to the Traffic Management System through the RS-TMS_BSD connection as well as to the Roadside Unit trough the RS-RSU_BSD connection. This information is sent through the Communication Provider Back Office to the Service Provider Back Office. The SPBO will receive location data for PIDs using PID-SPBO_BSD connection. The SPBO will then send the detection information using the CPBO and RSU to reach the OBUs.

Table 20: Blind Spot Detection - Protocols used for connections

Name	From	To	Protocol Layer						Datatypes Reference
			Application	Facilities	Transport & Networking	Access	Management	Security	
TMS-SPBO_BSD	TMS	SPBO	HTTPS	JSON	IPv4, IPv6, TCP			TLS	Not defined yet
SPBO-TMS_BSD	SPBO	TMS	HTTPS	JSON	IPv4, IPv6, TCP	Generic Access	SNMP	TLS	Not defined yet
TMS-SPBO_MTTA	TMS	SPBO	HTTPS	JSON	IPv4, IPv6, TCP	Generic Access	SNMP	TLS	Not defined yet
CPBO-SPBO_BSD	CPBO	SPBO	HTTPS	JSON, MQTT	IPv4, IPv6, TCP	Generic Access	SNMP	TLS	Not defined yet
SPBO-CPBO_BSD	SPBO	CPBO	HTTPS	ETSI ITS DENM, MQTT	IPv4, IPv6, TCP	Generic Access	SNMP	TLS, ETSI ITS-S Security Architecture	Not defined yet
CPBO-SPBO_MTTA	CPBO	SPBO	HTTPS	JSON, MQTT	IPv4, IPv6, TCP	Generic Access	SNMP	TLS	Not defined yet
CPBO-RSU_BSD	CPBO	RSU		ETSI ITS DENM, MQTT	IPv4, IPv6, TCP			TLS, ETSI ITS-S Security Architecture	Not defined yet
RSU-CPBO_BSD	RSU	CPBO		ETSI ITS CAM, MQTT	IPv4, IPv6, TCP			TLS, ETSI ITS-S Security Architecture	Not defined yet
CPBO-RSU_MTTA	CPBO	RSU			IPv4, IPv6, TCP, UDP	ETSI ITS G5	SNMPv3 MIB	TLS	Not defined yet
RS-RSU_BSD	RS	RSU							Not defined yet
RS-TMS_GLOSA	RS	TMS			IPv4, TCP	Generic Access	SNMP	TLS	Not defined yet
RSU-OBU_MTTA	RSU	OBU			GeoNetworking	ETSI ITS G5		ETSI ITS-S Security Architecture	Not defined yet

The table above shows the protocols which shall be used for the respective layer. Those listings may also contain alternatives, e.g. IPv4 or IPv6. The specific reference for the used protocols are listed in WP5.

The protocol layers used here are the layers as defined by ETSI. See ETSI EN 302 665 for details.

3. Detailed technical/protocol information

Due to the ambitious TRL target in C-MobILE, the technical team faced several points that needed to be addressed within the project in order to comply with the objectives. Main points were missing profiles, messages formats, cross-border interoperability definition and specifications. Some of those were still not defined in WP2 and WP5 tasks at the time of D3.3's submission (June 2018), therefore they are included, in a very basic way, in the D3.5.

As a summary, some C-MobILE services did not have a standard ITS messages associated (neither in Day 1 nor Day 1.5) or the interpretation of the standards did not comply with the expected services way of working. Moreover, new interfaces have been defined in order to reach a new cross-border interoperability approach, different from state-of-the-art and other current projects and initiatives, based on lower-level systems, involving the latest components of the architecture (PIDs and CPBOs) in the communication chain, instead of SPBOs and TMCs.

3.1. Interoperable TLS security

Security is a topic that is usually wrongly addressed in a later stage of the implementation process and it can ruin interoperability. As shown in the communication viewpoint, many of the interfaces of the services use TLS as main security protocol. It is a very robust protocol, but it still needs an agreement on the way it must be implemented in order to ensure that "shared" interfaces are interoperable each other.

Transport Layer Security (TLS) is a cryptographic protocol that provides end-to-end communications security over networks. It brings a good way to introduce privacy in a system compatible with multiple types of devices, as it is very widely extended. It is usually used for confidentiality and authentication purposes. During C-MobILE design phases, TLS was thought to uniquely identify users and systems (authentication). However, due to large-scale targets of the project, using TLS for authentication is not easy. Any user can download apps and use the systems so providing them specific C-MobILE certificates would harden the registration process.

Instead, TLS is only used as confidentiality protocol, which prevents some well-known attacks such as man-in-the-middle. During the registration process, any user with a smartphone can connect to the servers in order to get a token to enjoy the C-ITS services (business models and contracts among entities still not defined) in the city. To make sure about cross-border interoperability, all servers (Registration Servers) from all regions shall implement the same security approach, which shall let anyone with a valid token and certificate (signed by a trustable Certification Authority) join, regardless the source country. Only this way, interoperability is ensured at security level.

3.2. The POI format for MPA

The POI format for MPA is the same as for UPA. We are using a derived version of the ETSI POI (ETSI TS 101 556-1) message, adapted for parking facility description. This format was produced by COCSIC, a specification group that works for C-Roads use cases. This is also an ASN structure that is encoded in UPER (ASN.1 files attached in the Annex)

3.3. PID handover

When crossing a border between the area of one GeoMessaging to another, the PID has to establish the connection with the new GeoMessaging server. This procedure is often referred to as a handover. Concretely speaking, in C-MobILE most countries have their own server, but the three Spanish sites each have their own server. This implies a handover is not just limited to the border of a country. To understand the process of the handover, it is important to consider that a client device always uses its home Registration Server to obtain an access token for a particular GeoMessaging Server. The handover should therefore be included in the PID app logic of obtaining a token. There are a number of reasons that trigger a client device to obtain a new access token:

- Starting the client device software (App)
- Expiration of the currently used access token ("exp" claim in the token)
- Leaving the current country (e.g. detected via the phone network)
- Leaving the current region (if available, otherwise the country is leading)

The home Registration Server has the means to obtain an access token for a client device, which will be sent upon request. This of course follows the general C-MobILE architecture guidelines that put the responsibility of checking end-user identity on the service provider that provides the end-user app. In theory this service provider should also host a registration server and is in turn responsible of negotiating contracts with the providers of the GeoMessaging servers. On top of that, there could even be specific data streams and sinks that have a different service provider on the back-end which are also involved in the contract negotiation. However, such business issues should be tackled in D4.6. This deliverable focusses on providing a technical implementation that offers flexibility on the business side.

In more detail, the owner of a Registration Server has to negotiate the available services that it will support for roaming devices. It could happen that a given set of services is different from one country/region to another. If services used by roaming devices are paid, the payment of the foreign GeoMessaging Platform must be handled by the home Registration Server owner. These costs may then be invoiced to the device owner by the home Registration Server owner, but again it is a business decision how to generate income from the end-users.

The responsibility of obtaining access tokens for the registration server also directly implies that if a country/area is not supported by the home Registration Server, no services are available in that country/area. If a region is not supported by the home Registration Server, the services available in the country must be used. This implies graceful degradation, stepping back one level of detail in order to potentially still have some services available.

The mechanism used by client devices to obtain a token could be re-used by a foreign Registration Server to obtain a token for one of its roaming clients. This requires special handling by the Registration Server:

- Each unique client device must be provided with a working access token (i.e. the token must contain the identity of the client device).
- The service usage of the roaming device must be invoiced to the foreign Registration Server, mentioning the identity of the roaming client device.
- The set of services is determined by the identity or contract number of the foreign Registration Server (because this has been negotiated up front).
- The foreign Registration Server may decide to only request a subset of those services depending on the contract it has with that particular end-user.
- The access token is returned to the requesting Registration Server, which will pass it on to the requesting (roaming) client device.

Section 2.5.2 of D5.3 further details the REST interface that is implemented to obtain a token. However, only an indication of the client's location was given there. This enables the registration server to provide a token for the current region of the client. However, an extension is required for the response to include a definition of the area for which the token is valid. Using this, the client knows when to request a new token.

4. Technical and Organizational Challenges

Implementing a C-ITS infrastructure in an existing traffic space brings several technical and organizational challenges, starting with the permission of the legal authority and the city council. One big aspect when implementing a C-ITS infrastructure is the permission to have access to different data sources such as traffic data or hazard warnings. A common challenge is to update already installed infrastructure to the C-MobILE standards in order to ensure interoperability. Interoperability is one of the main goals of this project, and as some DSs used mainly one kind of communication, e.g. ITS G5 communications, they need to adopt the other one (cellular communications) for their services too, in order to reach this goal. The implementation and integration of a GeoMessaging server is a huge challenge for those DSs which provide the access to it, especially in order to be interoperable with other devices from different DSs. Besides mastering those challenges, a DS has to implement the different services according to the specifications of C-MobILE.

Additional, further organizational issues arise when planning a large-scale demonstration. This means end user recruitment and training as well as providing devices such as On Board Units or smartphones, depending on the communications channel. The provision of mobile devices for each end user is only one point; all devices need a SIM card and therefore a mobile phone contract.

Therefore, each DS faces its own challenges during the operational implementation of the C-MobILE services. An overview of those is provided in the following sections.

4.1. Challenge Report for BCN

The challenges for Barcelona DS have been evolving with time. Taking into account that Barcelona had almost no infrastructure ready for C-ITS in the beginning of the project, the first main challenge was putting every partner, association and authority together in order to realize the impact of the missing points in terms of infrastructure. From that meeting, it was decided that some missing architecture blocks would need to be covered by other project partners.

The GeoMessaging server and the user's application were those points. An assessment from all possibilities was done, and according to the Barcelona DS's situation, the best choice was to go for Dynniq systems to cover CPBO and a specific component of the PID system. This was a complicated process involving technical, legal and management people.

When the general technical points were covered, we started working on the services. Some services were clearly defined, and their data sources identified, but others were missing. Emergency Vehicle Warning and GLOSA services had no data source immediately associated, which brought up another meeting involving all Barcelona DS partners to identify them. For EVW, some associated partners joined the Barcelona DS. However, there is only one Traffic Management Centre in Barcelona, therefore we had no alternatives as we had for EVW. Unfortunately, an agreement was not achieved and GLOSA and SVW services do not rely on real-time information from the TMC (as this is not available), which would be the ideal situation. Instead, we have to work with static data and provide those services as a proof-of-concept. The exploration of other, better alternatives will continue through 2020 though and, if we find a feasible way, we will increase the area and quality of GLOSA and SVW in the future.

