Architecture for C-ITS applications in the Netherlands

Version 1.00
March 2016

Igor Passchier (TASS), Marcel van Sambeek (TNO)
DUTCH ROUND TABLES FOR SMART MOBILITY
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Contents

Summery

The demand for mobility is growing faster than the available roadway infrastructure. Intelligent transport systems (ITS) have been deployed extensively over the last decades to solve or reduce issues like delays due to traffic jams, unreliable and unpredictable travel times, a lack of safety and air pollution, or at least to reduce the effects. A specific type of ITS systems is connected and cooperative ITS (C-ITS), where intelligent vehicles and intelligent roadside/back-office infrastructure communicate with each other to be able to implement even smarter and more effective applications to tackle these issues. For communication with vehicles, both short-range networks based on ITS-G5 and cellular networks are in scope.

This document describes a reference architecture for C-ITS applications that is based on an eco-system with business roles for both public and private stakeholders - in a Dutch context. The architecture should be considered as **descriptive** and is intended to be used as a basis for future ITS deployment projects in the Netherlands. This document is the **2015 update** of the architecture for Cooperative - Intelligent Transport System (C-ITS) applications in the Netherlands [1]. The update is based on deliverables published in 2015 from selected projects and expert group meetings on specific subjects for the "ITS round table" meetings on Architecture and on Standardization / Dutch Profile, held between June 2015 and December 2015.

The C-ITS architecture is described in a "Dutch context". This is done to explain the integration of new C-ITS systems with the existing (legacy) roadside, traffic management and traffic information systems in the Netherlands used for highways and in cities. Of course, when applicable International or European standards are used e.g. DATEX-II, TPEG and the ETSI ITS standards and message sets.

The reference architecture aims at providing a high-level architecture that will be applicable to all applications and systems in scope. The reference architecture is described in chapter 2, where a functional view, physical view, and communication view are detailed, at different abstraction levels. Due to the broad scope of the reference architecture, a full implementation of all components and interfaces in the architecture would lead in many cases to a more complex system than required in most deployment contexts. To provide more guidance for implementation projects, two implementation architectures have been described in chapter 3. These implementation architectures should be regarded as examples and are based on two typical contexts i.e. i) Dutch highway environment, and ii) Dutch city environment, consisting of a set of applications and legacy systems. In these implementation architectures, a subset of functional components and interfaces is selected and combined in a physical architecture view. In this way, the "gap" between the rather abstract reference architecture and concrete (future) implementation projects is minimized.

In chapter 4, a mapping is made between the architectures of three implementation projects and the reference architecture. The projects considered are the Spookfiles A58, C-ITS Corridor, PPA and the iVRI project. In this chapter, recommendations related to the architecture of these projects are also provided.

In 2016, an update of the reference architecture will be made based on the discussions in the C-ITS Architecture round table, input from relevant Dutch projects, and international developments. The meetings of the C-ITS architecture table and Standardisation table will be combined, to strengthen the link between the Dutch C-ITS Architecture and the Dutch C-ITS profile. Relevant subjects for the 2016 update are 1) further detailing of the hybrid communication, specifically the cellular communication, 2) information exchange between road operators and information providers, and 3) functions to search and use a wide range of information sources from different stakeholders. Relevant projects will be the new projects from the Beter Benutten program, from PPA project (phase 2), and the ITS corridor project.

Abbreviations

Abbreviation	Definition
B2X/X2B	Business-to-X, X=Business (B), Consumer (C) or Government (G)
BO	Back Office
C2C CC	Car-2-Car Communication Consortium
CACC	Cooperative Adaptive Cruise Control
CAM	Cooperative Awareness Message
CAN	Controller Area Network
CEN	European Committee for Standardization
CENELEC	European Committee for Electrotechnical Standardization
CIS	Central Intelligent Transport Sub-system
C-ITS	Cooperative Intelligent Transport System
CMD	Cooperative Mobility Device
CP	Communication Provider
DAB	Digital Audio Broadcasting
DATEX-II	Data Exchange – release 2
DENM	Decentralized Environmental Notification Message
DITCM	Dutch ITS Test site for Cooperative Mobility
DP	Data Provider
DVM	*Dynamisch Verkeers Management (Dutch)*
EOBD	European On-Board Diagnostics
ETSI	European Telecommunication Standards Institute
EV	Electrical Vehicle
FCD	Floating Car Data
GLOSA	Green Light Optimized Speed Advice
GPS	Global Positioning System
HMI	Human Machine Interface
INS	Intersection Safety
IP(v4/6)	Internet Protocol, version 4 or 6
IPTS	Intelligent Pedestrians Traffic Signal
IRP	Intermodal Route Planner
ISO	International Organization for Standardization
ITS	Intelligent Transport System
ITSC	Intelligent Transport System Communications
ITS-S	Intelligent Transport System-Station
ITS-G5	ITS at 5 GHz frequency band
IVERA	IVER ASTRIN
IVI or IVS	In Vehicle Information or Signage
LDM	Local Dynamic Map
LTE	Long-Term Evolution (also called 4G mobile networks)
NDW	*Nationale Databank Weggegevens (Dutch)*
OBU	On-Board Unit
PID	Personal Information Device (e.g. smart phone)
PTW	Powered Two Wheel vehicle
RDS	Radio Data System
RDS-TMC	Radio Data System – Traffic Message Channel
RHW	Road Hazard Warning
RIS	Roadside Intelligent transport Sub-system
RLVW	Red Light Violation Warning
RSU	Roadside Unit
RWS	Rijkswaterstaat
SD	Service Directory

Abbreviation	Definition
SP	Service Provider
SPES	Service Provider Exchange System
SPAT	Signal Phase and Timing
TIS	Traffic Information System
TLC	Traffic Light Controller
TMS	Traffic Management System
TPEG	Transport Protocol Experts Group
UMTS	Universal Mobile Telecommunications System (also called 3G mobile networks
VEE	Vehicle Electrical and Electronic system
VMS	Variable Message Sign
V2X/X2V	Vehicle-to-X, where X can be Vehicle (V), Roadside I or Infrastructure (I)
VIS	Vehicle Intelligent transport Sub-system
VRU	Vulnerable Road Users
VRUITS	improving the safety and mobility of Vulnerable Road Users by ITS applications

1 Introduction

This document is the 2015 **update** of the architecture for Cooperative - Intelligent Transport System (C-ITS) applications in the Netherlands, as described in [1]. C-ITS is used for ITS systems that exchange information between each other. Different types of communication technologies can be used in ITS to exchange information e.g. via direct or ad-hoc communication between ITS systems (based on ETSI ITS-G5 or LTE direct) or via network based communication via a roadside ITS network (based on ITS-G5) or via cellular networks (3G/4G/5G, with/without cell broadcast) or radio broadcast networks (RDS, DAB(+)).

The update is based on deliverables published in 2015 from selected projects and expert group meetings on specific subjects for the “ITS round table” meetings on Architecture and on Standardization / Dutch Profile, held between June 2015 and December 2015.

1.1 Explanation of the Dutch context

The C-ITS architecture is described in a “Dutch context”. This is done to explain the integration of new C-ITS systems with the existing (legacy) roadside, traffic management and traffic information systems in the Netherlands used for highways and in cities. When available International or European standards or specifications are used e.g. the ETSI/CEN ITS framework and protocols like DATEX-II and TPEG.

Examples of this “Dutch context” is:

- NDW (National Data Warehouse, [2]): the road operators in the Netherlands make use of a central entity, called NDW, to disclose traffic information from their systems to external service providers. NDW is also used as central point-of-contact for contracts with business entities for e.g. floating car data;
- Rijkswaterstaat (RWS) uses a Dynamic Traffic Management System along highways with dynamic speed limits and Dynamic Route Information Panels (DRIP) on a large section of the Dutch Highways;
- Traffic Light Controller (TLC) with specific architecture and options to support external algorithms for advanced dynamic traffic control and protocols like VLOG and IVERA [3];
- Traffic Management: exchange of information between traffic management is enabled via the DVM Exchange specification, under control of DVM Exchange [4].

1.2 Scope of ITS architecture 2014

In 2014, the architecture for C-ITS applications was described via an open “eco-system” with business roles for both public and private stakeholders - in a Dutch context. The architecture both described the technical part (system architecture with physical, functional and communication view) as well as the business model aspects (business model view).

The architecture should be considered as **descriptive** and can give guidance to these stakeholders involved in future ITS deployment projects in the Netherlands. Descriptions of the ‘building blocks’ of the ITS architecture - both physical and functional components - are provided, which should ease the composition and development of deployment architectures of future C-ITS systems in Dutch projects. The following seven projects were used as input for the ITS architecture:

1. Shockwave Traffic Jams A58 [5],
2. ITS Corridor [6],
3. Praktijkproef Amsterdam (PPA) [7],
4. DITCM 1.0 architecture project [8],
5. Converge [9],
6. MOBiNET [10] and

7. VRUITS [11].

ITS applications from these projects were used to describe the business model view and the technical system view of the architecture.

Business model aspects

The business model aspects of the eco-system related to the business roles of the identified stakeholders in deployment projects are analysed. Using a business-engineering framework for service-dominant business (named BASE-X [12] [13] [14]) business model blueprints have been designed for a set of ITS applications to act as templates for concrete models in specific projects. A business model blueprint of a particular ITS application shows the stakeholders that are involved in offering that solution including their contributions and the main cost and benefit involved in the deployment of the solution. The business framework acts as a guideline in understanding and presenting the operative and economic aspect of ITS applications. Specific business models can be designed for current and future C-ITS offerings in relevant projects and by market parties, facilitating an open collaboration of stakeholders in an operational way.

System architecture

The ITS applications of the selected projects were used to create the system architecture. From these applications the hardware and software 'building blocks' have been derived together with the interfaces between these 'building blocks'. The overall system architecture covers a **representative** set of ITS V2V, V2I and I2V applications for vehicles based on either short range (ITS-G5), cellular or hybrid communication. Also a representative set of ITS safety-related applications for vulnerable road users are included, taken from the VRUITS project [11]. The architecture also describes relevant I2I components to support an open system (e-Market place) for multiple service providers and communication providers to deploy ITS applications to end-users, based on the projects Converge [9] and MOBiNET [10].

1.3 Update 2015

In this document implementation architectures are described for ITS applications for highway traffic systems and for city traffic systems. The information is collected from the following projects:

1. Highway traffic systems: Shockwave Traffic Jams A58 (in Dutch "Spookfiles A58") and the ITS Corridor project from Austria, Germany and The Netherlands;
2. City traffic systems: iTLC (intelligent Traffic Light Controller, iTLC, or in Dutch iVRI) project of the program Beter Benutten [15]. This project was part of program Beter Benutten and published its deliverables in December 2015.

Important developments in 2015 related to ITS are:

- 3GPP started a study on support of V2X in LTE (see drafts of 3GPP Technical Report 22.885, 3GPP Release 14). The future 3GPP specifications might be useful for a future update of the communication view in the reference architecture;
- Car2Car Communication Consortium [16] announced on Oct. 30, 2015 that initial deployment of ITS-G5 systems based on C2C profiling in commercial vehicles is not expected before 2019: *"Working under the assumption that the open issues can be resolved with all the required standards in place by 2016, initial deployment of cooperative vehicles could begin as soon as 2019"* [17]. This results in a delay for the initial deployment of ITS-G5 based in-car systems;
- Start of the Dutch part of the ITS Corridor project with publication of first deliverables in October 2015 [18]. These deliverables are included in this update;
- The C-ITS Deployment platform released in Jan. 2016 their findings on the steps to get ITS started in Europe. Some of the key recommendations will be relevant for a future update of the reference architecture;
- Converge project finished in June with public deliverables on architecture (a.o.) and demonstrations;

A limited number of expert group meetings on specific subjects were organised with input from stakeholders that actively participate in the projects and the “ITS round table” meetings on Architecture.

2 Reference architecture for C-ITS system

2.1 Introduction

In this chapter the reference architecture of the C-ITS system is briefly explained. The full description can be found in the document of the 2014 project [1]. This system architecture is **descriptive** and not prescriptive, and is described with 'building blocks' in several dimensions.

Several ITS applications – using V2V, V2I, I2V and/or I2I communication – are used to derive the actors, layers and building blocks (physical/ functional) exchanging information. Sequence diagrams are defined to explain the information flow between the building blocks, including the type of information.

A detailed description of this approach to describe the architecture can be found in [1]. A similar framework is e.g. developed by the US Connected Vehicle Reference Implementation Architecture (CVRIA) [19], and is supported by a specific tool called SET-IT. With this tool a project-specific architecture can be generated by selecting predefined ITS applications in scope of the project.

The architecture is described in three views:

- Physical View: describes the physical sub-systems and the communication interfaces between these sub-systems;
- Functional View: describes the application objects (or functional components) that are attached to the physical objects as well as abstract functions (processes) within application objects and their logical interactions (data flows) between functions; ITS applications are selected from earlier EU and NL research and running deployment projects and are used as the basis for system architecture; The system architecture will support the functionality as described in the ITS applications, but the functional requirements are not included in this document
- Communications View: describes the interfaces between the physical and functional building blocks via a layered set of communications protocols that are required to support communications among the sub-systems. Also a reference to specifications or detailed descriptions of sub-systems and interfaces is given where applicable

In Figure 2-1 the relation between the three architecture dimensions is shown.

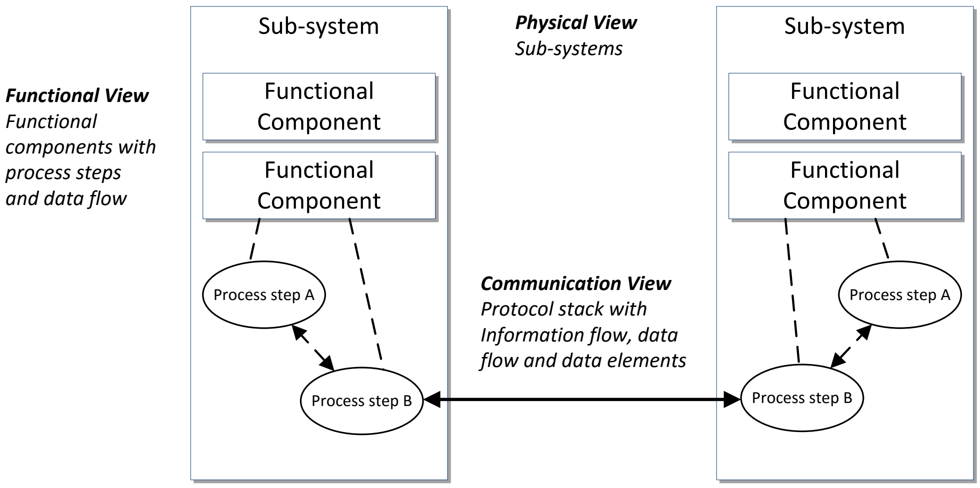

Figure 2-1 System architecture in several views.

In the next section the 'building blocks' within the views are defined to build the reference architecture.

2.2 Physical view

2.2.1 Introduction

In the physical view the system architecture is depicted as a set of sub-systems that interact and exchange information to support the C-ITS applications.

Sub-systems are defined to represent the major (physical) components of the connected vehicle environment. Sub-systems include functional components that define more specifically the functionality and interfaces that are required to support a particular connected vehicle application.

The system architecture is based on best common practice in previous ITS projects i.e. a split in three main physical ‘layers’ or ‘domains’ for Vehicle, Roadside and Central (or back-office). Two additional layers for Traveller / VRU and for Support are added. The sub-systems in the different domain are capable to communicate with each other. For mobile sub-systems or nodes wireless communication technologies are used, for fixed roadside nodes both mobile and fixed networks can be used. Back office systems are typically connected via Internet or private networks, e.g. internal networks from road operators like Rijkswaterstaat (VCnet).

(Human) actors are treated as external entities that interact with the system (see Figure 2-2).

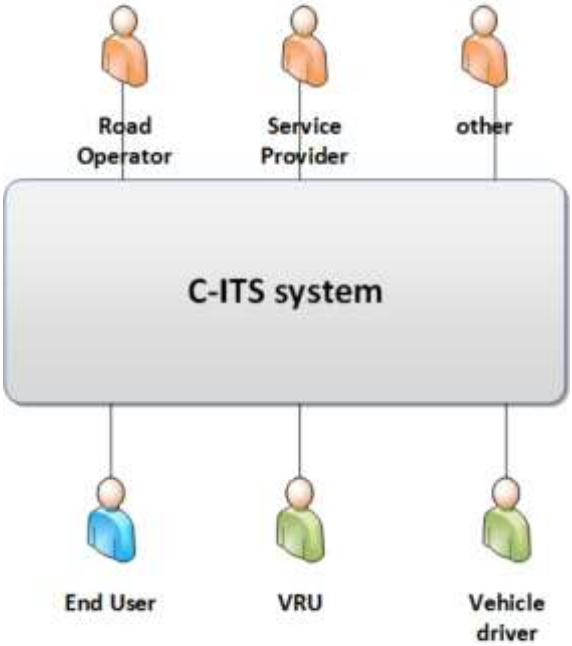

Figure 2-2 System reference architecture and external actors

2.2.2 Physical view - aggregated for all selected applications

The architecture is shown in the next figure. Detailed sequence diagrams of C-ITS application from [1] were used to create this view.