This shows how big a challenge is to engage key partners, with different targets and readiness levels.

Another organizational challenge was to involve people for the Barcelona DS training, held at RACC premises on May, 7 2019. In this case, all partners had huge commitment to bring people to the meeting and teach them on how to use the C-MobILE services in Barcelona DS.

4.2. Challenge Report for BIL

The main challenge for Bilbao DS has been the integration of the GeoMessaging server. Almost all the infrastructure was ready for the operation of the services deployed in Bilbao. The adaptation of Bilbao DS has been mainly related to the creation of the GeoMessaging Server and its interoperability tests with other Deployment Sites. Additionally, Blind Spot Detection Service has been developed. This service provides the collision risk information between bikes and buses. The mobility information of each user will be used in the future (out of the scope of C-MobILE) for the evaluation of the collision risk between different users in different transport modes. That leads in a collision risk matrix evaluated in real time.

The previous deployed services in Bilbao have facilitated the further deployments for the services of Urban Parking Availability, Road Works Warning and Road Hazard warning. The information was ready in the Open Data for being used for these services. The Open Data contains the information in DATEX II, which has facilitated the access to the information from servers outside of Bilbao Infrastructure. The development team has completed the GeoMessaging server and the testing with remote servers. Previous infrastructure developed in Bilbao has led to an easier deployment of further services and in a quicker adaptation of the infrastructure for ensuring the interoperability with other Deployment Sites.

4.3. Challenge Report for BOR

The main challenge for Bordeaux DS was to create the GeoMessaging architecture, as this is the first time the MQTT protocol has been used. But once this was done, providing the GeoMessaging server with data was pretty straightforward as we already had data sources ready.

One big point was also to be interoperable with other deployment sites, especially regarding the registration. The last issue was to adapt the PID architecture to be able to create the evaluation log data easily.

4.4. Challenge Report for CPH

The main challenge for the City of Copenhagen has been connecting a number of existing but separate systems for interoperability purposes, as well as sourcing the foundational data for the C-MobILE services, which we were to provide.

The City of Copenhagen already had a C-ITS server, G5 equipment such as RSU and OBUs, as well as an HMI/app that could in essence be adopted and utilized for the services in C-MobILE project. Though, naturally, these all needed to adhere to new standards for interoperability between different deployment sites and service providers.

As an example, the existing app and C-ITS server and HMI/app needed to be reconfigured to be interoperable with others from the different deployment sites. A challenge here was that some project documentation was not perceived as clear enough by service providers, to be able to execute the configurations efficiently in an interoperable way.

As stated, the second big challenge was sourcing both information about as well as the actual data itself for the services. As an example, the GLOSA or rather the TTG/TTR data from the traffic light controllers was first presumed to be present, but later it became clear that this data was not present or at least not communicated from the TLCs. For this reason, to make sure that the services would be ready for the large-scale demonstration by September 2019, we the City together with its suppliers chose to proceed with a two-stage solution for the system architecture.

Using the Dynniq GeoMessaging server which was already in place for other deployment sites we were able to create a quick fix for the GLOSA TTG/TTR issue, making sure that the services were provided functionally to the users. This required Technolution to configure the app to be interoperable with the Dynniq server, something that would already have to be done, and which secured an inherent interoperability test for the project.

The second stage consists of Dynniq updating the TLCs to use the RSMP protocol which is then able to transmit TTG/TTR information to the C-ITS/GeoMessaging server of the City of Copenhagen, which in the meantime will also be configured to adhere to C-MobILE standards for interoperability.

The transition between the servers is designed to be seamless with an uninterrupted continuation of the services, as perceived by the end users.

A third and last major issue referred to the update of the G5 equipment from the ETSI 2015 to the 2016 standard. A number of the RSU installed in the city of Copenhagen were installed in the Compass4D project in 2013 and were not able to be updated to the new standard and still provide the Green Priority service as this was based on CAM messages in the 2015 standard but on SRM in the 2016 standard. This same fact, though concerning OBUs instead, had already been realized in the Province of Helmond previously, but for different reasons, e.g. the one stated below, it was not realized that the same issue would also apply to Copenhagen. Even though both partners were in Compass4D and fundamentally had the same equipment.

Organizationally, some of the issues above were the result of a period surrounding the 2018 ITS World Congress, where there was a drain on City of Copenhagen personnel, unfortunately coinciding with a change of deployment site leadership. This resulted in a period where the City of Copenhagen was not as effective in ensuring engagement and progress for the project. Though this issue was mitigated by the end of 2018, only with minor delays as a result.

4.5. Challenge Report for NEW

Newcastle, like Copenhagen, already has a G5-based system for green priority and GLOSA from the Compass4D project and has faced some of the same issues.

A decision was taken shortly after Compass4D to expand G5-based C-ITS to an additional arterial corridor in Newcastle and deploy on board units (OBUs) on express buses to deliver GP and GLOSA. As part of this project an HMI was designed for bus drivers using a fully collaborative approach, with the aim to use this also in C-MobILE. The initial challenge faced by Newcastle was procurement of OBUs, which significantly delayed the implementation phase of that project, which was intended to be up-and-running in 2017. Furthermore, the nature of the eventual procurement of equipment meant that the structure of the delivery and deployment of the equipment was more complicated due to the contractual arrangements between parties.

Compounding this issue, and specific to C-MobILE, the DS lacked a full-time technical partner on the project until summer 2019 as a result of Siemens being sub-contracted rather than a full project partner. Although Siemens was working on the implementation of the previous project, C-MobILE required them to be a full system integrator. Since the completion of the sub-contract, the DS has been successful in identifying and proposing mitigation strategies for previous delays, as well as implementing the requirements of C-MobILE, notably delivery of RHW/RWW via DENM messaging, and work with NeoGLS to supply GeoMessaging. This has also relieved pressure on the other local DS partners, which have small, largely non-technical staff.

However, despite the resolution of a technical partner as system integrator, helping deliver the architecture and service implementation, there are now some legacy issues, primarily the need to upgrade the bus OBUs from 2015 to 2016 plug test for C-MobILE compatibility, with an eventual aim to upgrade both corridors to 2019 plug test. Although the latter is a nice-to-have, the former is a must-have as far as effective C-MobILE operations are concerned.

In summary, the issues Newcastle has faced have been both technical and organizational (lack of expertise, procurement delays) and unintended knock-on consequences of upgrading legacy equipment causing further delay.

4.6. Challenge Report for NBR

To a large extent the challenges in North Brabant are not of a technical nature. The cost involved for providing services to end users has been much larger due to unforeseen updates of firmware on devices, the data service contracts and in several cases the need for new devices. Secondly, there are several C-ITS deployment activities in the region that interfere with assessment of the impact from C-MobILE services. Finally, traffic issues on some target locations have been resolved in other ways by the local authorities, making it challenging to find a relevant location where the benefits of C-ITS can be demonstrated.

The deployment of ITS G5 services on a large fleet is clearly planned for an identified large group of users. On cellular services that are provided through a smartphone the user recruitment is pending service completion. For both user groups the rollout is pending successful validation of the services, including data provision for evaluation. Finally, for some services associate partners are involved for the realization with the aim to establish sustainable deployment with a business-sensible service delivery. The rollout of that deployment is pending the assessment of required partnerships and setting up business contracts.

4.7. Challenge Report for THES

The main challenge for Thessaloniki was the development of new systems and the integration of the existing ones according to the C-MobILE architecture. C-ITS services have been implemented in the city of Thessaloniki also in the past (projects Compass4D, CO-GISTICS) though concerning architecture, upgrades and new developments were necessary, in order to support the operation and functionalities of the C-MobILE C-ITS services. Existing systems had to be upgraded while new interfaces had to be developed taking into account the interoperability requirements and specifications imposed by the project.

Regarding the development of new systems, a major challenge was the development of the GeoMessaging Platform as Thessaloniki proceeded with the implementation of its own GeoMessaging Platform, including both a GeoMessaging Server and a Registration Server. Developments were based on the architecture proposed for a whole project solution (Dynniq's GeoMessaging Platform) so as to ensure interoperability with the rest of the deployment sites.

Moreover, a new App had to be developed for the provision of the services implemented within C-MobILE. Applications had been developed in the past within the scope of previous projects but especially for C-MobILE a new development was necessary, in order to be compliant with the architecture and to support interoperability.

Concerning the existing systems, upgrades were mainly focused on integration activities associated with the traffic light controllers of intersections in the city center and the western entrance of the city for the operation of the GLOSA service. More specifically, the raw data, including traffic lights status, times to change, etc., had to be converted accordingly, in order to create the MAP/ SPAT messages in ASN.1 format which are distributed by the server and then provided to the App.

4.8. Challenge Report for VIG

The main challenge for the City of Vigo was connecting the existing infrastructure to the cellular network to make the services available through this technology instead of ITS G5. Added to this, the interoperability requirements implied the development of the GeoMessaging platform, for the cellular communication, according to the project specifications. Also, the C-ITS server and user application needed to be developed and/or updated to be interoperable with other deployment sites.

Another challenge for this deployment site is about the logging features to be implemented, as the definitions were not completely clear and needed many iterations until the last version.

5. C-MobILE Architecture and ARC-IT

ARC-IT provides a common framework for planning, defining, and integrating ITS. ARC-IT, previously called the National ITS Architecture, was first developed in 1996 and has been updated many times over the years to reflect changes in technology and define new ITS services. ARC-IT now includes all content from the Connected Vehicle Reference Implementation Architecture (CVRIA), which until recently was the repository of all C-ITS related architecture material in the United States' reference. ARC-IT includes material content and tools which aim to assist agencies in the development of regional ITS architectures, hence helping regions understand how an individual project fits into a larger regional transportation management context [4].

ARC-IT is organized around four viewpoints used to describe: Enterprise, Functional, Physical, and Communication. The scope of ARC-IT is defined by a set of ITS Services, meaning transportation services that can be provided through the use of ITS. The range of services covered by ARC-IT is broad and incorporates all the applications of the National ITS Architecture, the CVRIA, and additional ITS services defined internationally. ARC-IT uses the concept of Service Packages to describe the portion of the architecture needed to implement a particular service. Service Packages include the portions of each of the four views needed to describe the service. Service Packages are not intended to be tied to specific technologies, but depend on the current technology and product market in order to actually be implemented. The Areas of Services include Commercial Vehicle Operations, Data Management, Maintenance and Construction, Parking Management, Public Safety, Public Transportation, Support, Sustainable Travel, Traffic Management, Traveler Information, Vehicle Safety, and Weather [4].

The primary goal of the collaboration between C-MobILE and ARC-IT is to facilitate application of ARC-IT and its tools to the C-MobILE project. The use cases developed for the C-MobILE services were input into the ARC-IT project architecture development process with the goal to produce a representation of the system architecture using ARC-IT language and depictions.

For the purposes of producing the C-MobILE system architecture, the SET-IT tool was used. SET-IT is one of the companion free tools for ARC-IT. It is a graphical tool, providing the user with visual feedback and tools necessary to manipulate service package physical and enterprise diagrams, develop communications stack templates, specify standards at all protocol layers, and export that information in a variety of forms and formats. The tool was considered appropriate as it is project-focused and can apply to an individual project deployment. The whole process produced artifacts which served as pre-design documentation for the C-MobILE system architecture, enabling the identification of functionalities within subsystems and interfaces between subsystems.

The representation of the C-MobILE system architecture, produced by SET-IT, is comprised of several Physical View diagrams depicting the Physical Objects (p-objects), i.e. persons, places, or things participating in C-ITS, as well as the information flows (highest-level definition of interfaces) between them. Each diagram describes the interactions between the support, center, field, traveler and vehicle systems involved in each C-ITS service. P-objects are defined as follows:

- Center (green rectangle): Element providing application, management, administrative, and support functions from a fixed location not in proximity to the road network.
- Field (orange rectangle): Infrastructure proximate to the transportation network performing surveillance, traffic control, information provision and local transaction functions.
- Support (light green rectangle): Center providing a non-transportation specific service.
- Traveler (yellow rectangle): Equipment used by travelers to access transportation services pre-trip and en-route.
- Vehicle (blue rectangle): Vehicles, including driver information and safety systems applicable to all vehicle types.

An information flow contains one or more dialogs that contain one or more messages (which may be unicast, multicast or broadcast); each message contains one or more data elements. Arrows indicate the direction data flows, though messages may go in both directions as part of request-response type interactions. Line colors indicate whether the key messages are expected to be authenticable (green) or authenticable and obfuscated (red) or neither (black). Alphanumeric codes indicate time and spatial relevance (A-D, 1-4 respectively). Information flow initiators are indicated by the presence of a small white square affixed to the flow, located inside the initiating p-object. A small bar perpendicular to the flow line on the side of the line opposite the arrow indicates that the flow is expected to include some form of acknowledgement.

The following Physical View diagrams represent the system architecture of the C-MobILE services including the whole number of use cases which address the needs of three stakeholders' categories: 1) Customers/ End-users, 2) Technology Providers, and 3) Legal Authorities.