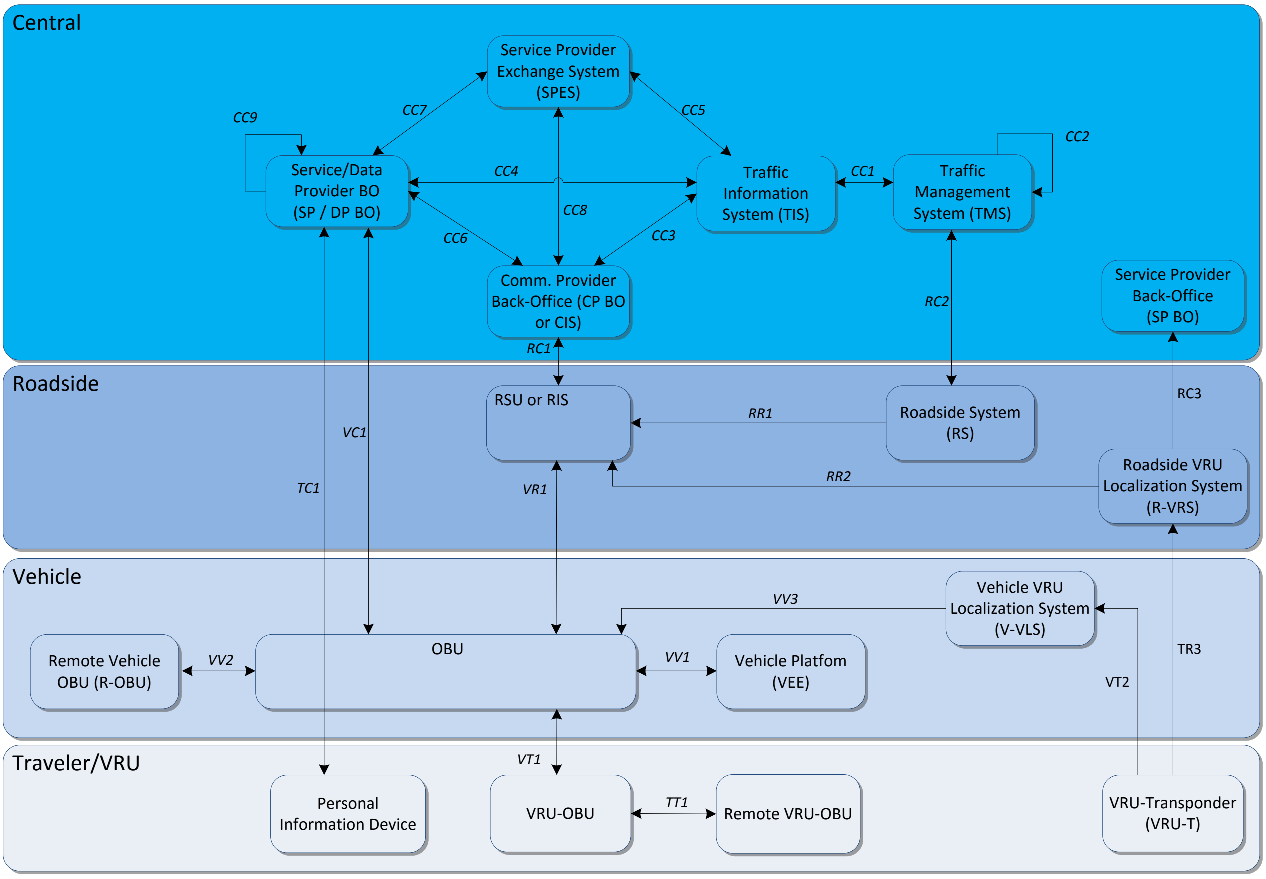

Figure 2-3 Architecture – physical view with sub-systems (16) and interfaces (24) – aggregation level 2. Note: the support layer is not included, for readability.

The physical view uses four layers, marked with different colours:

1. Vehicle layer: Covers the intelligent/cooperative on-board systems (advanced driver assistance / safety systems, navigation, remote data collection or information). Also specific sub-systems for fleet–type vehicles are included e.g. for signal priority, monitoring activities, fleet management or passenger services;
2. Roadside layer: Covers the ITS infrastructure along the physical road infrastructure, e.g. traffic surveillance or traffic control systems (signal/lane control, ramp meters, or systems to collect and supply information from/to connected vehicles);
3. Central (or back-office) layer: Sub-systems to support connected vehicles, roadside and mobile devices and to perform management and administration functions. The sub-systems in this layer are typically virtual systems that can be aggregated together or geographical or functions distributed. It should also be noted that functions like traffic monitoring and control can be distributed i.e. deployed on either a (stand-alone) roadside system or on a central system, depending on the chosen deployment option;
4. Traveller or vulnerable road user (VRU) layer: Covers both “personal” devices (e.g. mobile devices, navigation devices) and specific systems connected to vehicles of VRU’s or VRU’s itself (e.g. tags).

A support layer with sub-systems to support the ITS system with e.g. governance, test and certification management and security and credentials management is not included. A security view of the C-ITS architecture is not included in this document. A definition of the building blocks can be found in section 6.

2.3 Functional view

2.3.1 Introduction

In the functional view functional components are attached to the physical sub-systems. The functional components define the functionality and functional data flow with interfaces that are required to support a particular ITS application. Information flows depict the exchange of information between sub-systems and their functional components. The detailed information flow is described in the sequence diagrams. In section 6.1 examples are given for some applications.

2.3.2 Functional view with functional components and interfaces - aggregated for all applications

The architecture from a functional view is shown in Figure 2-4. Compared to Figure 2-3, this architecture gives more detail on the functionality of the physical components, so this architecture is at a more concrete level of abstraction than the physical architecture in Figure 2-3. The functional components are descriptive and used to explain the generic functionality included in a specific system. A description of the functional components is given in section 6.3.

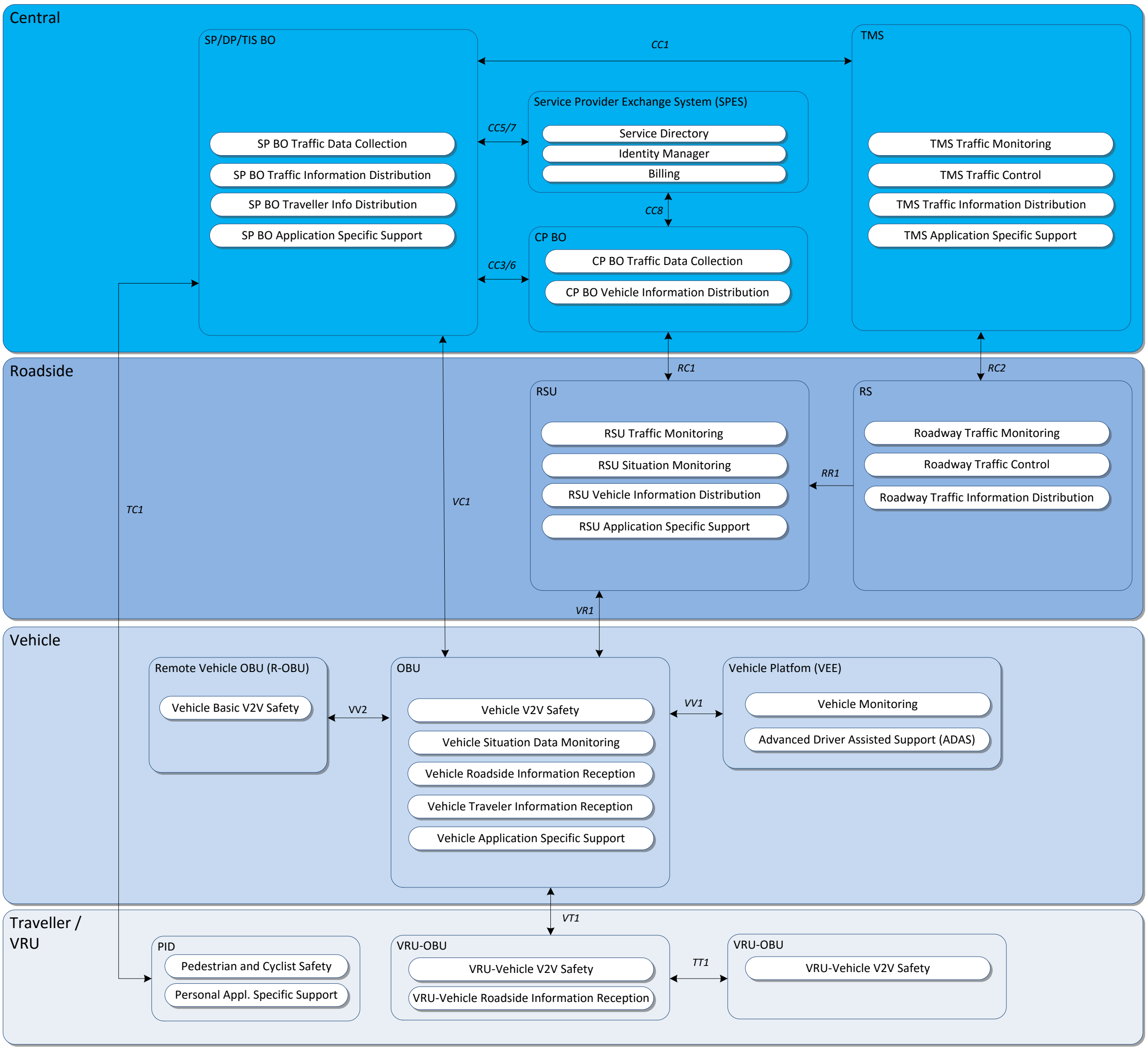

Figure 2-4 Detailed architecture functional view with sub-systems, functional components and interfaces – aggr. level 2[1].

2.4 Communication view

The communication view shows the interfaces between sub-systems and the data flow between the processes within the functional components. In the physical view (Figure 2-3) and functional view (Figure 2-4) these interfaces are shown. In Section 6 the data flow is explained in the sequence diagrams, with an explanation of the information exchanged. In section 6.4 a detailed description is given of the some deployment architectures from the communication view with gateways to enclose a R-ITS-S network. More details on the communication view can be found in the document of the 2014 project [1].

2.5 Update reference architecture 2015

The reference architecture for V2V applications in [1] was based on ad-hoc communication via ITS-G5 (as defined by ETSI ITS). In 2015 a study was started in 3GPP on the feasibility of LTE to support V2X type of communication. The results will be published in a technical report 3GPP TR 22.885 that is expected to be ready in Q1 2016. In this study V2X communication via LTE networks is in scope, including the use of direct communication between User Equipment (UE's). The message sets itself as defined by ISO/CEN/ETSI (CAM, DENM, IVI, etc.) used for ITS applications are not in scope, and are regarded 'as is' in this 3GPP study. This development might be interesting for future deployment projects - after 2017. This development is not included yet in the 2015 update.

Cooperative information exchanged between vehicles and roadside stations is used in in-car systems, either as additional information for ADAS systems to inform drivers or - in the near-future - for direct vehicle control systems, e.g. for automated driving. The information from in-car sensor systems (radar, camera, LIDAR, etc.) will be enriched with exchanged cooperative information. Especially information from remote vehicles that cannot be retrieved from in-car sensors of the host vehicle or is more accurate, has added value, e.g. information on vehicle state, beyond line-of-sight or on intended moves (lane change, merging). The exchange of this information is in scope, but the integration with in-vehicle ADAS systems / control systems is not updated in this release, and is described in [8].

The architecture for I2V applications in [1] was based on input from projects as Converge, A58 and ECo-AT. The architecture contains a split of central elements like CP BO (with CIS) and a roadside ITS network (with RIS) and introduced explicit connections from the CP BO to other back-office systems like TIS, DP BO, SP BO etc. Several options are still possible to disclose a roadside ITS network of a communication provider for central back-office systems of other roles, e.g. different layers (at application, facilities or network & transport layer via so-called 'gateways'). The best practices are described in section 3.2.

[1] The VRU elements for VRU localization (VRU Transponder and Vehicle and Roadside VRU Localization systems are for readability not included, see Figure 6-21 for these elements).

3 Implementation architectures

3.1 Introduction

The reference architecture as described in chapter 2 needs to be applied to a specific context to be able to define an implementation architecture. Such context consists at least of the (set of) ITS applications that need to be implemented, the existing legacy systems that need to be integrated with, but can will also contain financial, time, and/or business model constraints, especially which stakeholders are involved with additional roles, and which role is connected to which function and underlying information system.

Based on the discussions that have taken place in the public meetings on the Dutch C-ITS architecture (called "ITS round table") and the output from various projects, two contexts have been selected in this 2015 update to create corresponding implementation architectures:

- Highway: this architecture is focusing on C-ITS applications for highways (and inter-urban) roads, i.e. for large-scale traffic management and commercial services on highways. These services are offered on highways and inter-urban roads by both the responsible road operator or traffic manager (like Rijkswaterstaat in The Netherlands) and commercial service providers. The services are I2V / V2I type of services, i.e. information from / to back office or roadside systems is sent to / received from vehicles. Projects like A58, Converge and the Dutch part of the European ITS Corridor project (ECo-NL) are used to extract best practices.
- Urban or iTLC: this architecture is focusing on C-ITS applications in an urban (and rural) environment i.e. for local traffic management and commercial services. These services are offered in an urban environment by both the responsible road operator (local cities) and commercial service providers. The services are I2V type of services, i.e. information from back office or roadside systems is sent to vehicles. The project iTLC (Dutch *intelligente VerkeersRegelInstallatie (iVRI)*, or intelligent Traffic Light Controller) is used to extract best practices.

Whereas the reference architecture aims at providing an architecture that will support all projects and related implementation architectures in scope, the implementation architectures presented in this chapter are based on specific choices made, both in the context, and in the implementation architecture itself. These architectures are also **descriptive**, and leave options open for individual organisations on the split of functional and physical elements with their interfaces.

Other implementation architectures on data / information services, in-car applications, coordinated traffic management and vulnerable road users are not in scope in this 2015 update.

3.2 Implementation architecture for C-ITS applications on highways

3.2.1 Context

The context for the implementation architecture on highways is defined as follows. Both commercial services targeted at individual needs of end users, and traffic management services are implemented. These traffic management services are typically relevant for a geographical area between 500 m and 20 km. It should be possible to provide services both by commercial service providers and by a public traffic manager. Due to the current and expected state of communication technologies, it should be possible to is provide services either via ITS G5 based communication, and via cellular networks. For ITS G5 networks, it is assumed that a "high quality" back-haul communication network is available between (i) central back-office systems and (ii) decentralized roadside systems or vehicle/personal systems of road users. High quality means that this IP-based communication network will not be a bottleneck with respect to delays, bandwidth, and/or reliability for the services. In an actual deployment, a physical system can be placed at any location e.g. in a local traffic management center or in a data center ('cloud'), but due to the high-quality IP network / Internet, the system can be regarded as virtual and can be placed anywhere.

This context is typically applied to traffic management and commercial mobility services for vehicles on the highways network. However, other contexts, like services on large city roads (ring road) networks could also fit in this context.

3.2.2 Physical architecture with functional building blocks

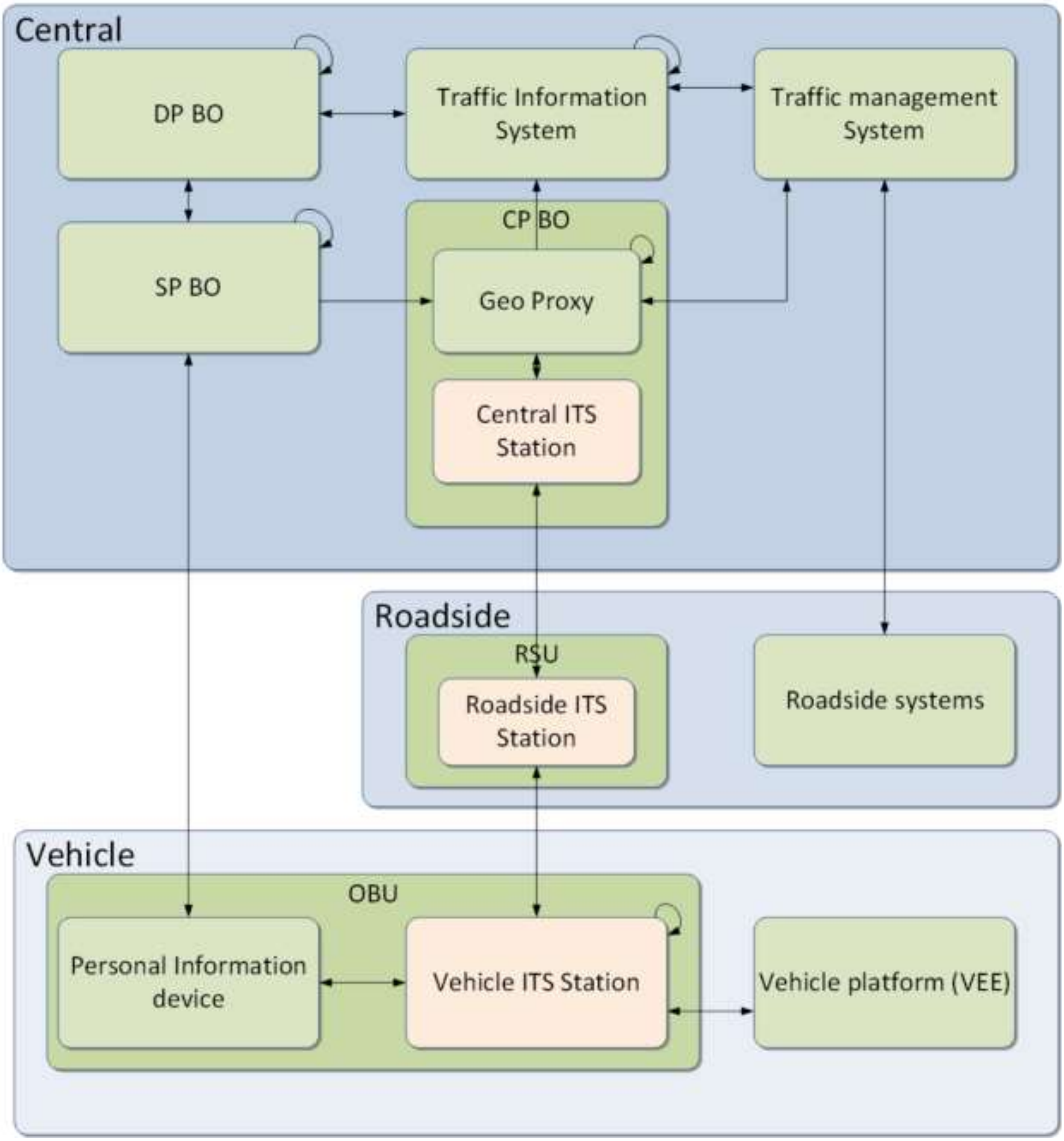

Figure 3-1 Physical architecture with functional building blocks at central, roadside and vehicle layer for the centralized traffic management context. The red boxes represent the elements for ITS-G5 networks

Figure 3-1 shows the physical architecture for this context. On the central layer, information between the service and data providers is exchanged with the traffic management system via a traffic information system. Multiple traffic information systems can be put behind each other to aggregate information at different levels, as is operational today via e.g. NDW. The existing roadside systems (e.g. Variable Message Signs, VMS) are no locally connected towards the Road Side Unit (RSU, with application and communication unit), but centrally via Traffic Management System (TMS) and Traffic Information System (TIS). In this way a flexible and scalable solution is possible, where existing legacy systems like VMS and new ITS-based systems (with application and communication) are interconnected at a single point. Information for I2V services can be distributed from Service Provider Back-Office systems (SP BO) to vehicle systems via either cellular networks and/or ITS-G5 networks via Geo Proxy and CIS/RIS.