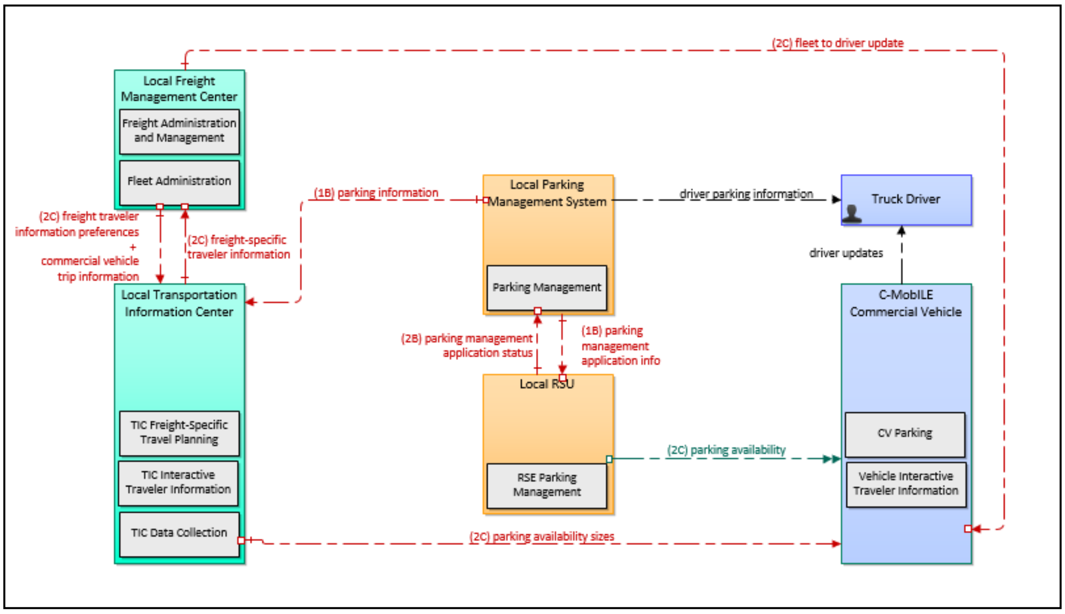

Figure 52: Rest Time Management

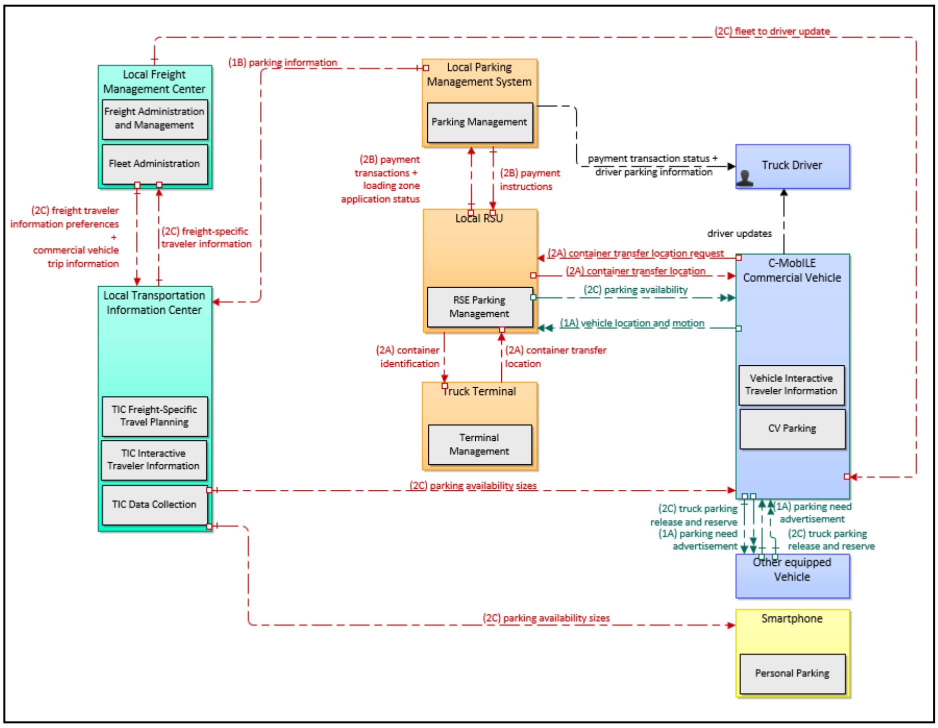

Figure 53: Motorway Parking Availability

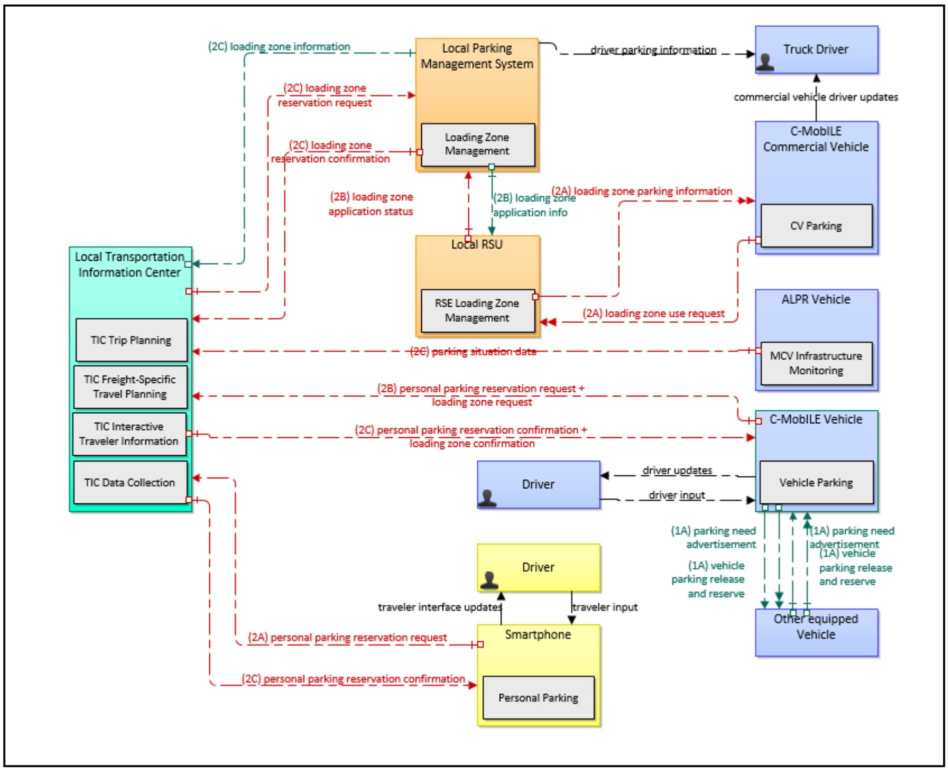

Figure 54: Urban Parking Availability

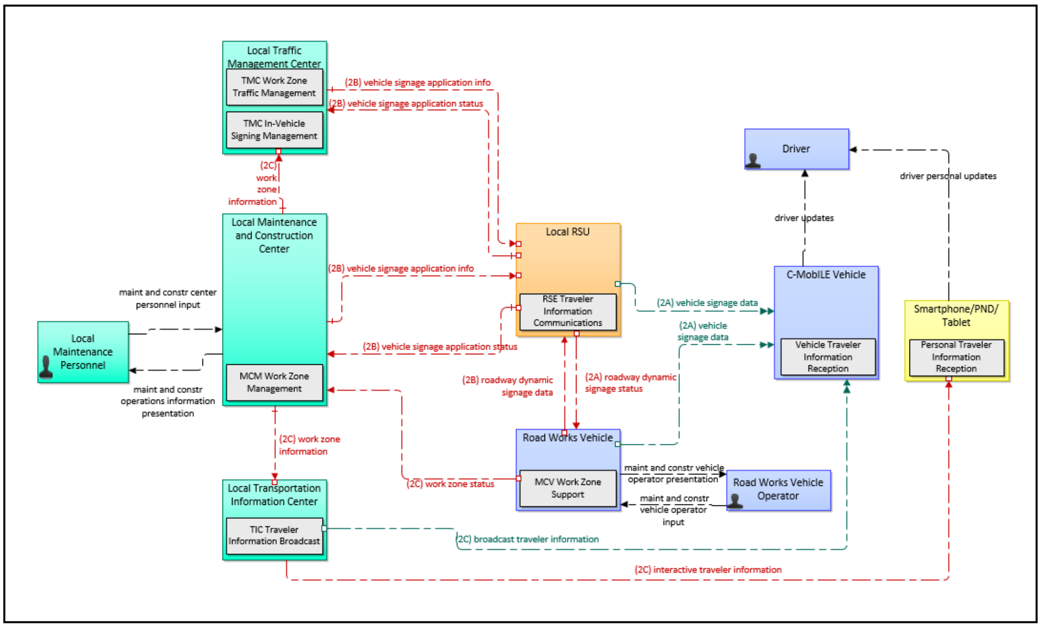

Figure 55: Roads Works Warning

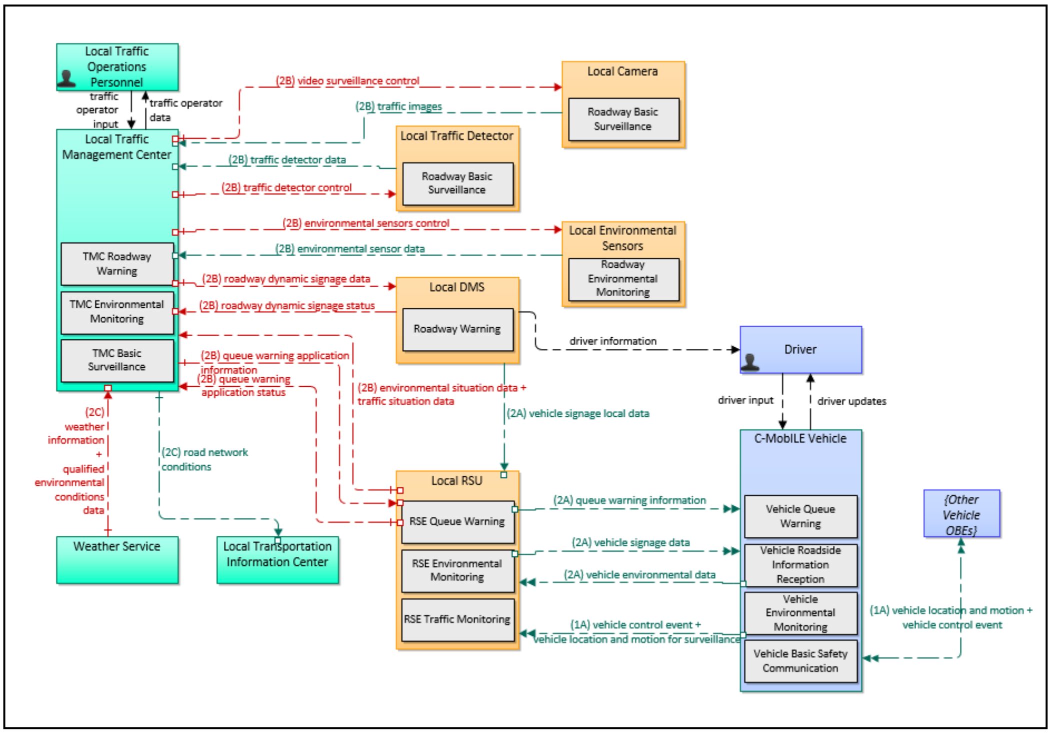

Figure 56: Road Hazard Warning

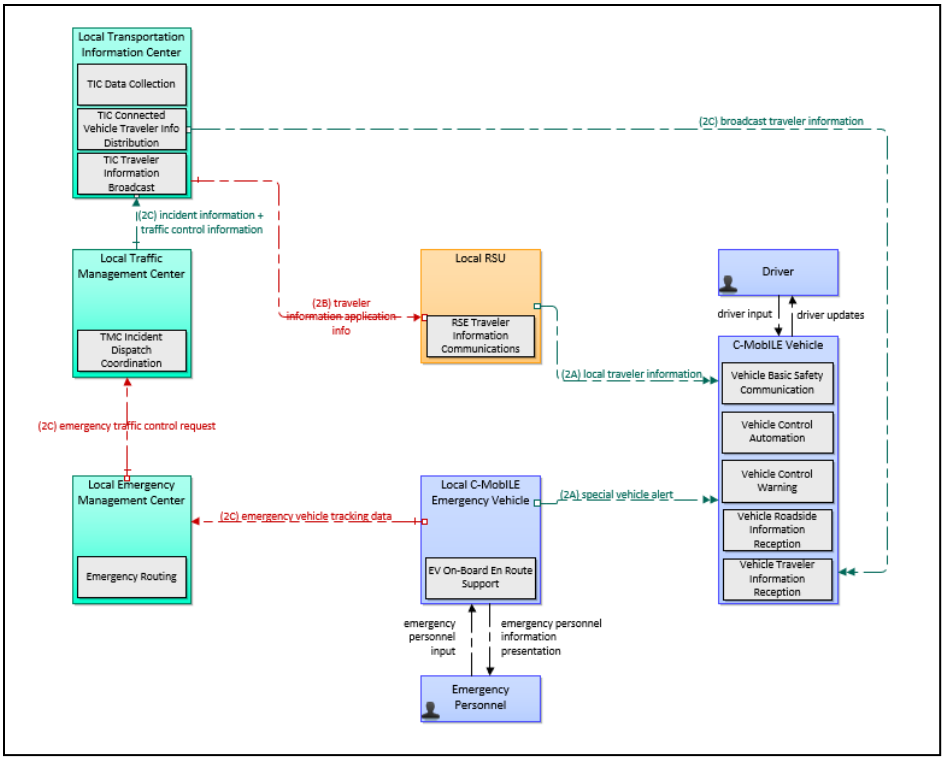

Figure 57: Emergency Vehicle Warning

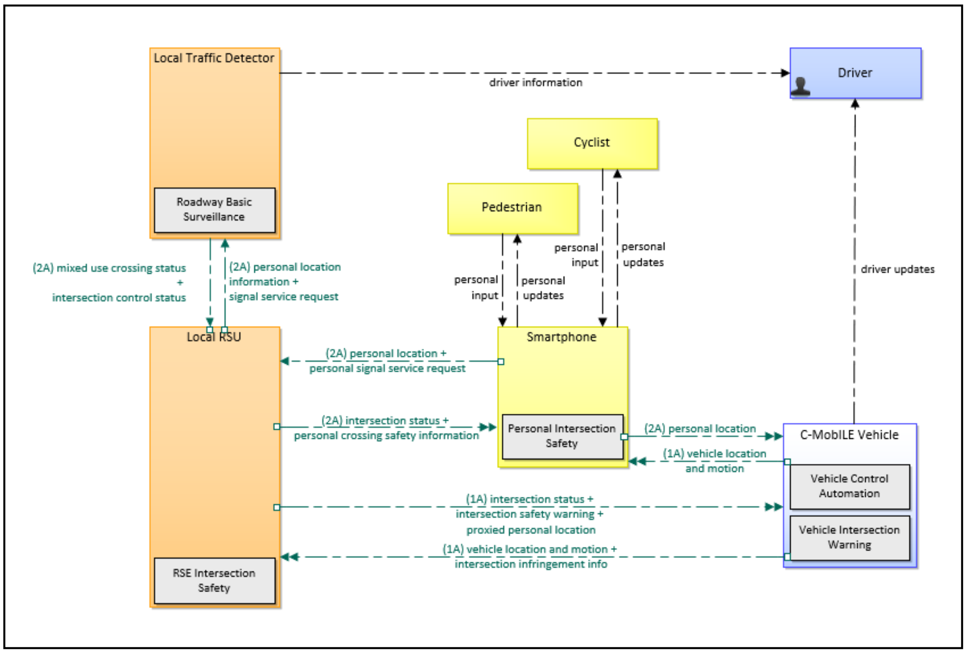

Figure 58: Warning System for Pedestrians

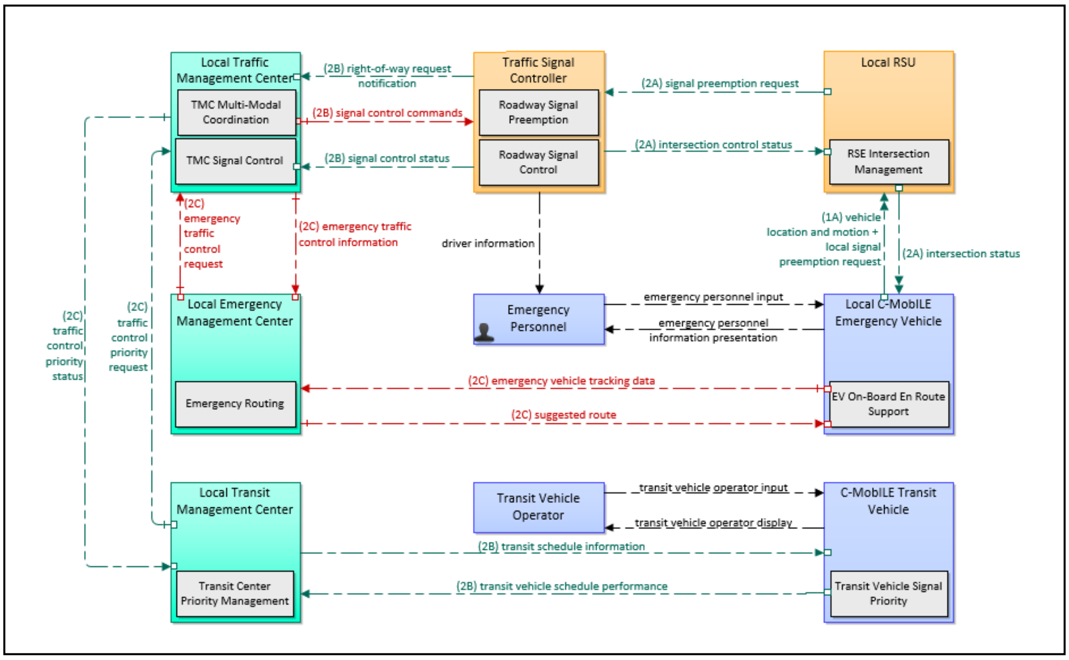

Figure 59: Green Priority

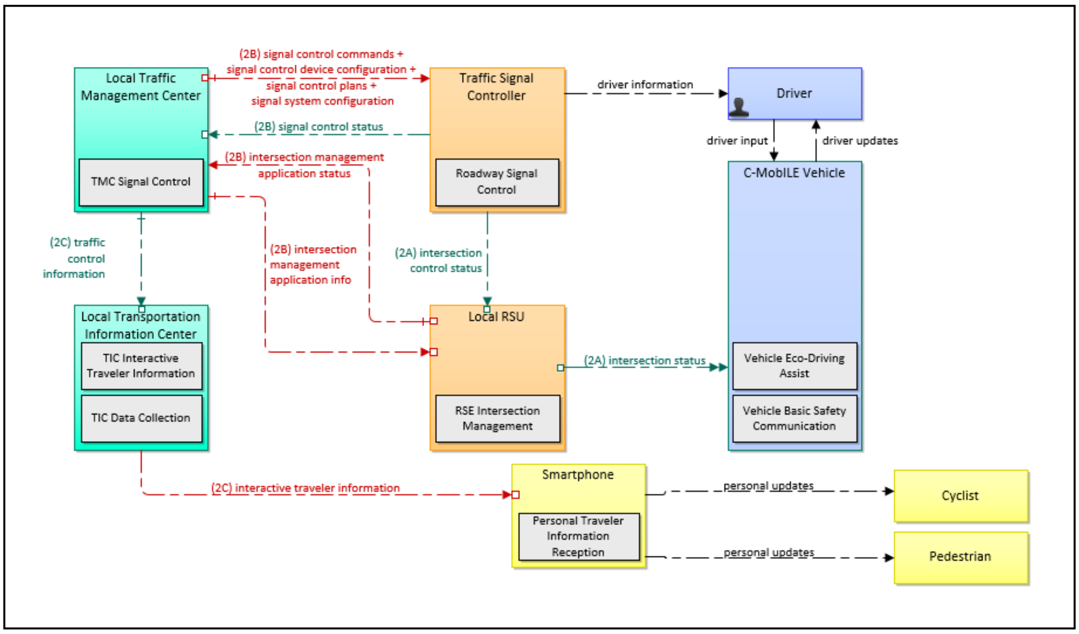

Figure 60: Green Light Optimal Speed Advisory

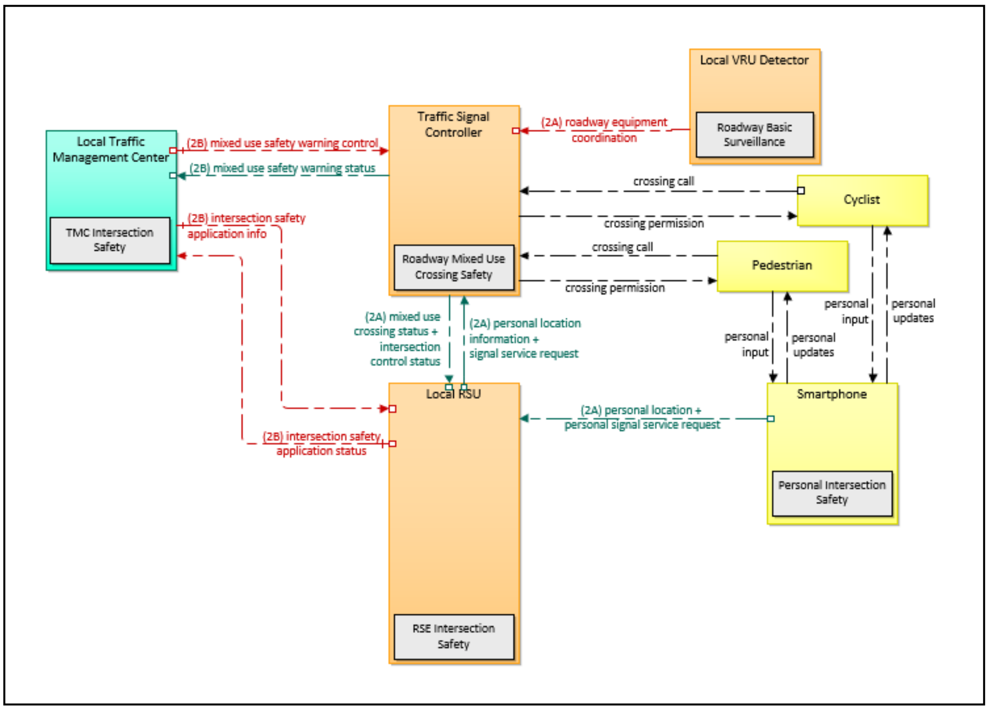

Figure 61: Cooperative Traffic Light for VRUs

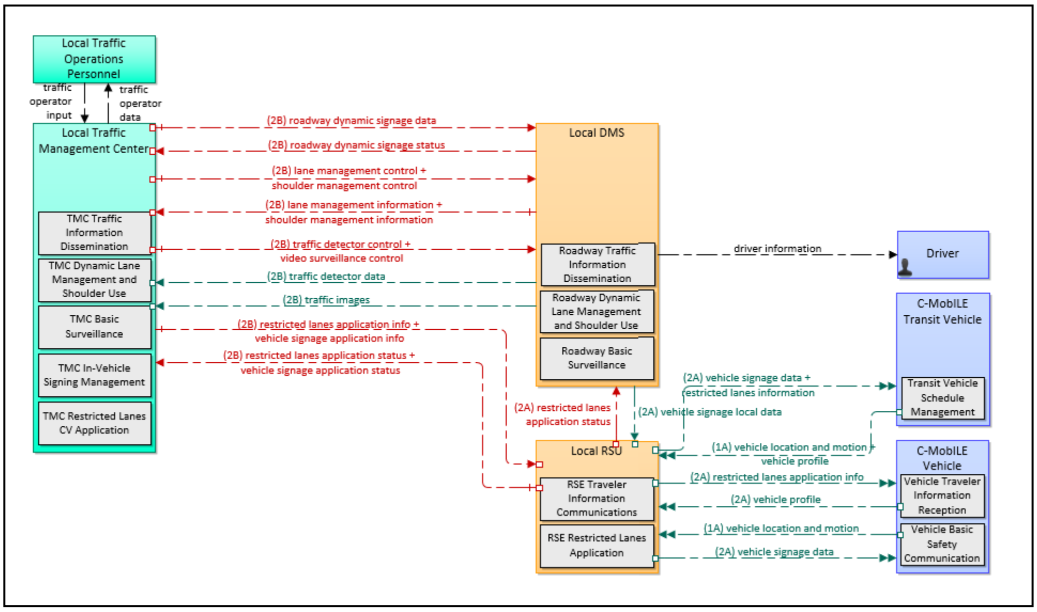

Figure 62: Flexible Infrastructure

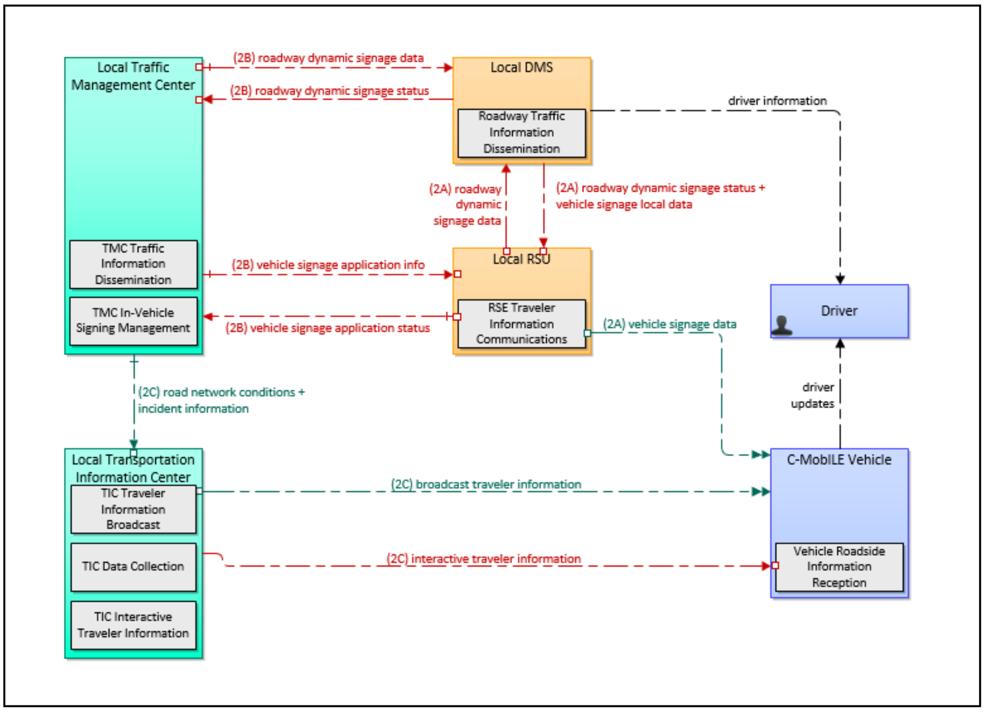

Figure 63: In-Vehicle Signage

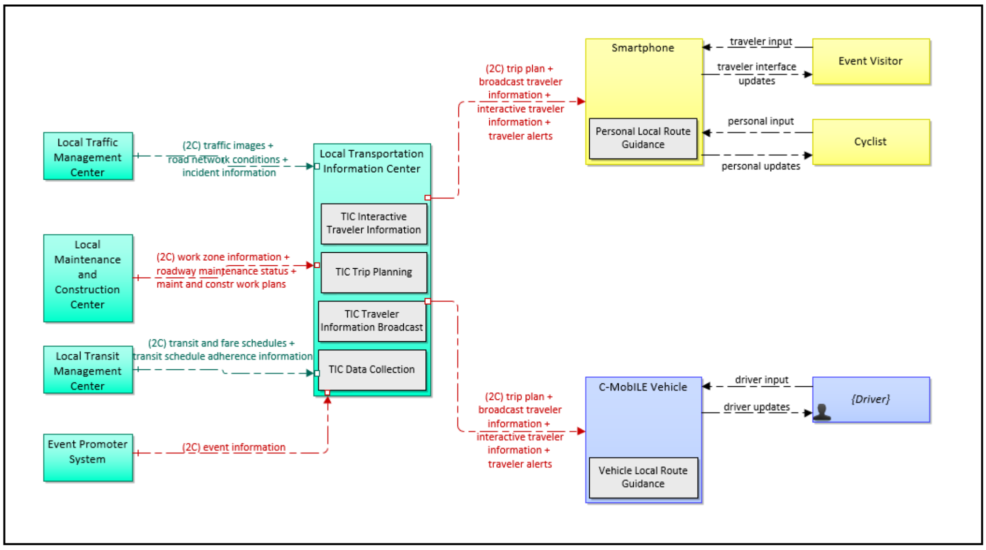

Figure 64: Mode & Trip Time Advice

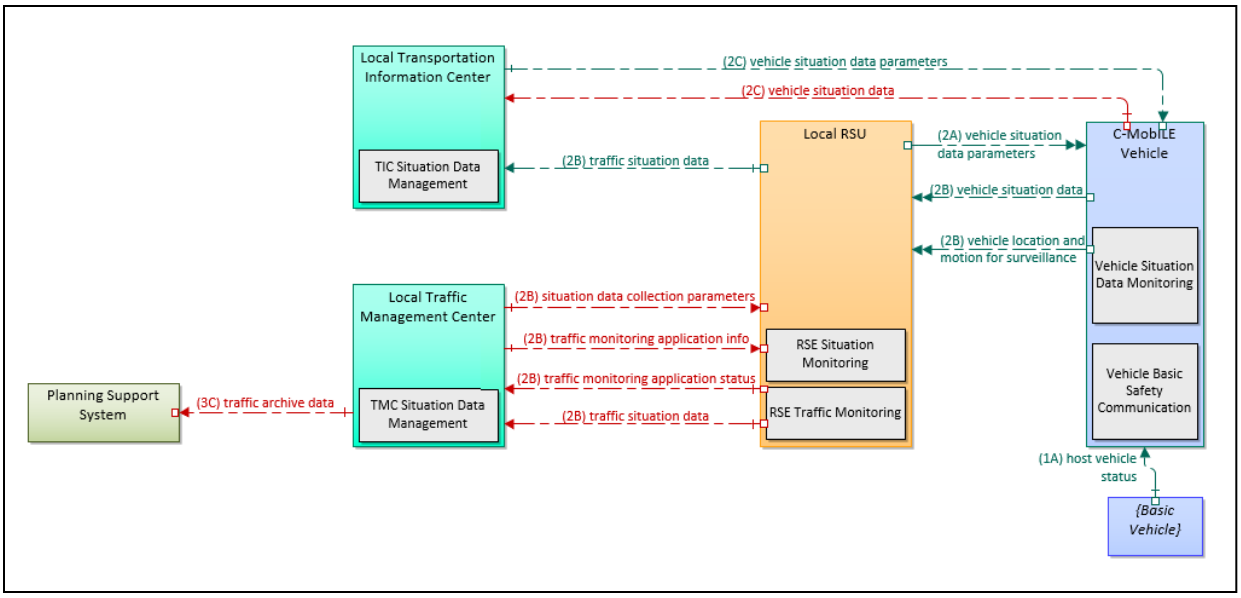

Figure 65: Probe Vehicle Data

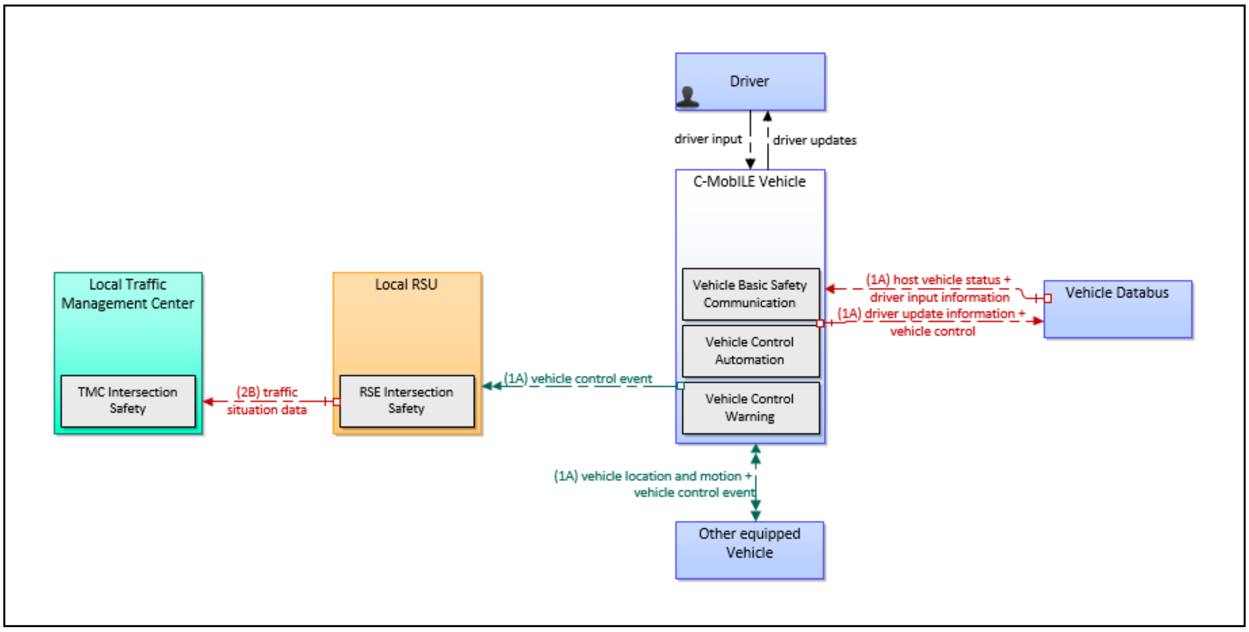

Figure 66: Emergency Brake Light

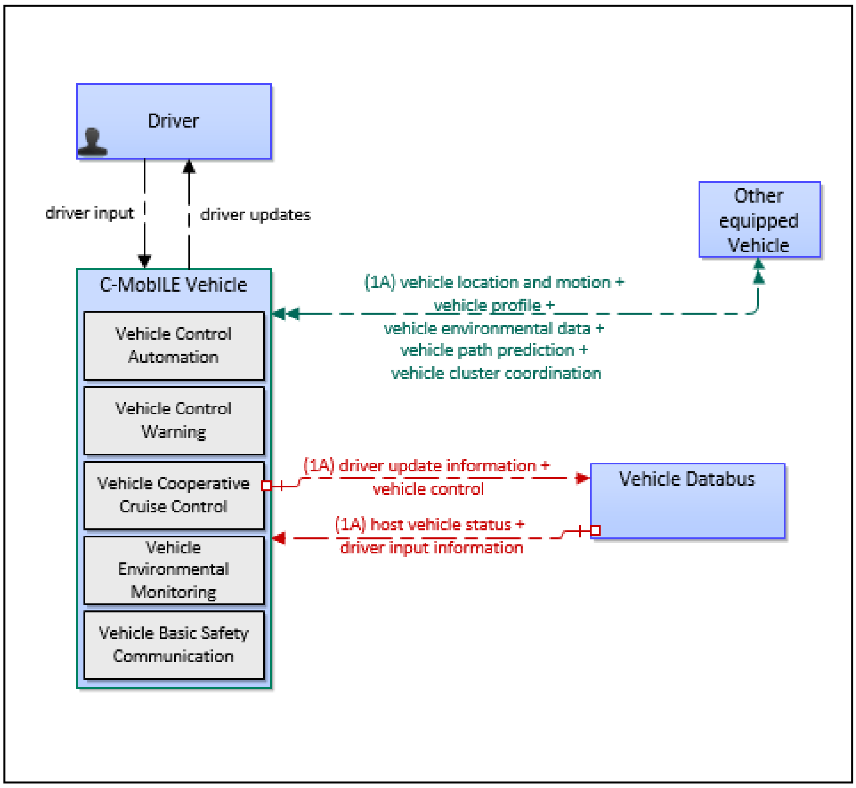

Figure 67: Cooperative Adaptive Cruise Control

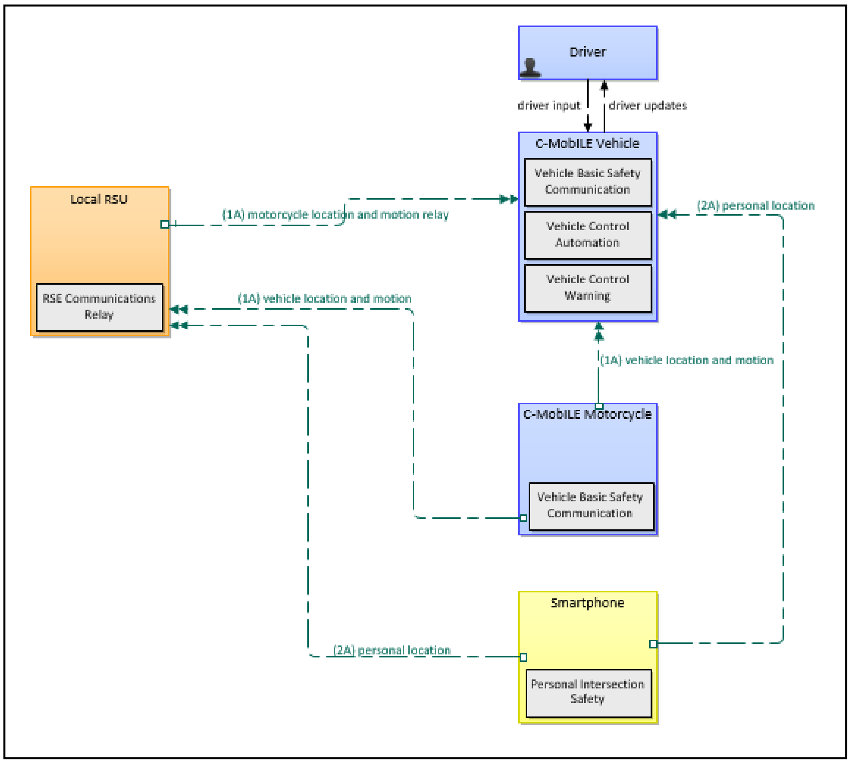

Figure 68: Motorcycle Approaching Indication

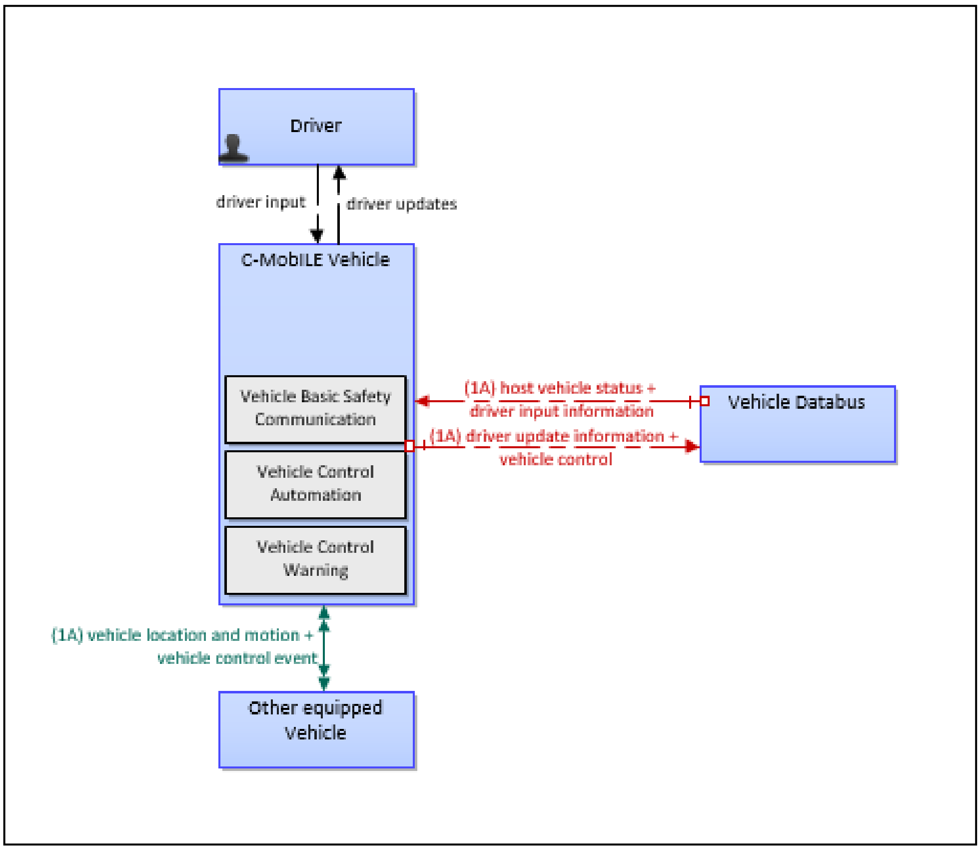

Figure 69: Slow or Stationary Vehicle Warning

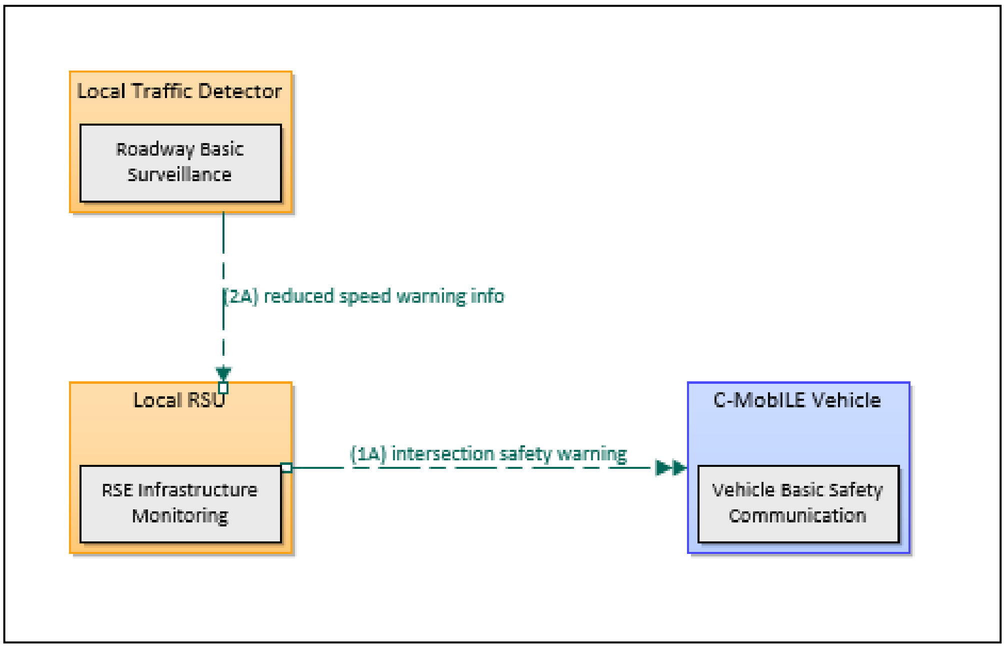

Figure 70: Blind Spot Detection/ Warning

6. Open Points for a Roll-Out