The Geo Proxy – part of the CP BO, together with the CIS - enables the distribution of messages via the cooperative infrastructure without exact knowledge by the user (service provider or road operator) of the actual network topology: location based information is offered to the CP BO via the Geo Proxy, and the Geo Proxy takes care of message delivery via the appropriate roadside ITS Stations. The Geo Proxy only operates at the networking layer, and does not convert data to the correct format. Geo Proxies can be organized in a hierarchical, tree-like structure, where the tree-structure could reflect the geographical structure of (a part of) The Netherlands. To allow for fast distribution of real time data from the cooperative roadside systems, the Geo Proxy is directly connected to the Traffic Information System.

The Geo Proxy concept could also be used for other broadcast communication networks that can be addressed geographically (e.g. RDS (with RDS-TMC), DAB (with DAB-TPEG) or LTE Broadcast), but that has not been worked out in detail in this document.

The Central ITS Station (CIS) typically takes care of the conversion of messages at the appropriate facilities layer. If additional functionality is required for specific applications, this can be implemented in the application layer of the CIS. On the other hand, if no data conversion is required, the functionality of the CIS is limited to the networking layer.

The Traffic Management System (TMS) is assumed to be similar to a Service Provider Back Office (SP BO) and does not know the cooperative network layout/topology. The TMS is in the same way connected to the CIS as the SP BO, i.e. via a Geo Proxy.

The role of the data provider is made explicit in this architecture. Only the Data Provider BO (DP BO) is connected to the Traffic Information System (TIS), and not the Service Provider BO: a service provider is assumed to get (all) its data from one or more data provider.

At the roadside layer, no interface is available between the (existing) Roadside Systems (RS) and the Road Side Units (RSU), so no local interface between the roadside sensors and actuators, and roadside cooperative systems. Due to the high quality data network between the roadside systems and the central systems assumed in this context, the network performance will not be a limiting factor, Furthermore, as the applications are assumed to cover a larger range than can be typically overseen with a single roadside system or RSU, the added value of having a local connection is limited. By *not* providing this interface, it is expected that it will be simpler to implement changes in either the RSUs, or the roadside systems.

3.2.3 Detailed architecture with options of interfaces of cooperative ITS-G5 elements

Some of the functional components, mostly those relevant for the cooperative systems, are worked out in one level more detail, see the figure below. Note, that some components (like DP BO and TIS) that are not worked out, have been left out for simplicity.

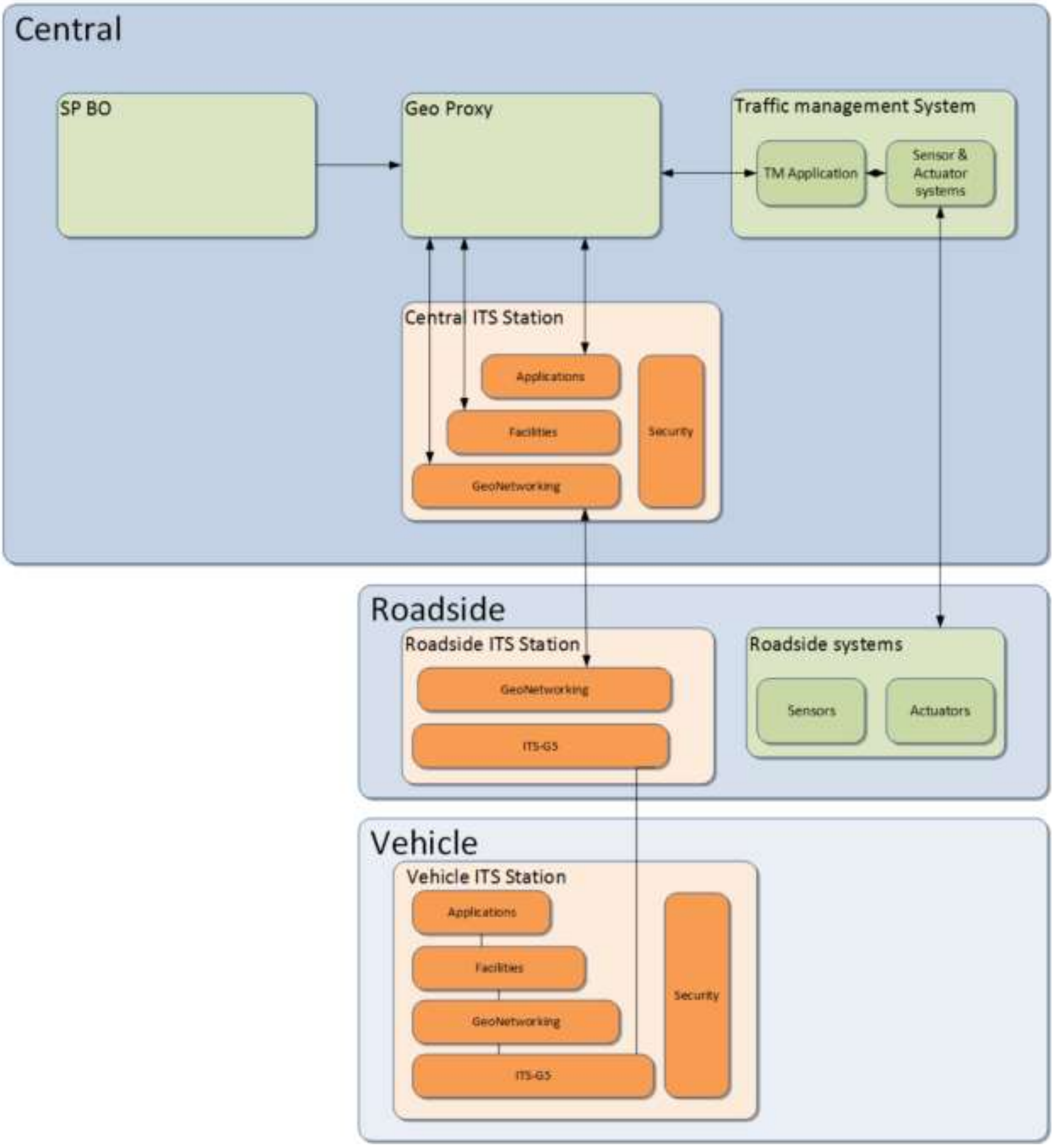

Figure 3-2 Detailed architecture with the options on the communication interfaces for the elements of the cooperative ITS systems at the vehicle (VIS), roadside (RIS) and central layer (CIS)

SP BO and TMS don't have to know the exact topology of the ITS G5 network(s) and the specific ITS-G5 protocol stack / message sets, and have a single interface towards a Geo Proxy to distribute messages via local ITS-G5 broadcast to drivers in a certain area. The Geo Proxy connects to a CIS via 3 communication options:

- Applications layer, if application level functionality is required: in this option an Application Level Gateway is used at the CIS to receive information that can be used in ITS applications. The CIS will generate ITS-G5 messages. This option results in application-specific messages from Geo Proxy to CIS - typically exchanged via SOAP/JSON/xml type of Internet protocols – and require no direct interface with functions in the ITS-G5 protocol stack.
- Facilities layer, for data conversion: in this option an Facility Layer Gateway is used at the CIS, with access via the Geo Proxy to ITS G5 defined facilities like DENM, CAM, LDM, etc. This

option results in ITS G5 requests (like start / stop / update of DENM / IVI messages) from Geo Proxy to CIS.

- Network layer (i.e. GeoNetworking), if only data transport is required: in this option, a Network Layer Gateway is used at the CIS. Complete ITS G5 messages (i.e. GeoNetworking frames) from the Geo Proxy are tunnelled (over IP) to the different roadside stations connected to the central ITS station and then threated as a normal GeoNetworking frame. This option results in streaming of ITS-G5 messages (DENM, IVI, etc. at typically 1 Hz) from Geo Proxy to RIS, via CIS. The advantage of the Access Layer Gateway scenario is that the new facilities and applications can be introduced at vehicle and central ITS station components without interference of the roadside ITS network. Also the security certificates of the implementer of the application (e.g. an external SP or external road operator) can be used to sign the GeoNetworking frames, which is not possible in the above two options.

It should be noted that other implementations as presented in the above Figure 3-2 are possible between CIS and RIS and are covered in detail in section 4 of the document of the 2014 project [1]. In these options the Facility or Access layer gateway functionality is used in the RIS. In the 2014 document also a Proxy Layer Gateway was explained, where an additional internal Geo Proxy is used between CIS and RIS.

The traffic management application functionality is implemented in the Traffic Management (TM) application, which has direct connections to the Sensor and Actuator systems for data collection from and actuation in Roadside Systems. At the same time, it has also an indirect connection to the application layer of the Central ITS Station, via a Geo Proxy. The application component in the Central ITS Station does not contain the traffic management logic, but will only provide the data collected from the cooperative vehicle and roadside systems to the TM Application, or specializes the output from the TM Application to fit the cooperative systems. Examples of the latter are the selection of specific Roadside ITS Stations to use, and adoption of the messages to be transmitted based on the actual network layout.

The Central ITS Station also contains a GeoNetworking and security layer. The main purpose of the security layer in cooperative systems is to sign and authenticate cooperative messages. The security related information is added to the networking layer. By combining the security and GeoNetworking layers in the Central ITS Station, it will become possible to implement the message generation and security functionality in a single system in a back office, potentially improving the reliability and scalability of these components. Furthermore, due to the GeoNetworking layer in the Central ITS station, messages originating from this system will be recognized as being identical, even if transmitted by multiple Roadside ITS Stations. This will improve processing efficiency in the Vehicle ITS Stations, and will reduce the network load on the wireless ITS G5 network due to multi-hop forwarding.

The Roadside ITS Station can be kept very simple, with only a networking layer and ITS G5 layer. No application and facilities are required, and it is even possible to remove the security layer. The security layer is currently regarded as the limiting factor for the throughput of messages in a Roadside ITS Stations; so eliminating this component improves performance of the system as a whole. An additional advantage is that the required functionality at the facilities and application layer are expected to change more than the underlying network and radio access layers, and are much stronger dependent on (future) addition of new applications and message sets like IVI, SPaT, MAP and others.

This distribution of networking functions over the Roadside and Central ITS Station requires that GeoNetworking can be used for the communication between those units. It is not foreseen that GeoNetworking will be implemented directly on the (Ethernet) layer 2 network between these components: only IP communication (IPv4 and/or IPv6) will be supported. Therefore, it is required to somehow tunnel the data. Several solutions could be used, e.g. based on IP multicast, various layer 3 tunnelling protocols, or a dedicated application level tunnelling solution. None of these have been specified in detail yet, nor have they been standardized.

3.2.4 Discussion

3.2.4.1 Support for different roles of CP, DP, SP and TM

The split in 'roles' for Service Provider (SP), Data Provider (DP), Communication Provider (CP) and Road Operator (RO) / Traffic Manager (TM) is seen as very useful and should therefore be made explicit in the architecture. Functional elements like SP BO, CP BO, TIS, TMS are coupled to these roles, and support different deployment and exploitation models.

The CP is responsible for message distribution to vehicles and message collection from vehicles via ITS G5 networks for SP, DP and RO / TM. In this way both public and commercial services can be offered in the same way, via the CP network, via a central interface on the CP BO. In the A58 project 3 types of interfaces were developed [20], i.e.

1. D1: interface between SP BO and CP BO at Applications layer
    a. Interface to request to send DENM, IVI or TSM message;
2. D10: interface between SP BO and CP BO at Facilities layer
    a. Interface to request to send trigger / update / terminate DENM and IVI message (not TSM) and
3. D11: interface between SP BO and CP BO at Network & Transport layer FA
    a. Request to send TSM messages including BTP & GeoNetworking header; also receive (option to send /receive DENM, CAM, IVI at BTP level is not defined!)

An interface specification between back-office systems (SP/DP BO) to the CP BO of a ITS G5 roadside network is needed to prevent vendor lock-in and to allow other providers (like SP's and OEM's) to use ITS-G5 networks to communicate with their in-vehicle systems. The internal interfaces in the ETSI communication architecture [[21] should be specified to unlock a RIS / CIS system at the different levels i.e.

1. Interface NF: support of tunnelling of GeoNetworking over IP (or over TCP/UDP) for sending & receiving messages => Converge
2. Interface FA: support for sending & receiving messages (CAM, DENM, IVI, TSM, SPAT, etc.), i.e. both trigger (create) / update (change) / terminate (delete)
3. Interface A: gateway that translates generic (XML) messages to a specific ITS G5 message

3.2.4.2 Thin client RIS implementation

The RIS in this implementation architecture is kept as thin as possible: only a geonetworking and ITS G5 layer are present. This is possible due to the specific context chosen. If no high-quality back haul network is available, more application intelligence might be needed physically located at the roadside, so as part of the RIS. This would require an application layer to be present, and therefore also a facilities and security layer. Similarly, if a direct coupling between the RIS the (legacy) Roadside Systems would be needed, e.g. for reliability or to meet time constraints of specific applications, then also a facilities layer and security layer are required in the RIS. Finally, for robustness or performance reason, it might also be needed to have local implementations of safety applications. What these applications will be, what additional sensors might be required, and what the detailed constraints are, has not been worked out yet.

3.2.4.3 Interface from RIS to VIS

This RIS-VIS interface is used for I2V and V2I applications, like RWW, PVD and IVI. A first specification of this interface is defined in the Dutch Profile [22] and is meant to be included in a Day-1 profile of the Amsterdam Group [23] for I2V applications.

Within the Amsterdam Group functional descriptions for RWW, PVD-PDM and IVI are under development. An Amsterdam Group (AG) profile for I2V applications - similar to the C2C CC profile [24] - is needed for interoperability. The profile defines which ETSI standards and specifications are applicable and how they are used, i.e. with a translation of the functional description towards the information in the data elements of the messages. The AG profile for the Day-1 applications is still work in progress.

3.2.4.4 Probe Data: collection and distribution of individual vehicle data (micro data) and road segment data (macro data)

In the projects several specifications and solutions were developed to collect vehicle 'probe' data or floating car data:

- Macro data NDW [2]: point speeds, traffic volumes, vehicle classification, with one minute aggregation
- Vehicle Detection (micro data, A58) on detection points: speed and vehicle length of individual vehicle crossing, on lane level (part of A58 interface H [25], based on [26])
- Connected FCD (micro data, A58) : track data for 1-30 seconds with position (longitude/latitude in WGS84), speed and heading (A58 interface G [27];
- Cooperative PVD (micro data, A58): CAM data collected by RIS is forwarded to CP BO and enclosed for DP (via A58 interface A*); the interface of the DP to SP includes different types of (aggregated) information;

The different information sources for probe data use different location referencing systems - both absolute (via WGS84) and relative (road, lane, hectometre position) - and different levels of aggregation are used, both in time and in space/road segment depending on the detection method (loops, FCD/PVD collection in vehicle, roadside or back-office).

A uniform, compact, format might be preferred for the different probe data, with information on detection method, location referencing system, timing & position accuracy and type (latest, real-time (streaming), historic).
Also separate interfaces or web services are preferred for the different information sources i.e. web services for:

- Vehicle state (micro data)
- Vehicle event (e.g. hard braking, accident)
- Traffic state (macro data)
- Traffic event (e.g. incident, etc.)
- Network location state (micro data)
- Network segment state (closed lanes, dynamic speed limits)

3.2.5 Information distribution from Rijkswaterstaat on VMS and TMS via Internet to SP/DP

The starting point for RWS is to provide traffic management information via a centralized point-of-contact, either via NDW or via Internet (push/pull web service).

In the A58 project an Internet-based service was used to enclose information from VMS and TMS. The interface H [26] encloses three types of information sources:

- Variable Message Sign: information on dynamic speed limits per lane and blocked lanes, for road segments on highways equipped with VMS
- Speed and Flow: average speed and number of passed vehicles per lane during one minute;
- Vehicle Detection: individual passing on a detection point

In this solution traffic management information is enclosed for any third party SP/DP via Internet and can be used for SP-specific applications. The accuracy of location and time of the events (especially of vehicle detection and VMS) is not specified.

3.2.6 Multiple speed advices by private SP's and effect on traffic efficiency

In A58 project multiple SP's provided speed advice solutions to their customer group. The implementation architecture supports this solution. The effect of multiple individual speed advice systems on traffic efficiency i.e. reduction of traffic jams via shockwave damping is under study in this project.

It is recommended that for public information services (like speed advice on a road section) standardized message sets like IVI, DENM, CAM or SPAT, and not via proprietary, SP-specific messages like TSM. In this case the send information can be regarded as publically open data, either directly distributed via a ITS-G5 roadside network or via a centralized interface.

3.3 Implementation architecture for C-ITS applications in urban environment

3.3.1 Scope

In the context of the second implementation architecture that is worked out, the focus is on local, real-time applications in an urban environment. Part of the traffic (light) control services are assumed to be real time and with a local scope (typical relevant area < 500m). In this context, it is assumed that no reliable high performance communication network is available (or affordable) between (i) central back-office systems and (ii) decentralized roadside systems or vehicle/personal systems of road users. This is a context, which is typical today for urban signalized intersections controlled by a traffic light controller, but could also relate to services provided at a ramp of a highway. The TLC and locally integrated RSU with ITS-G5 communication function can be regarded as stand-alone system, and information is sent real-time via ITS G5 broadcast. It should be possible to offer at least part of the functionality also via cellular networks.

3.3.2 Physical architecture with functional components

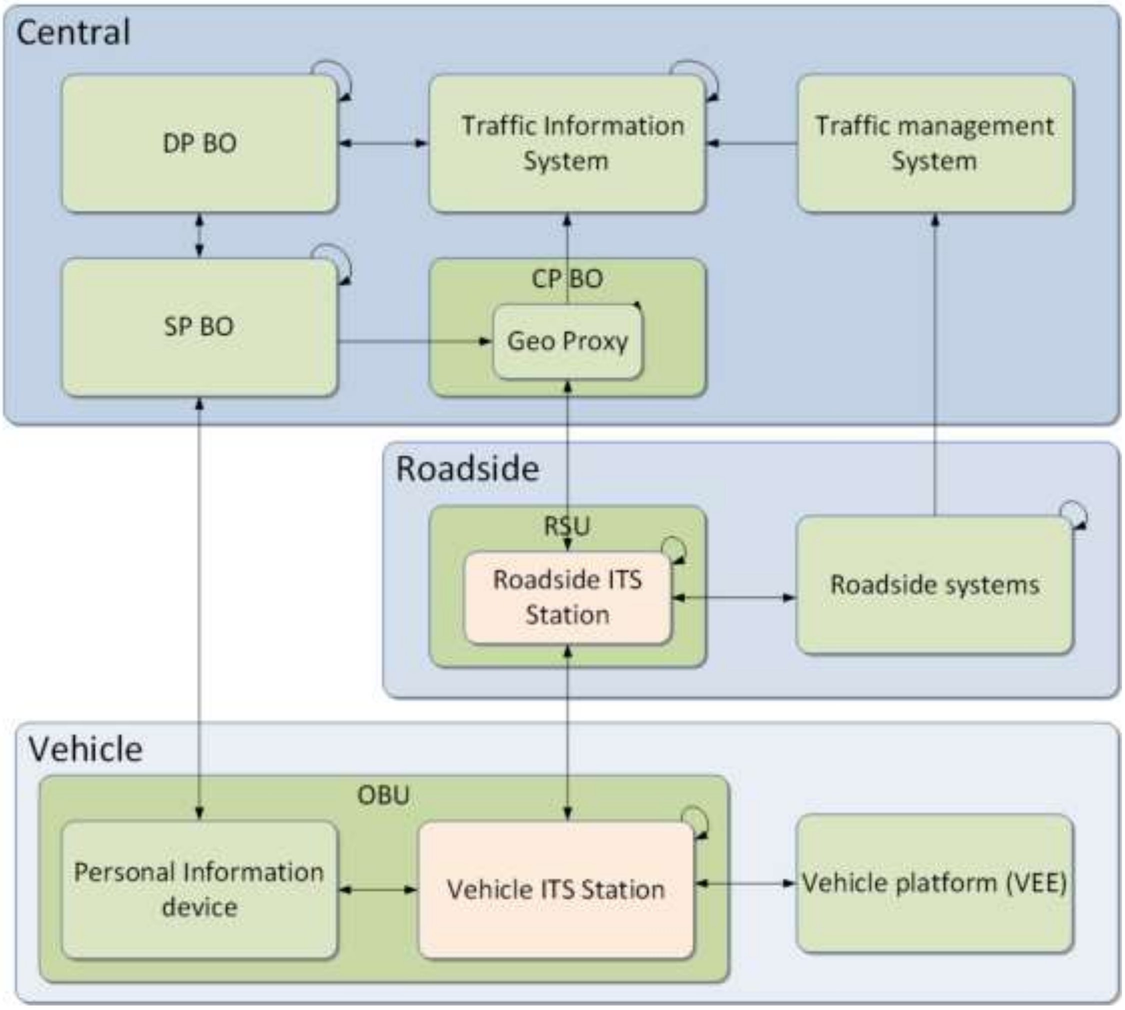

Figure 3-2 Physical architecture with functional components at central, roadside and vehicle layer, for local traffic applications context.

Figure 3-2 shows the high level architecture of this context. Due to the smaller geographical scale of the applications and the absence of a high performance communication network, the traffic management applications are implemented at the roadside and integrated with the existing Roadside Systems, e.g. with existing TLC, or in the RSU. The central component is only used for collecting information and providing it via the Traffic Information system to data providers. Because all traffic management functions are implemented locally in the roadside layer, it is required to implement a facilities layer or application layer functionality in the Roadside ITS Station to process data coming from the central Geo Proxy. For that reason, no Central ITS Station is provided.

A local connection between Roadside Systems and Roadside ITS Stations allows for a direct coupling of the cooperative and traditional functionality. Also, both the Roadside ITS Stations, and the Roadside Systems can also be linked to (close by) other Roadside ITS Stations and Roadside Systems. In this way, it will be possible to extend the communication range of applications beyond the scope of a single location, e.g. for green-wave type of applications.

To allow for cellular based services, provided by service providers, a link between the roadside ITS Station and a Geo Proxy is provided. Note, however, that under the assumption of the absence of a high-quality data network, the services that have stringent requirements on latency, high bandwidth and high reliability might be limited via this channel, compared to the local services with ITS G5 broadcast. At the central level, the architecture for the two contexts for the service and data providers is kept identical, so their interfaces towards the Traffic Information System and Geo Proxy are the same for the two contexts. Also the vehicle layer is identical.

3.3.3 Detailed architecture with options of interfaces of cooperative elements

The detailed architecture showing the different communication options is presented in Figure 3-3. The Roadside ITS Station is a complete ITS Station, i.e. including all four layers in the communication stack and the security layer. Both the Roadside Systems and the Roadside ITS Station have an application layer, and both have access to the facilities of each other. In that way, it is possible to implement functions either in the (legacy) Roadside Systems, or in the (new) Roadside ITS Station. As Roadside Systems like TLC's are used the maximize safety for road users at intersection, an explicit "safety control" layer between the applications and the actual sensors and actuators is used in TLC's. The "safety control" layer is responsible that the actuators are always in a safe state, even if incorrect or conflicting requests are made by one or more applications.

Similar to the connection between the Geo Proxy and the Central ITS Station in the first context, here the Geo Proxy has connections to both the Application, Facility, and GeoNetworking layers in the Roadside ITS Station. Which layer to use depends on the type of information being exchanged. However, due to the assumed network performance of the network between the roadside and central layer, it is likely that an aggregation application at the roadside will be required to reduce bandwidth in the upstream direction. Similarly, it is likely that some application level functionality will be required to minimize the downstream traffic.

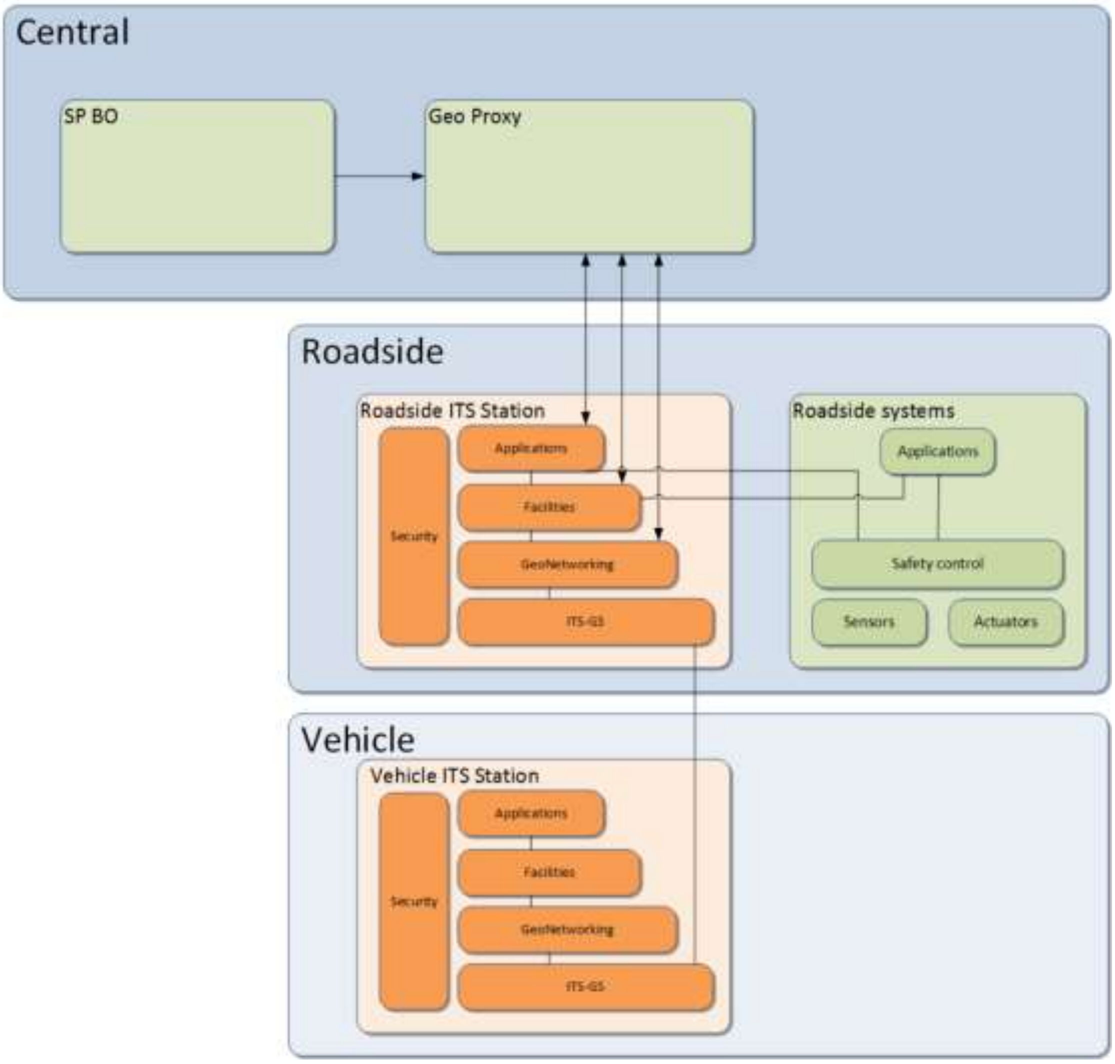

Figure 3-3 Detailed architecture with the options on the communication interfaces for the elements of the cooperative ITS systems at the vehicle (VIS) and roadside (RIS)

3.3.4 Discussion

The deployment architecture presented in this section is consistent with the architecture developed in the iVRI project (see also section 4.4). However, the level of detail at the roadside level and the interfaces from the roadside systems towards the central layer is larger in the iVRI architecture. On the other hand, the integration of the intelligent traffic light with other components at the central layer, like geo proxy and service providers, is more extensive in the architecture presented here. Furthermore, different naming has been used.

At the roadside layer, the essence of being able to deploy applications on either the ITS station or the roadside system that can make use of the facilities in either system is the same. Other deployment solutions are also presented in the iVRI architecture which are not covered here, but are not contradicting. In the iVRI architecture, a distinction is made between the traffic management system and traffic control system. This distinction can be seen as a refinement compared to the architecture presented here.

A significant difference between the iVRI architecture and the architecture presented here, is the way the real-time data is provided to the central layer. In the iVRI architecture, the real-time data from the TLC facilities (in our architecture: roadside systems safety control layer) is directly going to a traffic data center. On the other hand, the real time data from the RIS facilities are not provided to a central layer at all. In our architecture, we do not explicitly define if and how the real-time data from the Safety control layer are provided to the central layer. However, we do specify that the a connection is available at the application, facilities and geonetworking layers. Also, in our architecture these interfaces are made with a geo proxy at a communication provider, and not directly to a traffic data center or traffic management system.

It needs to be investigated further whether these differences observed here, and that can be traced back to the fact that our reference architecture has a broader scope, and is also based on input from e.g. the A58 project, are fundamental in nature, or are merely refinements that can be made to either architecture.

3.4 Summary and discussion

In this chapter, two implementation architectures are presented for two different contexts. The main difference between the two architectures is where the application intelligence is implemented: in the back office layer, or in the roadside layer. In the ‘Highway’ implementation architecture, the intelligence is placed in the back office. This results in a “thin” roadside system, and no need to couple legacy roadside systems to cooperative systems. In the ‘Urban’ implementation architecture, the intelligence is placed in the roadside layer. This results in a “thick” roadside system, and a need to couple legacy roadside systems directly to cooperative systems, and possibly create local connectivity between different roadside systems. The “thick” roadside system is in essence similar to the “thin” version, but with additional functionality. Therefore, the “thick” RSU could also be used in cases where only a “thin” RSU would be required.

On the central layer, the main difference is the functionality that needs to be provided by the communication provider. At the central layer the opposite from the roadside solutions is true: the functions that need to be provided by the CP in the ‘Urban’ implementation architecture, are all included in the solution that need to be provided in the ‘Highway’ implementation architecture. In other words, an ‘Highway’ CP BO can also connect to a ‘Urban’ RSU.

In case of a thin RSU and a complete CIS, including Security and GeoNetworking layers, it is required that GeoNetworking frames are transported to the roadside systems. However, GeoNetworking will not be implemented on the network connecting these elements, so a new technical solution needs to be defined, based on existing tunnelling techniques.

From the central traffic management, data provider, service provider and vehicle perspective, the solutions are identical (at the prescribed abstraction level), so that allows for easier integration between systems implemented based on the two different architectures.

4 Implementation architecture of projects

4.1 Introduction

In this section the method described in the previous chapters is applied on the applications of three selected projects, i.e. Shockwave Traffic Jams, ITS Corridor and iTLC. Other projects from the 2014 architecture like PPA, VRUITS and Converge are not updated in this document.

4.2 Project Shockwave Traffic Jams A58 (*Spookfiles A58*)

4.2.1 Short description of project

The main objective of this project is to prevent traffic jams with no direct cause (incident, road works) and is called "shockwave damping [28]. The use of individual speed (and lane) advice for road users provided by private service providers is used to study the effect on traffic management / traffic control.

One should note that besides these individual speed advice applications of private SP's also the existing traffic management systems with dynamic speed limits is still in use.

The approach of this project is market-driven i.e. with a vision on horizontal market dynamics and service versatility. Three horizontal market roles are defined - service provider, data provider and communication provider of a cooperative ITS roadside network - and supported by the system architecture by the definition of well-defined interfaces to exchange information between the market roles to support the market dynamics. However, the individual market parties have the freedom to develop differentiated applications, to have a differentiated service offering compared to competitors and will therefore depend on a suitable individual business model.

4.2.2 Implementation architecture of project

The architecture for this project is based on the following main requirements:

- Horizontal market: support for different roles in the value chain (SP< CP, DP) via a 'horizontal' split with open interfaces to enable market competition; less focus on specific use cases / ITS applications; the identified roles are Service Provider, Data Provider and Communication Provider of an ITS-G5 network with roadside systems;
- Several entities (both public and private) can fulfil the same business role: multiple instances of the same application are possible;
- Enable access to traffic flow data at different levels (i.e. raw, fused, enriched);
- "Talking Traffic" concept: i.e. synergy between connected and cooperative communication;
- Support of a broad set of use cases;

These requirements have led to the following project choices to support the 'horizontal' split in business roles:

- Hosting function on roadside communication system: applications/facilities run on hosted system, part of the CP BO; data exchange between applications (of different service/data providers) on a local hosting system is used to reach time constraints for local advices/warning;
- Central access to roadside communication system; different types of access (via interfaces D1/2/10/11, see Figure 4-3) are possible, i.e. direct ETSI-based message (DENM, TSM, IVI) or other data messages to hide complexity of ETSI formats with related PKI-based authentication schemes;
- Road operator becomes an entity that can support different roles and is no longer the central / integral entity for traffic data collection and traffic management.

The main application supported in the project *Shockwave Traffic Jams A58* is shockwave damping [28]. This project aims at applying an open horizontal architecture rather than a vertical stovepipe architecture. In this approach functions are split, i.e. end-user services from **service providers**, data information services from **data providers** and road-side communication services from **communication providers** (via ITS-G5 roadside network(s)) and well-defined interfaces between these functions are used. In this horizontal architecture a provider can focus on a certain layer of the system, e.g. a roadside communication network, rather than focusing on end-user applications, which would require implementations of all parts of the system. This corresponds to the philosophy of the project to formalize the interfaces between the different functional components, to allow different implementations of the components by different providers, so the market-oriented data and service providers can compete on the quality of the provided information.

Figure 4-1 illustrates the functional and organisational decomposition used by the A58 project. In this figure the colours of the physical objects (VIS, RIS, CIS, TMC etc) correspond to the roles of service provider (blue), data provider (red), communication provider (green) and road operator (grey) the. In this project the services are not described in detail, however the interfaces (orange lines) are specified in detail.

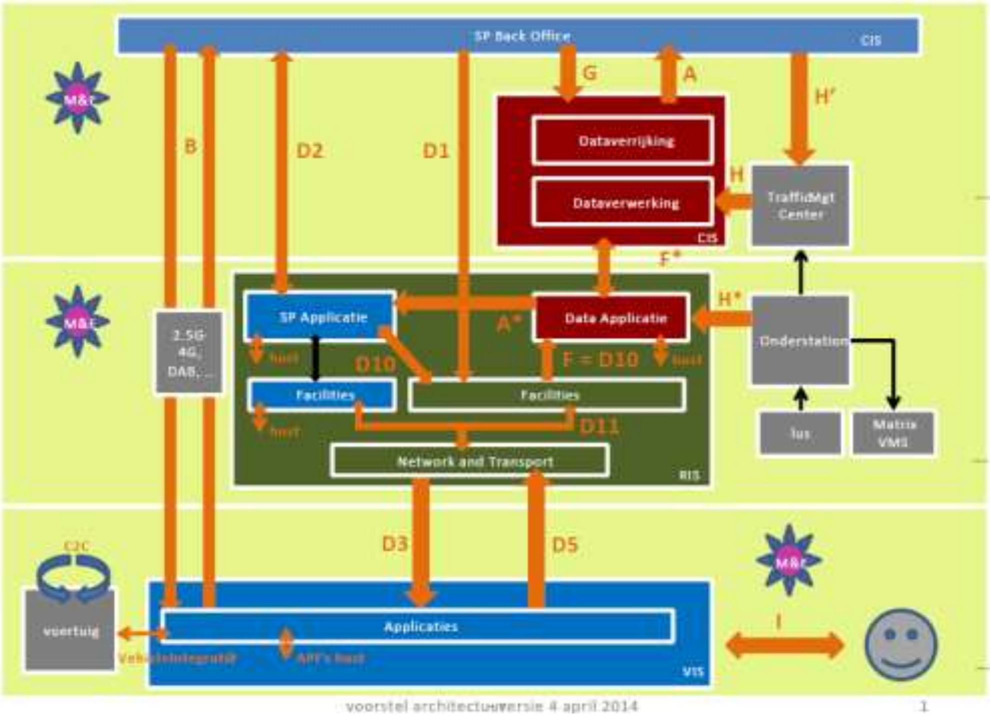

Figure 4-1: Architecture for the A58 project, illustrating the interfaces between the functional components of the difference roles (Blue = Service Provider, Green = Communication Provider of the cooperative roadside infrastructure and Red = Data Collection)

In Figure 4-2 the specific role of the communication provider is shown. The Roadside ITS station (RIS) includes a ‘hosting’ function for other service providers, who can install software for their specific C-ITS applications.