This section contains the open points that are not reached until the publication of this document. These points often relate to the organizational challenges for the different DSs. Open points do not mean, that those points will remain as open points, but they are still under development or are linked to other problems, that not have been solved yet.

6.1. Open Points for BCN

Barcelona DS has no TMC interfaces available to get traffic lights information. This activates the mitigation plan to implement GLOSA and SVW services as proof-of-concept in a first stage and evaluate a large-scale implementation in the future.

Moreover, some interfaces for the Registration process to a foreign GeoMessaging server (CPBO) are still not developed. Such interface specifications shall be finally defined and agreed in the Interoperability Task Force and then implemented by Dinniq and integrated into Barcelona's PID.

6.2. Open Points for BIL

There are no open points from the architecture point of view in Bilbao Deployment Site.

6.3. Open Points for BOR

There are no open points regarding the global architecture.

6.4. Open Points for CPH

As is the case in Barcelona, interfaces, e.g. surrounding the registrations server, are not clearly defined yet. Something that is handled in the Interoperability Task Force.

The City is in the process of updating the legacy RSUs to the ETSI2016 standards.

To ensure a long after-project life for the C-MobILE services, the City of Copenhagen stresses the importance of interoperability and detailed specifications for 3rd parties and developers to follow, independently of the C-MobILE partners and service providers.