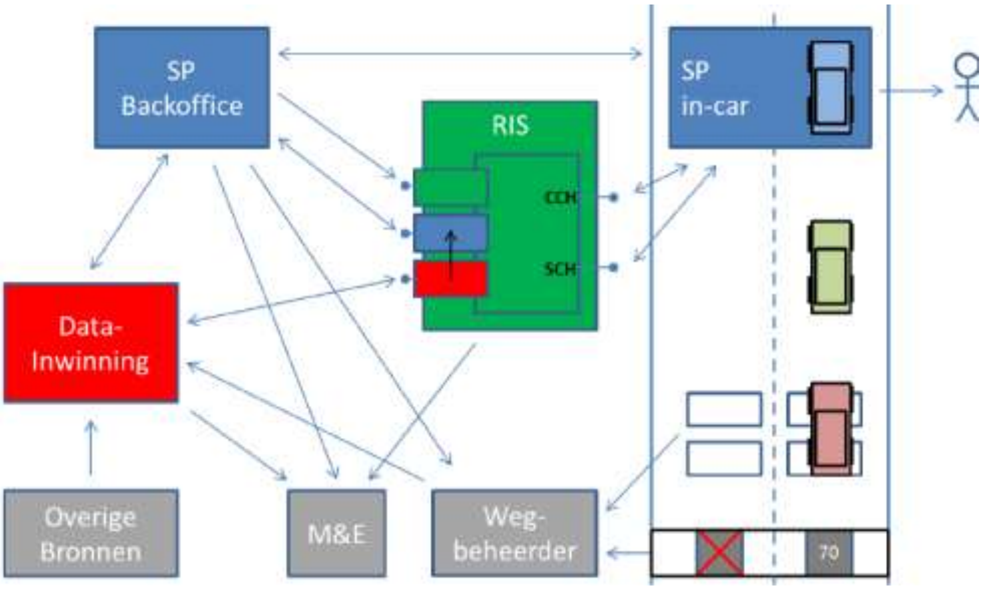

Figure 4-2: Functional decomposition of A58 project

4.2.3 Mapping of reference architecture to implementation architecture

For the *A58* project the architecture is modelled with the defined building blocks and shown in Figure 4-3.

In this figure the interface markings as defined by A58 [28] are plotted in the figure. The functional components are plotted in the sub-systems. With this architecture the applications in A58 are supported.

It should be noted that in the A58 project the role of the road operator is limited to providing information to data / service providers on traffic flow (local loop data) and traffic measures (dynamic speed limits). The architecture supports however also other roles for the road operator, e.g. sending safety warning (like road works warning). In this case the road operator fulfils the business role of service provider.

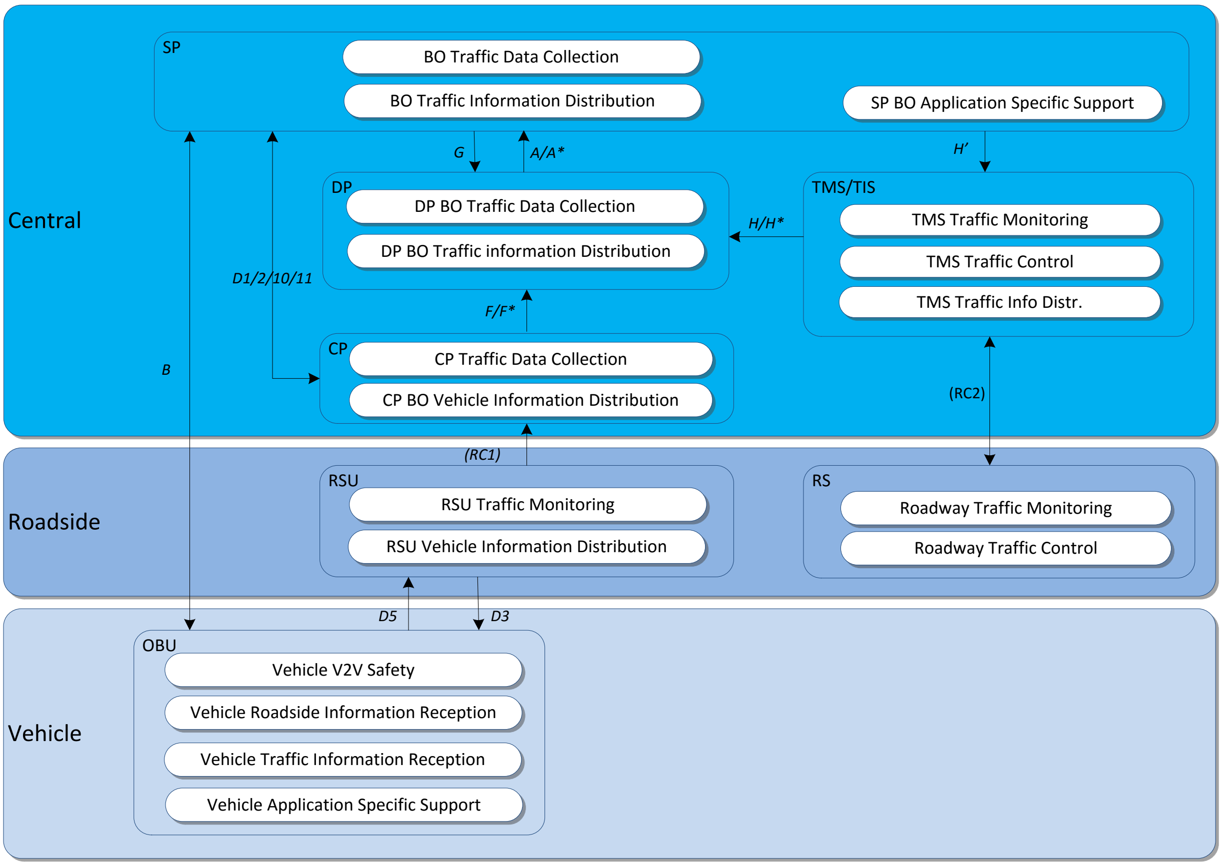

Figure 4-3 Architecture View of *Shockwave Traffic Jams A58*

The interfaces of the A58 project are shown in Table 1[2].

Table 1 Interfaces with reference between A58 and architecture.

A58	Ref. Arch.	Source	Dest.	Information Type
A / A*	CC9	DP BO	SP BO	Enriched Probe Vehicle Data
B	VC1	SP BO	OBU	Service provider specific information
B	VC1	OBU	SP BO	Service provider specific information, probe vehicle data
D1/10/11	CC6	SP BO	CP BO	ETSI DENM, ETSI TSM
D3	VR1	RSU	OBU	ETSI DENM, ETSI TSM
D5	VR1	OBU	RSU	ETSI CAM, ETSI DENM
F/F*	CC6	CP BO	DP BO	Aggregated Probe Vehicle Data
G	CC9	SP BO	DP BO	Aggregated Probe Vehicle Data
H	CC1/CC4	TMS via TIS	DP	Macro Traffic State / Control Data e.g. Dynamic Speed Limits, loop/camera data
H*	CC1/CC4	TMS via TIS	DP	Micro Traffic State / Control Data
H'	CC2	SP	TMS (via TIS)	Speed advice

Within the A58 project four different types of interfaces (D1/2/10/11) are defined between SP and CP. The interfaces D2/10/11 rely on a 'hosting' model where the service provider needs to install his application on the roadside hosting system.

[2] The interface specifications of the A58 project are available via the project.

4.2.4 Business Model Design

The project aims to support an open horizontal architecture rather than a vertical stovepipe architecture. In this approach functions are split, i.e. end-user services from service providers, data information services from data providers and road-side communication services from communication providers (via ITS-G5 roadside network(s)) and interfaces between these functions are defined to support this 'horizontal' split. In this architecture a provider can focus on a certain layer of the system, e.g. a roadside communication network, rather than focusing on end-user applications, which would require implementations of all parts of the system. The project leaves options open on the roles of the road operator, i.e. as responsible for law-enforcement and safety-related information distribution to road users.

4.3 Project ITS corridor

4.3.1 Description of project

The NL-DE-AT ITS Corridor was started on 10 June 2013 when the ministers representing Germany, Austria and the Netherlands signed the Memorandum of Understanding. The goal of the project is the implementation of future-oriented cooperative ITS services via

- A joint road map for the introduction of the initial cooperative ITS services
- Common functional descriptions of the initial cooperative ITS services and technical specifications
- Start of the actual implementation of the initial cooperative ITS services

The two initial services within ITS corridor are Road Works Warning and Probe Vehicle Data.

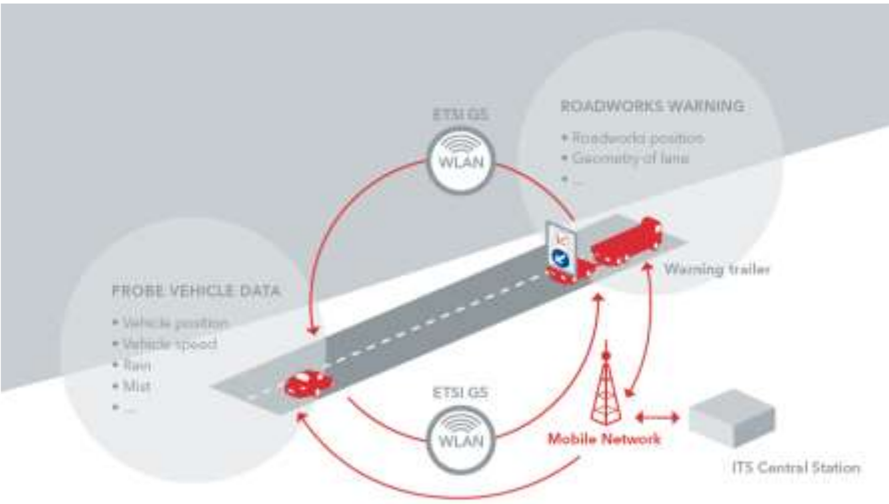

Figure 4-4 ITS applications in NL-DE-AT ITS Corridor project

4.3.2 Implementation architecture of the Austrian part, the ECo-AT project

The project of Austria in ITS Corridor is named the European Corridor - Austrian Testbed for Cooperative Systems (ECo-AT) project [29] and this project has released several releases of specifications on system definition (WP2), i.e. use case descriptions of the Amsterdam group Day-1 applications and a high-level system overview. The main applications are Road Works Warning and Probe Vehicle Data.

In the use case descriptions of ECo-AT the following ITS applications are described in detail:

1. Road Works Warning (RWW) [30]: several implementation options are described for both ad-hoc/short-term and long-term road works and the type of RSU systems used with trailers that are controlled with/without back-office integration. A 'profile' is defined based on the ETSI DENM specification;

2. Probe Vehicle Data (PVD) [31]: information from vehicles with CAM broadcast is collected by a RSU and - via CAM aggregation – send from RIS to CIS. The aggregation is performed by the RSU and identical to the current traffic information collection via existing loops. Additional information on e.g. individual vehicle information on position/speed is e.g. not forwarded in the current specification.
3. Intersection Safety (ISS) [32]: three use cases on intersection safety are described i.e. (i) vehicle speed optimization approaching an intersection based on signal status, (ii) fast pre-emption of traffic due to traffic light signal change (red to green) and (iii) red light violation
4. In-Vehicle Information [33]: information on dynamic and static signals is send via ETSI IVI messages, based on ISO/TS19321. The specification also describes the Austrian specific implementation to distribute the IVI information to external parties;
5. Other Road Hazard Warnings (other DENM [34]): existing road hazard warnings that are distributed today via digital audio broadcast radio (RDS-TMC) are also distributed from TCC via CIS and RIS to vehicles. The main DATEX-II codes used today for road hazard warnings are mapped to DENM codes.

Other specifications on e.g. roles & responsibilities, security architecture and convergence strategy for ITS-G5 and cellular) and detailed descriptions with functional requirements for all individual system components (TCC, RSU, OBU, security) will be

In the system overview [35] the high-level architecture is defined and shown in Figure 4-5

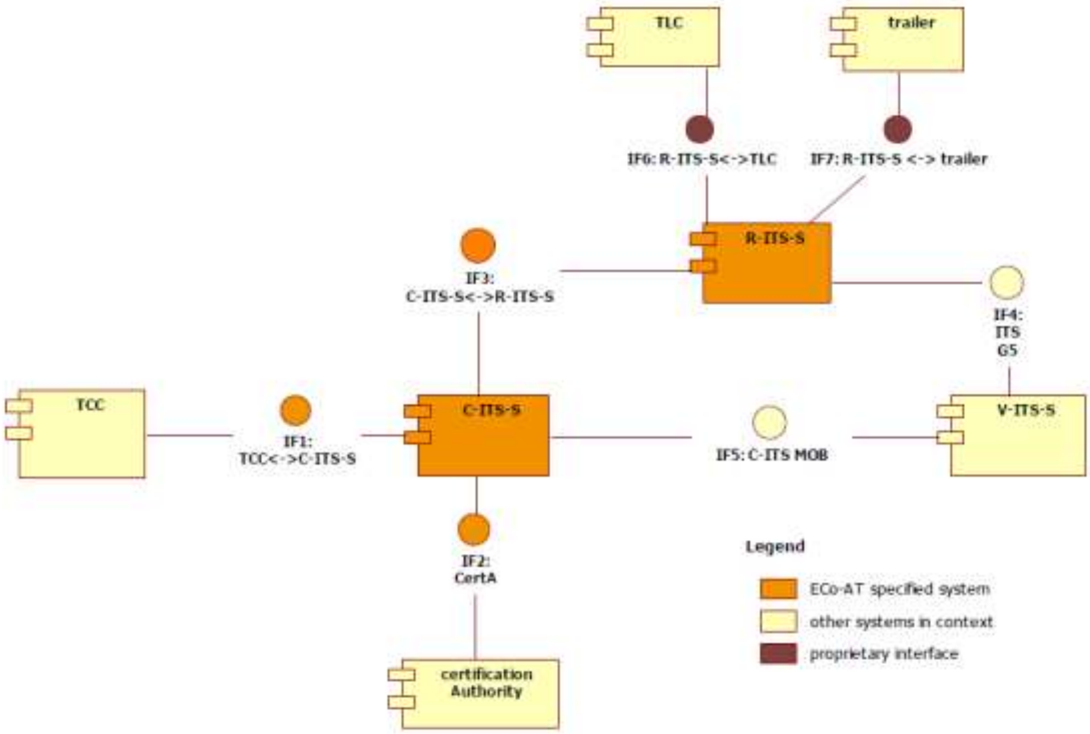

Figure 4-5 High-level Architecture ECo-AT project [35].

A road works vehicle can also send CAM (special vehicle) or DENM messages (stopped vehicle, slow vehicle) to approaching vehicles, but this is not included in the ECo-AT specification today.

4.3.3 Implementation architecture of Dutch part, the ECo-NL project

The Dutch project team of the European Corridor-NL project (ECo-NL) described a similar system architecture, as shown below

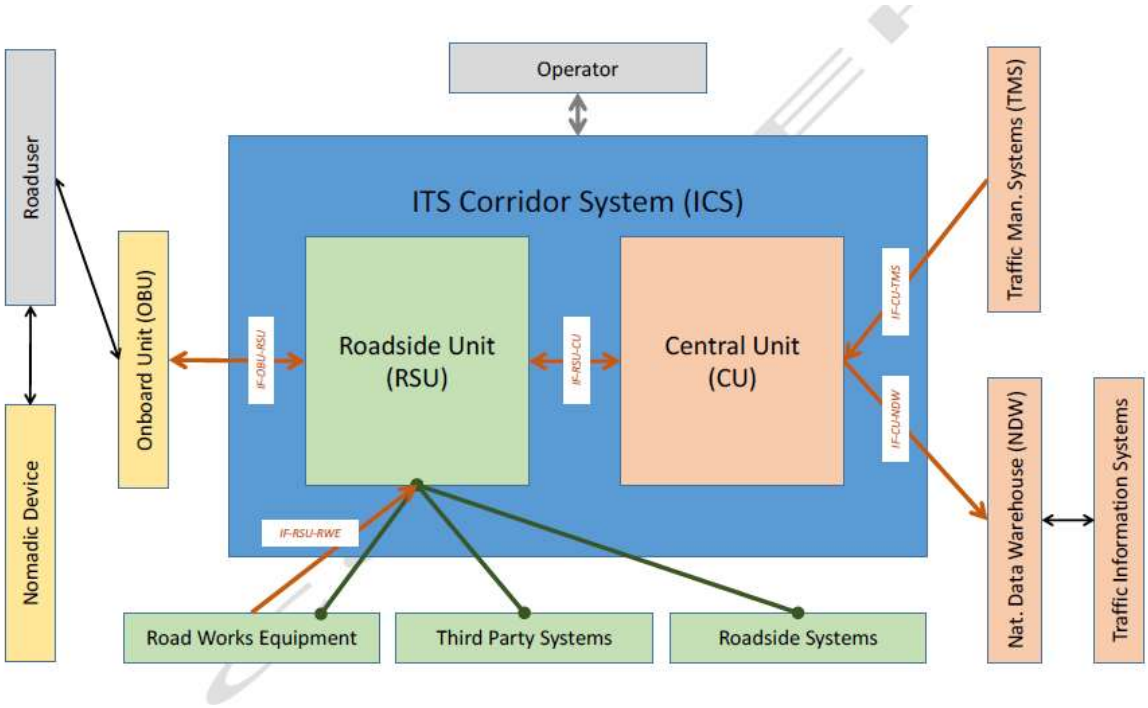

Figure 4-6 System diagram of ECo-NL with main components and interfaces. The ITS Corridor System (ICS) is shown in the blue box, with 4 external interfaces, and one internal interface between CU and RSU.