Furthermore, it is important that new standards which will be implemented in Europe are backwards compatible with equipment and services implemented in previous European projects.

6.5. Open Points for NEW

Upgrade of legacy OBUs to C-MobILE standards is a prerequisite for large-scale deployment

6.6. Open Points for NBR

The open points for North Brabant are to extend the users list for the cellular services, completion of the services with associate partners (i.e. Rest-Time management and Motorway Parking availability), and to deploy the Blind Spot / VRU Waring service at a suitable location in Eindhoven.

6.7. Open Points for THES

Concerning architecture, there are no open points for Thessaloniki. Developments and upgrades have been successfully performed taking into consideration the project requirements. The focus from now on is on the large-scale demonstration of the services including the recruitment of large numbers of end users.

6.8. Open Points for VIG

There are no open points from the architecture point of view in Vigo DS.

7. Conclusion

Based on the previous work within Work Package 3, we analysed which parts of the former architecture published in D3.3 are needed to be updated in this document. Therefore, partners within Work Package 3 and all deployment sites are involved to identify the differences between the implemented architecture and the former planned architecture.

To sum up the update from the deliverable "D3.3 Low-level implementation-ready architecture", most of the planned architecture is implemented as it was planned before. For some services changes needed to be adopted, for example, adapting former ITS G5 services to cellular-based communications. Some use cases are only implemented as a proof of concept and therefore the architecture is adopted to the respective requirements.

The challenge reports give a good impression of the problems that come up during the implementation and deployment of C-ITS services in such a large-scale environment, starting with the implementation itself, followed by the integration of the hardware, end-user recruitment and finally evaluation of the impact of the project.

The Section "Open Points for a Roll-Out" shows the next steps from each deployment site, that need to be done to perform the fully operational large-scale demonstration. Some deployment sites had to face unforeseen challenges that came up during the project. These challenges cause problems that sometimes lead to open points and define the roadmap for each deployment site.

Figure 71: C-MobILE logo

References

[1] D. Kadiogullari, M- Fünfrocken, J. Castells, D3.3 Low-level implementation ready architecture, C-MobILE project, 29/06/2018

[2] ISO/IEC/IEEE 42010:2011. Systems and software engineering – Architecture description. http://www.iso-architecture.org/

[3] Ege Adali O., Turetken O., Grefen P., D2.2 Analysis and Determination of Use Cases; C-MobILE project, 28/02/2018.

[4] CVRIA; Connected Vehicle Reference Implementation Architecture. [Accessed 09/10/2017]. http://local.iteris.com/cvria/html/about/about.html.