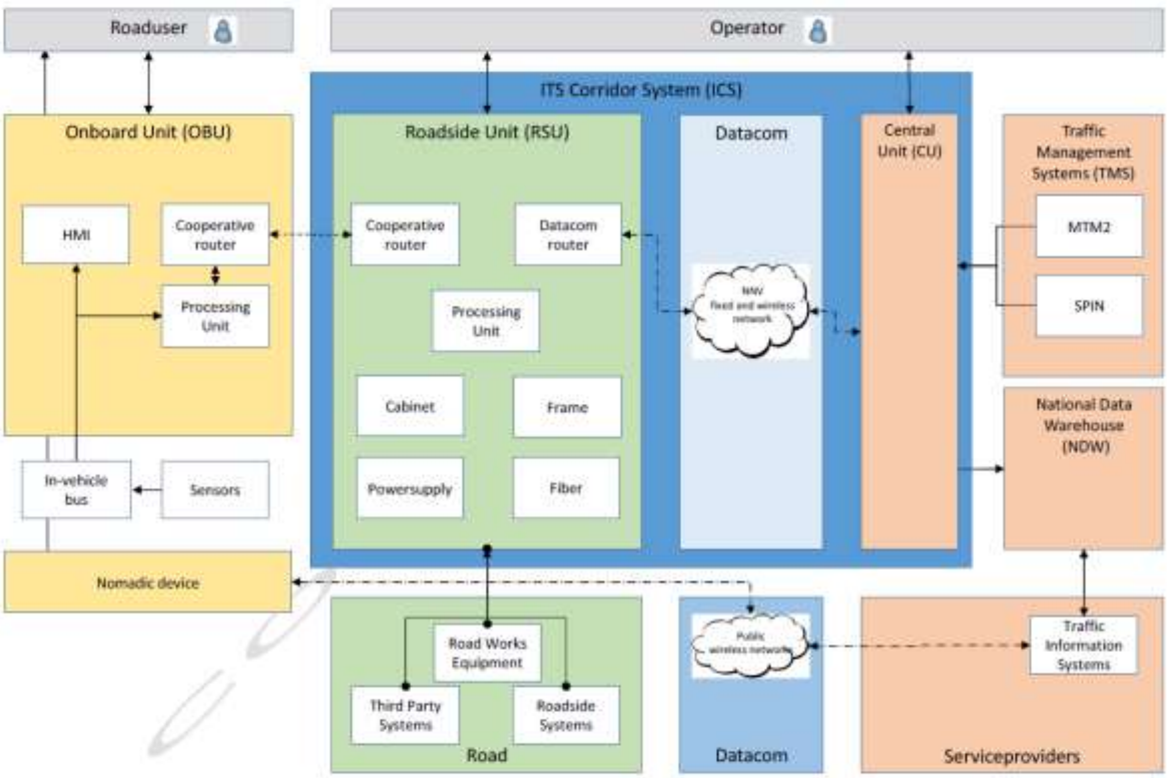

Figure 4-7 System diagram of ECo-NL with functional elements

4.3.4 Comparison of ECo-AT and ECo-NL and mapping of reference architecture to implementation architecture

In this section the architectures of the European Corridor projects of Austria (European Corridor, Austrian project (ECo-AT)) and the Netherlands (European Corridor, NL project (ECo-NL)) are compared and a translation is made to the reference architecture as described in section 2.

The interfaces of the two sub-projects are mapped in the following table, and compared to the Reference Architecture.

Table 2 Mapping of interfaces between ECo-AT and ECo-NL and with the Reference Architecture

IF1 TCC<->C-ITS-S	IF-CU-TMS	via CC3 (TIS<->CP BO) and CC1 (TMS <-> TIS)
IF2 CertA	<not described>	< not in scope, part of security architecture >
IF3 C-ITS-S<->R-ITS-S	IF-RSU-CU	RC1 (CP BO <-> RS)
IF4 ITS-G5	IF-OBU-RSU	VR1 (RSU <-> OBU)
IF5 C-ITS MOB	Via IF-CU-NDW	CC4 (TIS <-> SP BO) + VC1 (SP BO <-> OBU)
IF6 R-ITS-S<->TLC	<not described>	RR1 (RSU <-> RS)
IF7 R-ITS-S<->trailer	IF-RSU-RWE	RR1 (RSU <-> RS)
<not described>	IF-CU-NDW	CC1 (TMS <-> TIS)

The main observations from the mapping in Table 2 and a comparison of the implementation architectures in Figure 4-5 and Figure 4-6 are:

- Both projects make use of a central and roadside ITS station; the interface between CIS and RIS is defined but the detailed specification is under development;
    - **Recommendation**: the interface between RIS and CIS is not defined today. The different approaches of projects like A58, Converge, ECo-AT and ECo-NL should be evaluated to find the appropriate solution for centralized deployment. Special attention should be paid to the fact that the ITS-G5 communication network should be open for more than one providers, i.e. multiple road operators and/or service providers;
- Both projects have a direct interface between Traffic Control Center (TCC) of Traffic Management System;
    - **Recommendation**: it is recommended to include a Traffic Information System as explicit element in the ECo-NL architecture. This element should be positioned between TMS/TCC and communication elements like CIS and RIS. The TIS should have a central function to translate information from the traffic management system to a specific data format (DATEX-II, TPEG, DENM) and have an interface to the own communication elements CIS/RIS or to provider(s) of specific networks (mobile, RDS/DAB and or ITS-G5);
- The scope of the ECo-AT project is broader, with – besides Road Works Warning – also additional Road Hazard Warnings (based on the their existing information system). This approach gives ECo-AT the option to send similar information over different channels. In ECo-AT also other ITS applications are in scope, including In Vehicle Information and Intersection Safety. For this last application local integration between TLC and RIS is foreseen;
    - **Recommendation**: it should be considered to in ECo-NL to use a similar approach as ECo-AT, i.e. to build a solution that is directly suited for other Road Hazard Warnings, other than RWW. This will prevent that a single solution for RWW is created.
- Both projects have foreseen a **local** integration of RIS with either TLC (ECo-AT) or with trailer (ECo-AT) or Roadworks Equipment (ECO-NL);
    - **Recommendation**: it should be considered in ECo-NL to enclose the information from TLC, trailer or road works equipment via a central system to TIS and/or NDW
- The road works layouts – as defined in The Netherlands in CROW96a [REF] – and the chosen approach to translate all relevant information to one or a limited number of DENM messages shows both the complexity of this application and the limitations of the DENM message type. The information on (i) the change in road layout, (ii) other traffic signs (speed limits, closed lanes, narrow lanes) and (iii) the location of the road works are translated in one or several DENM messages.
    - **Recommendation**: it is recommended to use the ITS-G5 message should be used for I2V, i.e. topology information via MAP, In Vehicle Signage via IVI, TLC info via SPAT,

and only **Decentralized** Environmental Notification message for basic road hazard signalling e.g. a trailer blocking a lane.

In Figure 4-8 the ECo-NL architecture is described with the terminology of the Reference Architecture, as presented in chapter 2.

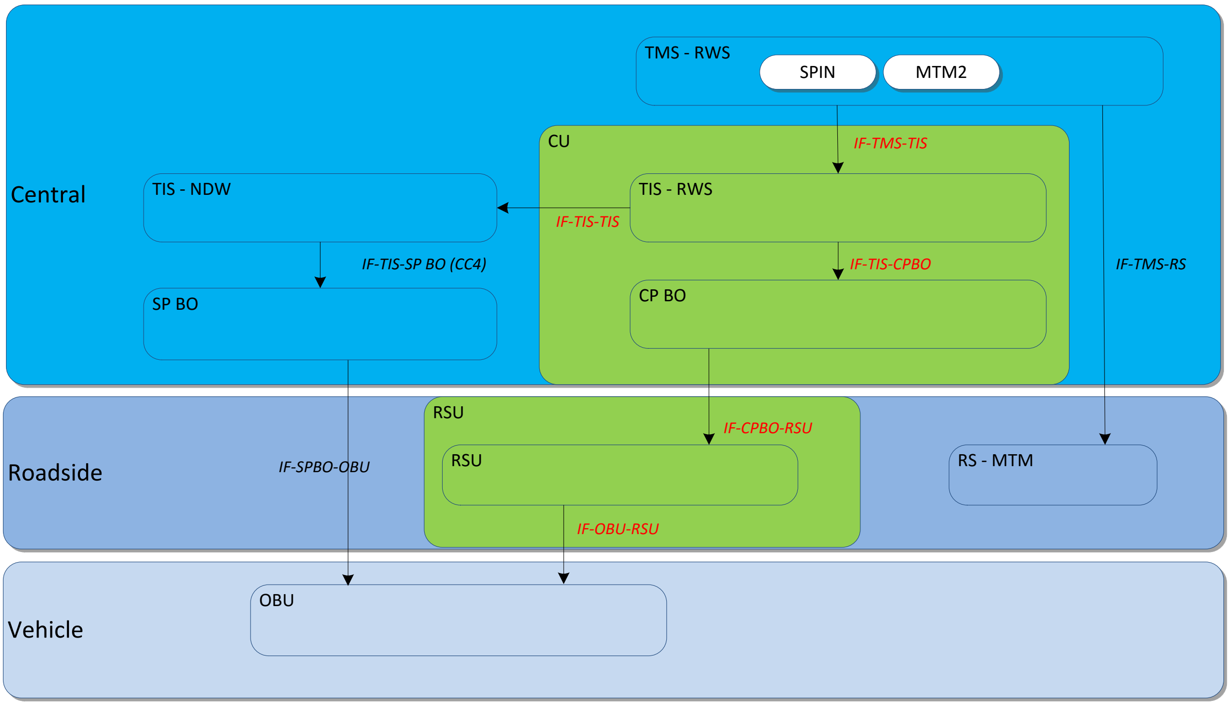

Figure 4-8 ECo-NL architecture described with the terminology of the Reference Architecture

The main adjustments are:

- The CU in Figure 4-6 of ECo-NL is split in a TIS system and a CP BO; in this way information from TMS is distributed via a TIS to e.g. other Service Providers and/or road operators via NDW and to ITS-G5 networks via a CP BO; In this way the interface options to the CP BO as defined in A58 can be reused by RWS in ECo-NL project, i.e. interface D1, D10 and D11;
- The TIS RWS is connected to TIS NDW; in this way similar information can be distributed via multiple networks/channels. An evaluation of the different message formats and location referencing methods (absolute via WGS84, or relative via e.g. OpenLR) should be reviewed.
- Note that the MTM information on dynamic traffic signs is already distributed by RWS via a push/pull web service, and used in PPA and A58 project; A specification can be found in [REF H Interface A58].

4.4 Project iTLC (*iVRI*)

The iTLC project (or iVRI in Dutch) is part of the program Beter Benutten [15]. The scope of the project is to provide ITS solutions for specific issues in the 12 regions (cities, city areas) involved in Beter Benutten. The scope of the iTLC project is define an architecture to enclose information of the existing legacy TLC systems in The Netherlands to support different value propositions. The information can be enclosed both at a local scale e.g. to send status information of TLC to nearby road users (via RIS with ITS-G5) and at a central level via TMS for network control of TLC's by external applications or to enclose sensor information. Examples of the value propositions in scope in the iTLC architecture project:

1. Value propositions for travellers (**up**), e.g. time to green
2. Value propositions about travellers (**down**), e.g. information for service providers with information for route optimisation

3. Value propositions with input for other business cases (**in**), e.g. support for priority services for OV
4. Value propositions with output to other revenue drivers (**out**), e.g. advertisements
5. Value propositions with external cost reduction (**cost**), e.g. reduction of loops.

In a first step the use cases were mapped in a functional “menu card” for grouping and for assessment on value-of-use and complexity. The use cases were grouped on several items:

- Use cases: several use cases are used to define and evaluate the iVRI architecture. ITS use cases on traffic light control are also in scope. Use cases are grouped in three areas:
    - Information: e.g. time to green, time to red (both status info (actual (t=0) and forecast (t=60))
    - Optimization: e.g. gap measurement, cooperative green wave
    - Prioritization: e.g. green extension heavy goods vehicles, conditional priority for public transport
- Road users: public transport, emergency vehicles, heavy transport, car, bicycle, pedestrian
- Scale of application: local, trajectory, network
- Type of TLC control: static, semi-static, dynamic per vehicle, dynamic for network
- Goal: safety, traffic flow, environment, comfort

The following preconditions were defined for the iTLC architecture:

- Business model: the architecture should support several business models e.g. an open market for C-ITS applications; split between infrastructure and C-ITS applications;
- Responsibilities: the responsibility for system integration should be clear, both from business and technical perspective;
- Relevant interfaces need to be defined, and reference to updates of standards.

Several constraints were also used to define the iTLC architecture e.g.

- Technical capabilities of the installed base TLCs;
- Architecture description must comply with applicable international and national standards (for example as published by ETSI, CEN/NEN and ISO);
- The iTLC still has to comply to all the existing national and international standards like NEN3384, EN12675 and HD638 etc.

The following architecture principles are used:

1. TLC is the responsible element for local steering of signal groups of the traffic lights
2. The C-ITS elements comply to the ETSI ITSC reference architecture
3. ITS applications have both access to the TLC and RIS ‘facilities’
4. Open standards and protocols are applied when possible / applicable
5. Access to RIS ‘facility’ is independent of access to TLC ‘facilities’ and vice versa
6. Interfaces to TLC and RIS should be generic to support international acceptance

The high-level architecture in [36] is described in different views. In Figure 4-9 the *context view* of the iTLC system is shown and in Figure 4-10 the *functional view*, with the intelligent TLC components shown in green and the blue components are (existing) external systems. Other views are e.g. deployment views, information views etc.

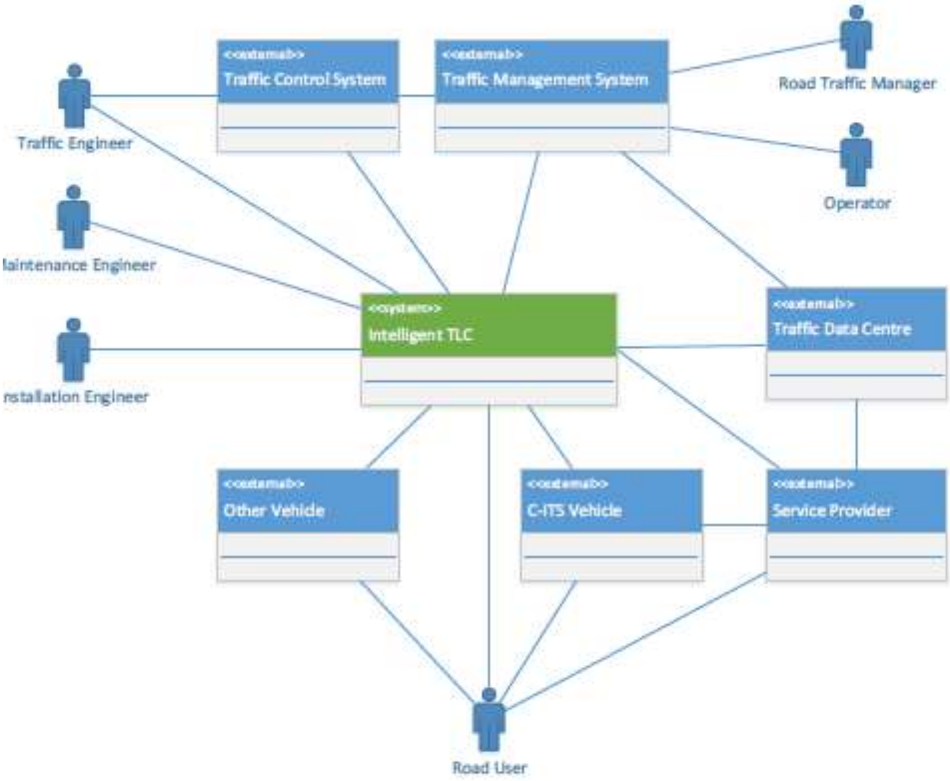

Figure 4-9 iTLC context view on architecture: the iTLC is the new system with interaction to external, existing systems like Traffic Control System, Traffic Management System and C-ITS Vehicle (from [36]).

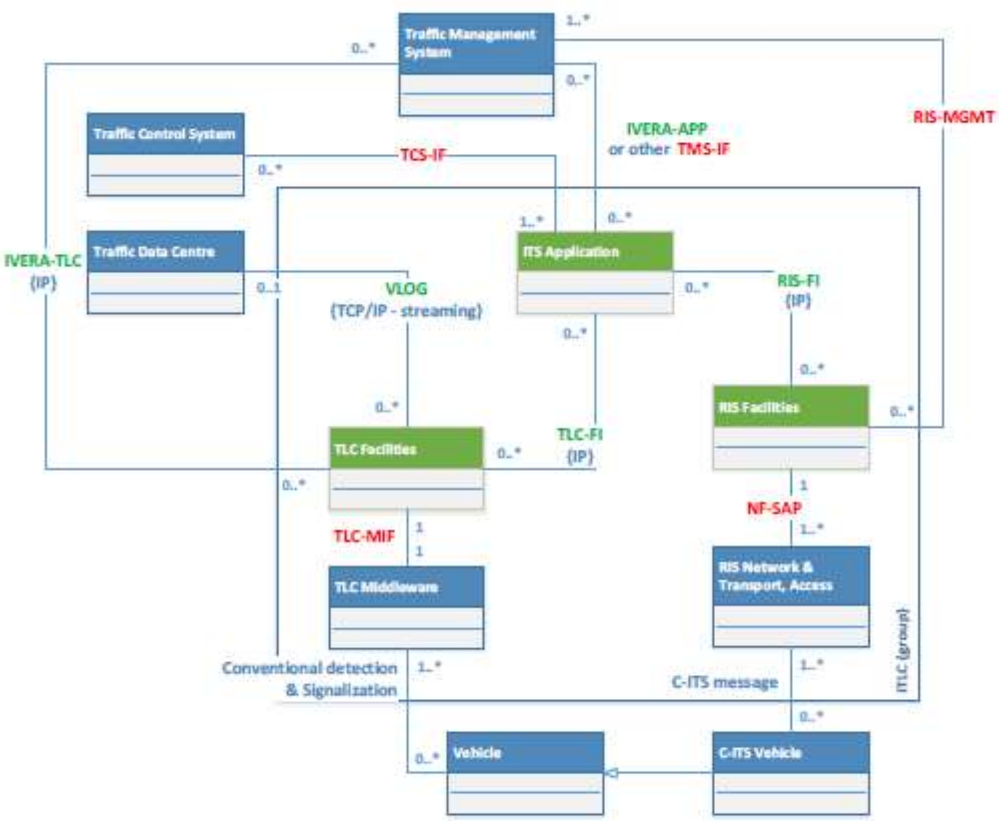

Figure 4-10 Functional view of iTLC high level architecture, with in green the iTLC functional components and in blue the external components. The interfaces in GREEN are developed in the iTLC project, the RED interfaces are out of scope (from [36]) .

The functional view of iTLC architecture as shown in Figure 4-10 shows a split in ITS application and TLC and RIS facilities. The interfaces to/from the iTLC elements are all based on IP communications (except for the C-ITS messages between RIS and VIS, via ad-hoc ITS-G5). This split enables a distributed architecture, i.e. functions and/or applications can be implemented on distributed systems by different roles. The use of the specified open interfaces like TLC-FI and RIS-FI allow for a flexible deployment architecture, with ITS application either in a roadside system (TLC, RIS) or in a central system. The interfaces also allow for a multi-vendor approach, with e.g. different vendors for (i) Traffic Control / Management System, (ii) TLC and (iii) RIS.

An overview of the interfaces is given in the following table, with a reference to (de-facto) standards:

Name	From	To	iVRI reference	Reference/standard
RIS-FI	ITS application	RIS Facilities	IRSIDD G1a+G1b	iTLC project
TLC-FI	ITS application	TLC Facilities	IRSIDD G2	iTLC project
IVERA-TLC	TMS	TLC Facilities	IRSIDD G3	IVERA 4.00
IVERA-APP	TMS	ITS application	IRSIDD G3	IVERA 4.00
VLOG	TDC	TLC Facilities	IRSIDD xx	VLOG v3
TCS-IF	TCC	ITS application	Not applicable	Proprietary
TMS-IF	TMS	ITS application	Not applicable	Proprietary
RS-MGMT	TMS	RIS Facilities	Not applicable	Proprietary
TLC-MIF	TLC Facilities	TLC Middleware	Not applicable	Proprietary
NF-SAP	RIS Facilities	RIS N&T	Not applicable	Proprietary

The new functionality in the iTLC architecture is:

- Sensor and actuator data of a TLC is real-time enclosed via an update of the VLOG protocol to support streaming information on loop data and on TLC status info; the information can be enclosed local in the TLC to a ITS application or central to a ITS application with a TMS or TCS;
- External applications can be developed to control TLC's via an interface between TLC Facilities and ITS Application, via TLC-FI interface. The ITS application can be either be integrated with a Traffic Control System, (via TCS-IF interface) a Traffic Management System (via IVERA-APP interface) or with a local TLC or RIS. The actual deployment will depend on ;
- RIS facilities are added locally (i.e. close to the TLC) to communicate with C-ITS vehicles for iTLC applications. The RIS facilities can be enclosed in a similar way as described in

The main observations on the iTLC architecture are:

- The iTLC architecture is flexible and allows for multi-vendor implementations for (i) TCS/TMS/TDC, (ii) TLC and (iii) RIS, with different deployment models for new ITS applications. This is made possible via the split in ITS application one side and RIS and TLC facilities on the other side. (Note: to support a multi-vendor implementations, the RIS-MGMT interface should be to another external system, not an existing TMS, but a new system);
- Support of new ITS applications for TLCs with integration with (existing) central TMS/TCS systems is defined via updates of existing de-facto Dutch standards like IVERA, VLOG and CVN-C, or via proprietary solutions (see TMS-IF, TCS-IF);
- In the Spookfiles A58 project the RIS is enclosed via the Facilities layer for DENM and TSM type of messages. In the iTLC project additional message services for SPaT, MAP and IVI are included. However, another interface to the Facilities is used, i.e. the LDM interface, for the distribution (transmit/receive) of messages, different from the Spookfiles A58. CAM messages are not directly available via the RIS-FI interface (see IRSIDD_RISFI_LDM_G5_002 in [36]), which is also different from A58, where both raw (micro-data) and aggregated (macro-data) are available.

4.5 Project Praktijkproef Amsterdam (PPA)

In the PPA Roadside project (*PPA Wegkant Fase 1*), the application *coordinated traffic management* is implemented [37] in which (raw) traffic state data from the road operators (both TLC status info, TLC loop data, and highway loop data (from MTM)) is used to realize coordinated traffic management (in a Coordination TMS, or C-TMS) between Rijkswaterstaat (HWN, highway A10) and the City of Amsterdam (SWN, i.e. S-roads). The main functionalities of the C-TMS are monitoring and controlling.

Monitoring: for monitoring several data sources are used to collect information on the traffic state on highway and S-roads (e.g. loops, TLC status). The information is used in monitor blocks, i.e. algorithms that can estimate e.g. congestion:

- Potential congestion estimator (*Kiemenspeurder HWN*)
- Traffic jam estimator (*Fileschatter HWN*) at the high-way A10,
- Queue length estimator (*Wachtrijschatter SWN*) and
- Buffer capacity (*Bufferruimte SWN*) on urban roads (*SWN*).

Controlling: In addition there is control on the high-way ramp meters (*TDI=Toerit Dosseer Installatie*) and traffic light controllers (*VRIs*) based on the control info from the supervisor algorithms (*Supervisor HWN/SWN*) of the high-way A10 and urban roads S10x connected to the A10. Information from the C-TMS is exchanged to the TMS of the public road operators, i.e. Rijkswaterstaat and the City of Amsterdam via DVM-Exchange, in which scenario management.

Several interface specifications are realized between roadside systems like TLC, and central systems like TMS and TIS systems, and can be retrieved from the PPA project. The interfaces are based on existing (defacto) standards like VLOG for TLC and made for the project, based on widely used Internet protocols like JSON, SOAP, XML, etc.

PPP In-car had its focus on solutions with connected cars to monitor traffic and to advise drivers, before and during a trip, during peak hours and during events.

In phase 2 the two parts (Roadside and In-Car) of the projects will be further integrated, e.g. to see if additional information sources (e.g. Floating Car Data from connected cars, or information form parking systems or events) can be used to improve the algorithms in the C-TMS, and if information on actuation can be used to inform drivers in connected cars.

5 Conclusions and outlook

In this document, the reference architecture for C-ITS in the Netherlands is presented. It is the 2015 **update** of the architecture for Cooperative - Intelligent Transport System (C-ITS) applications in the Netherlands [1]. The update is based on deliverables published in 2015 from selected projects and expert group meetings on specific subjects for the "ITS round table" meetings on Architecture and on Standardization / Dutch Profile, held between June 2015 and December 2015.

In addition to the reference architecture itself, also two implementation architectures for two typical Dutch contexts are provided.
The round table meetings will continue in 2016, to facility information exchange between different implementation projects and stakeholders. To improve the link between the architecture itself and the system specifications as developed in the Dutch profile, in the context of the Standardization table, it has been decided that the meetings of the Architecture table and Standardization table will be combined.

Several subjects have been identified based on (new) Dutch projects and international developments that could be relevant to be worked out in more detail in the coming year. The current architecture already foresees a hybrid communication infrastructure, containing both ITS-G5 and cellular networks. However, the communication and information infrastructure is only worked out in detail for the ITS-G5 network, since this is work-in-progress, whereas the ITS solutions based on cellular networks are already widely adopted, and have a focus on enclosure of real-time open data sources via API, via standardized or specified information formats. However, new developments in cellular networks (LTE Direct for V2X, LTE Broadcast) and an increased interest from the automotive industry to also use cellular networks for traffic and safety related applications in 'connected car' services, it might be useful to detail also the cellular communication in more detail, especially the central and in-car interfaces. The ETSI ITS framework is in theory network agnostic, but it still requires strong involvement of the automotive industry, mobile network operators and road operators to get support for message exchange of the ETSI ITS framework via cellular networks, especially via broadcast. Today, there is no direct need to distribute information via cellular networks for I2V applications, since a direct interaction from any SP to any end-user is possible, resulting in maximum freedom for end-users to choose an SP and for SPs to offer attractive services which are differentiating from other SPs.

The information exchange between road operators, and between road operators and information providers is only worked out at the highest level of abstraction. More work has already been done, e.g. in the PPA projects, which is relevant to be integrated in the reference architecture. A subject related to this, is functionality that is required for stakeholders to be able to find relevant information from other stakeholders in a more easy and more automated way. Although this is in general not an issue for a specific implementation project, this will become an issue for large-scale deployment. Different solutions have been developed already, e.g. by using a single, well-known aggregation point (e.g. NDW), or by using a service registry that contains all relevant business and technical information to be able to obtain the actual information (e.g. as worked out in detail in the Mobinet project).

The reference architecture will be used as a basis for new implementation projects. Vice versa, it is expected that results from these projects will be fed back into the reference architecture. Relevant projects for 2016 are at least the projects from the Beter Benuttten program, from PPA, and C-ITS-corridor.

6 Appendix A – Details on System Architecture

The information in this Appendix is taken from [1] and included in this document for reading convenience. The full text and the full set of sequence diagrams can be found in [1] and [8].

6.1 ITS applications in scope of system architecture

The following projects were selected in 2014 for the architecture:

- *Shockwave Traffic Jams A58* - deployment project of Dutch program *Beter Benutten*. This project is selected to verify that the public-private market roles and the corresponding systems and interfaces developed by market companies are supported in the architecture;
- *Praktijkproef Amsterdam* [7] – deployment project of Dutch program Connecting Mobility. This project is also selected to verify that the public-private market roles and the corresponding systems and interfaces are supported in the architecture;
- *ITS Corridor* – deployment project from Amsterdam Group [23]. This project is selected to verify how a first European deployment of a cooperative roadside network between three European countries (Austria, Germany and the Netherlands) can be supported in the architecture;
- *Converge* [9] – a German funded project on an open platform for multiple service providers and communication providers. This project is selected to verify that the Converge concepts and elements to support flexible interaction between multiple service providers and mobile end-user nodes are supported in a centralized, scalable structure via multiple hybrid communication network providers, both ITS-G5 as other mobile (broadcast) networks;
- *MOBiNET* [10] - EU FP7 funded project on an e-Market place for tradable ITS services throughout Europe. This project is selected to verify that the MOBiNET concepts and elements to support an e-Market place for C-ITS applications are feasible in the architecture;
- *VRUITS* [11] – EU FP7 funded project (April 2013 – March 2016) on ITS applications for vulnerable road users like pedestrians and cyclists. This project is selected to extend the architecture with ITS applications for vulnerable road users, like pedestrians, cyclists and drivers of powered two-wheel vehicles;
- *DITCM 1.0 architecture* – this project is selected for the cooperative ITS applications and corresponding architecture.

In these projects the following ITS applications were in scope:

6.1.1 V2V applications

In these applications direct V2V communication is used. A description of each application and examples of sequence diagrams of these applications are described in [ARC14].

Application	Project
1. Hazardous Location Warning	DITCM 1.0
2. Emergency Brake Light Warning	DITCM 1.0
3. Slow Vehicle Warning	DITCM 1.0
4. Cooperative Adaptive Cruise Control	DITCM 1.0

6.1.1.1 *Example of sequence diagram: Emergency Brake Light Warning (EBLW)*

In the Figure 6-1 an example is given of a sequence diagram with information exchange via cooperative networks (i.e. ad-hoc networks with roadside infrastructure, ITS-G5).

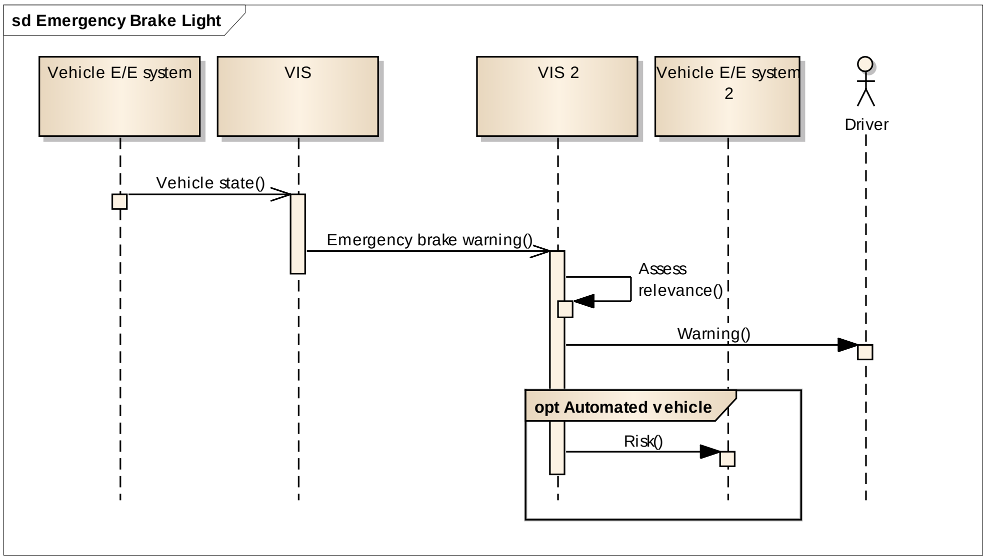

Figure 6-1 Sequence diagram for Emergency Brake Light

6.1.2 I2V applications

In these applications information is exchanged from infrastructure to vehicles via I2V communication. A description of each application and examples of sequence diagrams of these applications are described in [ARC14].

Application	Project(s)
1. Incident Warning[3]	DITCM 1.0
2. Road Works Warning	ITS Corridor, DITCM 1.0
3. Traffic Jam Ahead Warning	A58
4. Red Light Violation Warning	DITCM 1.0
5. In Vehicle Signage	ITS Corridor, DITCM 1.0
6. Merging Assistant (for CACC)	DITCM 1.0
7. Shockwave Damping (via Adaptive Speed Advice)	A58, DITCM 1.0
8. Green Light Optimal Speed Advice	MOBiNET, DITCM 1.0
9. Green Wave (via Speed Advice)	DITCM 1.0
10. Stopping Behaviour Optimization	DITCM 1.0
11. Pay How You Drive	MOBiNET, DITCM 1.0
12. Navigation related applications:	
a. Rerouting / Smart routing / Traffic Information	A58, PPA, DITCM 1.0
b. Intermodal Route Planner	MOBiNET, DITCM 1.0
c. Eco Route Planner	DITCM 1.0
d. EV Charging Point Planner	DITCM 1.0
e. Smart Parking Assistant	PPA, DITCM 1.0

6.1.2.1 *Example of sequence diagram: Road Works Warning (RWW)*

In Figure 6-2 and Figure 6-3 examples are given of sequence diagrams, with information exchange via connected (i.e. mobile networks, 3G/4G) and cooperative (i.e. ad-hoc networks with roadside infrastructure, ITS-G5).

[3] Incident Warning is a local real-time warning for drivers. Incident Information is global information service and is mostly part of Traffic Information Services (with traffic jams, predicted travel times, road works, etc.).

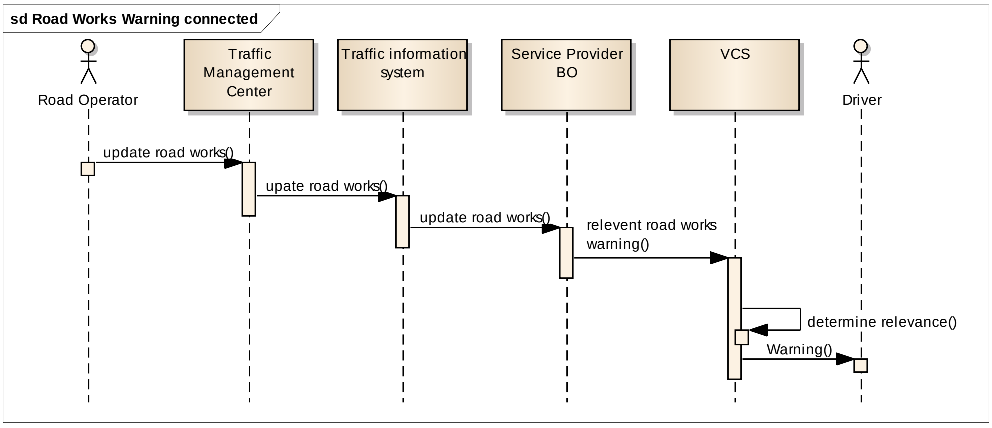

Figure 6-2 Sequence diagram for road works warning / information via connected communication

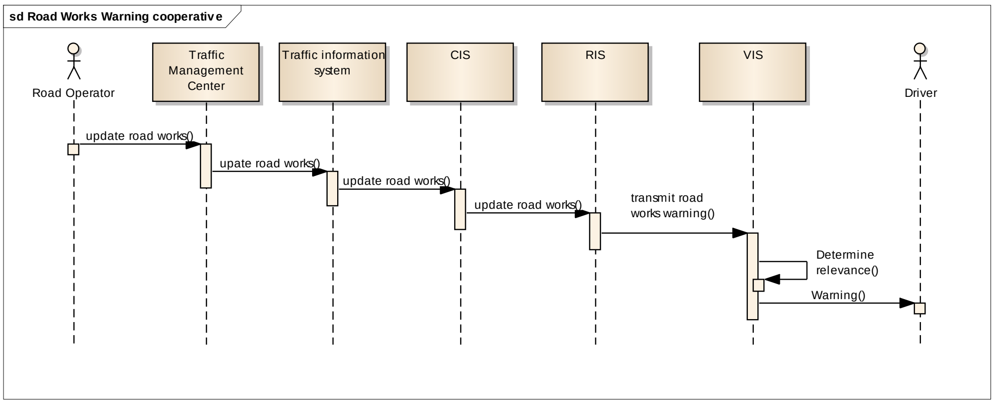

Figure 6-3 Sequence diagram Road works warning via cooperative communication

6.1.3 V2I applications

In these applications information is exchanged from vehicle back to the infrastructure via V2I communication. A description of each application and examples of sequence diagrams of these applications are described in [1]

Application	Project
1. Probe Vehicle Data from cooperative cars	A58, ITS-Cor., DITCM 1.0
2. Probe Vehicle Data from connected cars	A58, PPA
3. Priority Request	DITCM 1.0

6.1.3.1 Example of sequence diagram for Probe Vehicle Data

In Figure 6-4 and Figure 6-5 examples are given of sequence diagrams, with information exchange via connected (i.e. mobile networks, 3G/4G) and cooperative (i.e. ad-hoc networks with roadside infrastructure, ITS-G5)