[5] Reference: ETSI EN 302 665 - V1.1.1: Intelligent Transport Systems (ITS); Communications Architecture

Annex

-- POI from Projects SCOOP - INTERCOR - C-ROADS FR

--

-- Extension from ETSI TS 101 556-1 2012-07 (01v010101p(POI)) for charging spot for electric vehicle (EVCSN Message definition)

--

-- This ASN.1 was generated: 08.02.2019 (DD/MM/YY) by the SCOOP - INTERCOR - C-ROADS FR project

-- Published version location: Not defined yet, refer to handler of the projects (FR)

-- ASN.1 Start Definition

PoiManagement {cocsic (0) poi (101556) version (2)}

-- Replace : EVCSN-PDU-Descriptions {itu-t (0) identified-organization (4) etsi (0) itsDomain (5) wg1 (1) ts (101556) evcsn (1) version (1)}

DEFINITIONS AUTOMATIC TAGS ::= BEGIN

IMPORTS

ItsPduHeader, StationID, TimestampIts, ReferencePosition

FROM ITS-Container {itu-t (0) identified-organization (4) etsi (0) itsDomain (5) wg1 (1) ts (102894) cdd (2) version (1) }

Provider

FROM EfcDsrcApplication {iso(1) standard(0) 14906 application(0) version5(5)};

-- POIType Section

-- Used as well by EVCSN (ETSI TS 101 556-1 2012-07) than by POI Type introduced by FR projects (this asn extension)

POIType ::= INTEGER(0..65535)

-- Value "1" is for EVCS (as specified in ETSI TS 101 556-1 2012-07). Other value 2 to 65535 are used for other POI type (FR projects) with 11 for slots (SlotReferenceStatusPdu structure), 12 for docks (DockTimeslotPdu structure), 7522 for ParkAndRide (BasicPoi structure) or 20028 for CoachAndLorryParking (BasicPoi structure)..

ItsPOIHeader ::= SEQUENCE {

poiType POIType, -- see previous comment

```
    timeStamp              TimestampIts,
    relayCapable           BOOLEAN -- set to "false" when not relevant for the poiType
}



------------------------------------
-- Common Section
-- Used by several section
------------------------------------

OpeningPeriod ::= SEQUENCE {
        opening                         TimeOfDay,      -- Number of minutes after 00:00 when the parking opens or start of timeslot
        closing                 TimeOfDay       -- Number of minutes after 00:00 when the parking closes or end of timeslot
}

TimeOfDay ::= INTEGER {
        midnight(0),
        oneMinuteAfterMidnight(1)
} (0..1440)

------------------------------------
-- EVCSN Data Section
-- This part is unchanged in reference to the standard ETSI TS 101 556 2012-07.
-- This part is used when POIType will be "1" in the entry.
-- For other services (POIType from 2 to 65535), introduced by this asn extension, the following part is not used (skip to next section).
------------------------------------

EvcsnPdu ::= SEQUENCE {
    header   ItsPduHeader,
    evcsn    EVChargingSpotNotificationPOIMessage
}

EVChargingSpotNotificationPOIMessage ::= SEQUENCE {
    poiHeader   ItsPOIHeader, -- Specific POI Message Header
    evcsnData   ItsEVCSNData  -- Electric Vehicle Charging Spot Data Elements
}

ItsEVCSNData ::= SEQUENCE {
    totalNumberOfStations   NumberStations,
    chargingStationsData    SEQUENCE (SIZE(1..256)) OF ItsChargingStationData
}

ItsChargingStationData ::= SEQUENCE {
```

```
    chargingStationID       StationID,
    utilityDistributorId    UTF8String (SIZE(1..32))    OPTIONAL,
    providerID              UTF8String (SIZE(1..32))    OPTIONAL,
    chargingStationLocation    ReferencePosition,
    address                 UTF8String              OPTIONAL,
    phoneNumber             NumericString (SIZE(1..16))     OPTIONAL,
    accessibility           UTF8String (SIZE(1..32)),
    digitalMap              DigitalMap              OPTIONAL,
    openingDaysHours        UTF8String,
    pricing                 UTF8String,
    bookingContactInfo      UTF8String              OPTIONAL,
    payment                 UTF8String              OPTIONAL,
    chargingSpotsAvailable  ItsChargingSpots,
    ...
}

ItsChargingSpots ::= SEQUENCE (SIZE(1..16)) OF ItsChargingSpotDataElements

ItsChargingSpotDataElements ::= SEQUENCE {
    type            ChargingSpotType,
    evEquipmentID   UTF8String    OPTIONAL,
    typeOfReceptacle    TypeOfReceptacle,
    energyAvailability    UTF8String,
    parkingPlacesData   ParkingPlacesData   OPTIONAL
}

DigitalMap ::= SEQUENCE (SIZE(1..256)) OF ReferencePosition

ChargingSpotType ::= BIT STRING {
    standardChargeMode1(0),
    standardChargeMode2(1),
    standardOrFastChargeMode3(2),
    fastChargeWithExternalCharger(3),
    quickDrop(8),
    inductiveChargeWhileStationary(12),
    inductiveChargeWhileDriving(14)
}

TypeOfReceptacle    ::= BIT STRING

ParkingPlacesData   ::= SEQUENCE (SIZE(1..4)) OF SpotAvailability

SpotAvailability    ::= SEQUENCE {
    maxWaitingTimeMinutes INTEGER (0..1400), -- 0 if available or max waiting time (minutes)
    blocking            BOOLEAN           -- true if the spot can be blocked
```

```
}

NumberStations        ::= INTEGER(1..256)

------------------------------------
-- BasicPoi Data Section
-- This part is an extension of the asn of TS 101 556 in reference to the standard.
-- This part is used when POIType will be e.g "7520" ParkingLot (free park) or "7521" ParkingGarage (not free) or "7522" ParkAndRide or "20028" CoachandLorryParking.
------------------------------------

BasicPoiPdu ::= SEQUENCE {
    header          ItsPduHeader,
    basicPoi    BasicPoiMessage
}

BasicPoiMessage ::= SEQUENCE {
            poiHeader         ItsPOIHeader,
            poiNumber         PoiNumber,
            locationLocationData,
            status              StatusData
}

PoiNumber ::= SEQUENCE {
            serviceProviderId                   Provider, -- Imported from 14906 (IVI)
            basicPoiNumber                                BasicPoiNumber -- Unique identifier of the POI service for the provider
}

BasicPoiNumber ::= INTEGER(0..65535)

LocationData ::= SEQUENCE {
            refPoint                                    ReferencePosition,
            name                                        UTF8String (SIZE (1..31)),
            adress                                      UTF8String (SIZE (1..255)) OPTIONAL,
            phoneNumber                     UTF8String (SIZE (1..31)) OPTIONAL, -- eg +33 1 23 45 67 89
            website                                     UTF8String (SIZE (1..31)) OPTIONAL -- without "http://"
}

StatusData ::= SEQUENCE {
            openingStatus                   OpeningStatus,
            parkingStatus                   ParkingStatus,
            openingDaysHours                SEQUENCE (SIZE (7)) OF DailyOpeningHours OPTIONAL, -- Opening hours by day, starting by monday, in local time.
            additionalInformation    UTF8String (SIZE (1..255)) OPTIONAL
}
```

```
OpeningStatus ::= INTEGER {
	closed			(0),
	open			(1), -- only one place is available
	subscriberonly		(2),
	unknown				(15)
} (0..15)

ParkingStatus ::= SEQUENCE {
freeSpots		FreeSpots,
totalSpots		TotalSpots
}

FreeSpots ::= INTEGER {
	full			(0),
	onespot				(1), -- only one place is available
	freespaces		(16382),
	unknown				(16383)
} (0..16383)

TotalSpots ::= INTEGER {
	noparking		(0),
	unknown				(16383)
}(0..16383)

DailyOpeningHours ::= SEQUENCE (SIZE(0..4)) OF OpeningPeriod


-------------------------------------
-- SlotReferenceStatus Data Section
-- This part is an extension of the asn of TS 101 556 in reference to the standard.
-- This part is used when POIType will be "11".
-------------------------------------

SlotReferenceStatusPdu ::= SEQUENCE {
	header	ItsPduHeader,
	data	SlotReferenceStatusMessage
}

SlotReferenceStatusMessage ::= SEQUENCE {
	poiHeader		ItsPOIHeader,
	data			SlotReferenceStatusData
}

SlotReferenceStatusData ::= SEQUENCE {
```

```
	port			UTF8String (SIZE (5)), -- Locode Geographical place where the slot is validated
	operator		UTF8String (SIZE (1..31)), -- Operator code: Ex : APPLUSDKE
	terminal		UTF8String (SIZE (1..50)), -- SIRET of terminal for which the status are given
	slotReference	UTF8String (SIZE (1..50)), -- Booking reference for pick-up and or Cargo reference for delivery
	equipmentId		UTF8String (SIZE (1..31)) OPTIONAL, -- Container number
	operationType	INTEGER(0..399), -- Trade and Transport status codes Revision 6, UNECE CEFACT Trade Facilitation Recommendation No. 24
	expirationDate	TimestampIts -- Date of expiry of the status
}

------------------------------------
-- DockTimeslot Data Section
-- This part is an extension of the asn of TS 101 556 in reference to the standard.
-- This part is used when POIType will be "12".
------------------------------------

DockTimeslotPdu ::= SEQUENCE {
	header	ItsPduHeader,
	data	DockTimeslotMessage
}

DockTimeslotMessage ::= SEQUENCE {
	poiHeader		ItsPOIHeader,
	provider		Provider,
	terminalName	UTF8String (SIZE (1..31)), -- Name of Terminal
	webServiceUrl	UTF8String, -- WebService URL to do the dock and timeslsot reservation. Format http(s)://xxx.yy.com
	docks			SEQUENCE (SIZE (1..31)) OF DockTimeslotInformation
}

DockTimeslotInformation ::= SEQUENCE {
	dockId					INTEGER (1..16383), -- Internal Id of dock in the terminal
	dockName				UTF8String (SIZE (1..31)), -- dock name
	availableDayTimeslots	SEQUENCE (SIZE (0..7)) OF DayTimeslotInformation -- List of days of available timeslots
}

DayTimeslotInformation ::= SEQUENCE {
   dayTimeStamp		TimestampIts,-- Available day
	availableTimeslots	SEQUENCE (SIZE (0..23)) OF OpeningPeriod -- List of available timeslots of the day
}

END
-- ASN.1 End
```