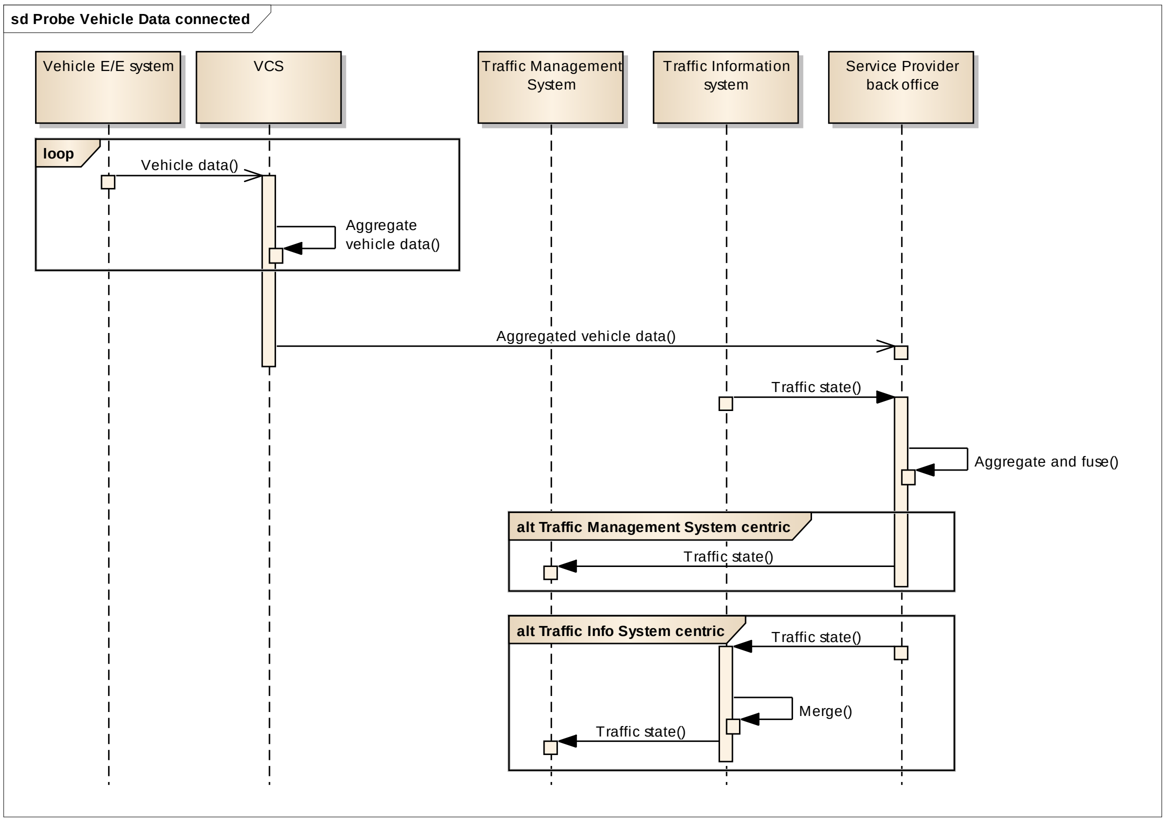

Figure 6-4 Sequence diagram for Probe Vehicle Data from connected cars

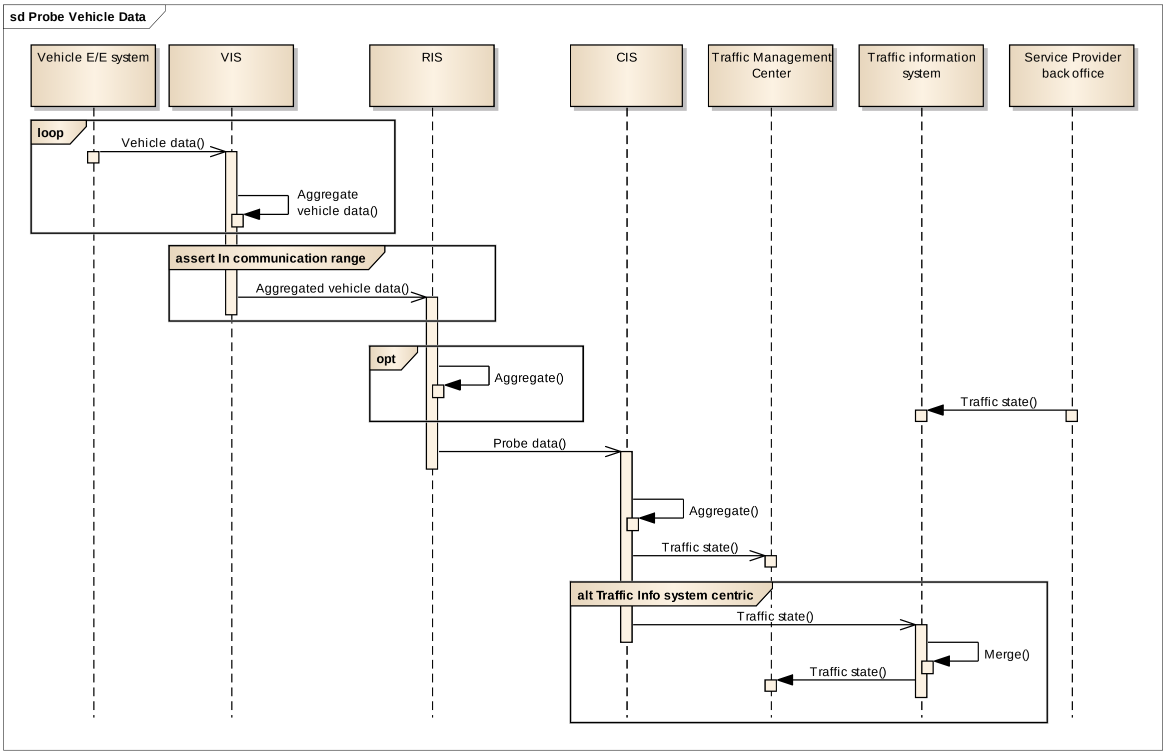

Figure 6-5 Sequence diagram for Probe Vehicle Data from cooperative cars (A58, PPA)

6.1.4 I2I applications

In these applications information is exchanged between back office systems via I2I communication. A description of each application and examples of sequence diagrams of these applications are described in [1].

Application	Project
1. Local Traffic State Data	A58
2. Local Traffic Control Data	A58
3. e-Market place for service providers	MOBiNET, Converge
4. Cooperative Message Distribution	A58
5. Coordinated Traffic Management	PPA roadside

6.1.5 VRU applications

Application	Project
1. Intelligent Pedestrians Traffic Signal	VRUITS
2. Intersection Safety for VRU's	VRUITS
3. VRU warning via VRU Beacon System	VRUITS
4. VRU warning via Cooperative VRU Detection	VRUITS

The applications and sequence diagrams from VRUITS are described in [38]. In [1] four selected applications are described based on the VRUITS D4.2 document [38]. All applications in the VRUITS project rely on localization of VRU's via (i) vehicle or roadside sensors (camera, radar, etc.), (ii) a tag-based communication system (VRU-T with V-VLS, or R-VLS) or (iii) VRU's with a PID or VRU-OBU capable for ITS-G5 and/or cellular communication. The solutions also differ in (i) the system that performs situation assessment (i.e. roadside, vehicle or VRU) and in (ii) the road users that are warned i.e. vehicle driver and/or VRU. Example of sequence diagram of the VRU application can be found in [1].

6.2 Building blocks in physical view

At the traveller / VRU layer the following sub-systems are defined:

1. *Personal Information Device (PID):* A personal information device is typically a smart phone or personal navigation device used by an end-user. The PID provides the capability for travellers to receive formatted traveller information wherever they are. Capabilities include traveller information, trip planning, and route guidance. It provides travellers with the capability to receive route planning from the infrastructure at home, at work, or on-route using personal devices that may be linked with connected vehicle on-board equipment. A PID might include the communication functionality of a Personal ITS station, as specified in ETSI ITS specifications;
2. *VRU Vehicle OBU (VRU-OBU):* an on-board unit is a sub-system attached to a VRU vehicle (e.g. moped, electric bike) and needed for VRU assisted applications to inform / advise a driver via a HMI;
3. *Remote VRU OBU (R-VRU-OBU)*: Remote VRU Vehicle OBUs represent other VRU vehicles that are communicating with the host VRU vehicle. The host VRU vehicle on-board unit, represented by the VRU-OBU physical object, sends information to, and receives information from the Remote Vehicle OBUs to model all VRU related V2V communications
4. *VRU Transponder (VRU-T):* a VRU transponder is part of a tag-based communication system. A transponder can be active (=with own battery, sending data at constant time intervals), semi-passive (with own battery, sending message at request of an interrogator) or passive tag/chip (without own battery, responding to interrogator request). The tags communicate with an external interrogator, called VRU Localisation System, which can be integrated in a vehicle (car, bus, truck) or in a roadside system:

- *Vehicle VRU Localization System (V-VLS):* A VRU Localization System is part of a tag-based communication system.
- *Roadside VRU Localization System (R-VLS):* A VRU Localization System is part of a tag-based communication system. The VRU transponder carried by a VRU, is an active (=with own battery) or passive tag/chip that can respond on an interrogation signal (trigger) from the VRU Localisation System. A VRU Localization System can be integrated in, e.g., a Traffic Light to detect the presence of a specific user, e.g. a person with a disability.

The VRU transponder carried by a VRU, is an active (i.e. with own battery) or passive tag/chip that can respond on an interrogation signal (trigger) from the VRU Localisation System. This transponder is different from a VRU OBU system, since the transponder is only able to send a limited amount of data (typically only ID and potentially some sensor values) and is not able of self-locating.

In the vehicle area the following sub-systems are defined:

1. *Vehicle Platform or Vehicle E/E system (VEE)*: The Vehicle Electrical and Electronic system (E/E) system includes all in-car sensors (speed, lights, etc.) and actuators (brake, etc.). The Vehicle Electrical and Electronic system provides sensor information (e.g. speed) from a vehicle to an external C-ITS system and optionally enables the control/actuation (e.g. speed control) of that vehicle by an external system. The Vehicle E/E must include safety measures to ensure the safe operation of the vehicle, independent of the interaction between the Vehicle E/E and external sub-systems. A further differentiation can be made per vehicle type, e.g. emergency vehicle, commercial vehicle or (public) transport/transit vehicle;
2. *Vehicle On-board Unit (OBU) or Vehicle ITS Station (VIS)*: An on-board unit is a sub-system attached to a car and needed for driver assisted applications to inform / advise a driver via a HMI. The OBU provides the vehicle-based processing, storage, and communications functions necessary to support connected vehicle operations. The radio(s) supporting V2V and V2I communications are a key component of the Vehicle OBU. Four different types of implementations are represented by the Vehicle OBU:
    a. Vehicle Awareness Device – This is an aftermarket electronic device, installed in a vehicle without connection to vehicle systems and is only capable of sending the basic safety message over short-range communications. Vehicle awareness devices do not generate warnings;
    b. Aftermarket Device – This is an aftermarket electronic device, installed in a vehicle, and capable of sending and receiving messages over a wireless communications link. The self-contained device includes GPS, runs connected vehicle applications, and includes an integrated driver interface that issues audible or visual warnings, alerts, and guidance to the driver of the vehicle;
    c. Retrofit Device – This is an electronic device installed in vehicles by an authorized service provider, at a service facility after the vehicle has completed the manufacturing process (retrofit). This type of device provides two-way communications and is connected to a vehicle data bus to integrate the device with other on-board systems. Depending on implementation, the device may include an integrated driver interface and GPS or integrate with modules on the vehicle bus that provides these services;
    d. Integrated System – This is a system of one or more electronic devices integrated into vehicles during vehicle production. The Integrated System is connected to proprietary data busses to share information with other on-board systems. The Integrated System may include many control modules.

    In retrofit and integrated implementations, the Vehicle OBU interfaces to other on-board systems through a vehicle bus (e.g., CAN), represented as the Vehicle Platform, this interface provides access to on-board sensors, monitoring and control systems, and information systems that support connected vehicle applications. The vehicle bus may also be the source for GPS location and time, and the access point for the vehicle's driver-vehicle interface. Self-contained devices include an integrated GPS and driver interface that supports direct visual, audible, or

haptic interaction with the driver. The Vehicle OBU includes the functions and interfaces that support connected vehicle applications for passenger cars and trucks. Many of these applications (e.g., V2V Safety applications) apply to all vehicle types including personal automobiles, commercial vehicles, emergency vehicles, transit vehicles, and maintenance vehicles. The Vehicle OBU is used to model the common interfaces and functions that apply to all of these vehicle types, i.e. also commercial, public transport or emergency vehicles;
3. *Remote Vehicle OBU (R-OBU)*: Remote Vehicle OBUs represents other vehicles that are communicating with the host vehicle. The host vehicle on-board unit, represented by the Vehicle OBU physical object, sends information to, and receives information from the Remote Vehicle OBUs to model all vehicle V2V communications.

In the roadside (or field) area the following sub-systems are defined:
1. *Roadside System (RS)*: Different types of existing roadside systems are identified:
    a. Roadside Substation (RSS): a system deployed along high-ways and includes sensors (loops), control logic and actuators. The system can run as a stand-alone closed loop system i.e. run stand-alone local traffic control functions (e.g. traffic jam tail detection and warning via Variable Message Signs) or can be controlled by the TMS;
    b. Traffic Light Controller (TLC): a TLC is a specific type of roadside system. It includes the input from loop detectors or other sensors, a control logic, and the actuation of the traffic lights. A TLC can be run as a stand-alone closed-loop traffic control system. A TLC can also be controlled by a central TMs, e.g. in green wave applications between different TLC's. A TLC is deployed on urban road or can be deployed at highway access roads for access control;
2. *Roadside Unit (RSU) or Roadside ITS System (RIS)*: A RSU/RIS is a cooperative roadside communication system responsible for the two-way communication functionality at a part of a road network (typically an intersection or a road section of 500m – 1km). This physical object is responsible for implementing communication functionality in the roadside layer and optionally also application functions. A RSU/RIS is included in the ITS reference architecture standardised by ETSI ITS. A RSU/RIS can be part of the roadside communication network with distributed radio units, and centralized functions in the Communication Provider Back-Office.

At the central layer the following sub-systems are defined:
1. *Traffic Management System (TMS)*: A TMS is the functional back-office system of the responsible road operator to enforce legal actions on urban or high-way road sections or intersections based on real-time traffic data from loops, cameras, speed sensors, etc. or actions by traffic controllers. The real-time data that flows from the Traffic Info System is integrated and processed by the TMS (e.g. for incident detection), and may result in traffic measures (e.g. traffic routing, dynamic speed limits) with the goal of improving safety and traffic flow;
2. *Traffic Information System (TIS)*[4]: A Traffic Information System is the functional back-office system of a road operator to collect and process real-time traffic data from traffic data systems (e.g. roadside sensor systems (loops, cameras) or connected vehicles) and to distribute real-time and/or aggregated information on traffic state (speed, flow and travel times) or road state to TMS or external systems like a SP BO. In practice several distributed TIS from different road operators can be interconnected to a central TIS (e.g. from NDW), which provides aggregated information for the Netherlands;
3. *Service Provider Back-Office (SP BO)*: A generic back-office system of a service provider used for the specific services of the SP to connected drivers or end-users to inform end users or other SP BO systems from providers. A SP BO can be used to support personal information services for, e.g. navigation or traffic information applications on OBU/PID. A SP BO can also be used to gather floating car data from OBU/PID;

[4] A split is made between TMS and TIS. A TMS receives traffic information always via a TIS, and sends traffic actuation measures always to external systems via a TIS. In real world a TMS consists of several building blocks for traffic control.

4. *Data Provider Back-Office (DP BO)*: A Data Provider BO system is a data system that collects and fuses floating car data and real-time traffic data from roadside sensor systems to increase insight in actual and expected traffic state (e.g. on traffic jams). The DS also distributes enriched (aggregated) information on traffic state (speed, flow and travel times) to service providers;
5. *Communication Provider Back-Office* (CP BO) or Central ITS System (CIS): A generic back-office system of a communication provider used for access at several communication layers from other BO systems (like SP BO, TMS, TIS etc.) to send and receive ITS information to/from vehicles or other road users;
6. *Service Provider Exchange System (SPES)*: an e-Market ('broker') system for discovery and exchange of ITS (end-user) services and ITS communication services; the SPES can support functions like service discovery, service authentication, authorization, accounting (AAA) and billing.

Other back-office systems can also be located at this layer depending on the type of application. One example is a Fleet and Freight Management System which provides the capability for commercial drivers and fleet-freight managers to receive real-time routing information and access databases containing vehicle and/or freight equipment locations as well as carrier, vehicle, freight equipment and driver information. Fleet and Freight Management Center also provides the capability for fleet managers to monitor the safety and security of their commercial vehicle drivers and fleet.

At the support layer the following sub-systems are defined:

1. *Governance system*: A system from policy makers for regulations & enforcement of the ITS system of environment / safety measures;
2. *Test and certification management system*: A system for registration of tested and certified communication systems for ITS (safety) applications;
3. *Security and credentials management system*: A high-level aggregate representation of the systems that enable trusted communications between mobile devices, roadside devices and centers, and protect data from unauthorized access. This sub-system will be implemented as an interconnected system of support applications that enable the secure distribution, use, and revocation of trust;
4. *Operational Management System*: A system for operational processes like fault, performance and configuration management of the sub-systems.

6.3 Building blocks in functional view

The main system functions of the sub-systems are: sensing, communication, situation monitoring and situation assessment, acting and trust management. The hierarchic decomposition of these functions is based on geometrical and temporal scale of information and information abstraction. Cardinality (multiple entities with the same functionality) of the system is supported and dependent on physical limitations of sensors and actuators and heterogeneity of goals;

Each sub-system contains one or more of the following generic functional components:

- *Sensing Support* includes the collection of information from in-vehicle or road-side sensors included in the physical objects;
- *Communication Support* enables secure, reliable communications with other connected devices. It provides the communication functions that add a timestamp, the message origin, and a digital signature in outbound messages and processes, verifies, and authenticates the same fields in inbound messages. It provides functionality to encrypt (outbound) and decrypt (inbound) sensitive data. Communication Support also includes information reception of formatted traffic advisories, road conditions, transit information, broadcast alerts, and other general traveller information broadcasts and presents the information to the traveller. The traveller information broadcasts are received by vehicle-attached or personal devices including personal computers and personal portable devices such as smart phones;

- *Situation monitoring and situation assessment* includes the processing of the information to determine a risk and to start actuation (e.g. a vehicle or road-side triggered event);
- *Acting Support* includes the option to present information to end-users via a HMI or to control in-vehicle (speed control) or road-side actuation systems (like variable message signs, traffic lights, etc.);
- *Trust Management* manages the certificates and associated keys that are used to sign, encrypt, decrypt, and authenticate messages. It communicates with the Security and Credentials Management System to maintain a current, valid set of security certificates and identifies, logs, and reports events that may indicate a threat to the Connected Vehicle Environment security.

Besides these *generic* components, application-specific support is also needed as the highest-level representation of the functionality required to execute a specific application, e.g. cooperative cruise control, rerouting, etc.

In Table 3 the functional components are listed that are required to support the ITS applications of Section 2. In the last column of Table 3 examples are given of (a group of) ITS applications that use the functional component.

Table 3 Functional components per sub-system

Layer	Sub-system	Functional component	Example of application
Vehicle	OBU	Vehicle V2V Safety	All V2V applications
		Vehicle Situation Monitoring	(Extended) Probe Vehicle Data
		Vehicle Roadside Information Reception	I2V applications with RSU
		Vehicle Traveller Information Reception	I2V applications with SP BO
		Vehicle Application Specific Support	CACC, Merging Assistant
Roadside	RSU	RSU Traffic Monitoring	V2I applications via V2V monitoring
		RSU Situation Monitoring	(Extended) Probe Vehicle Data
		RSU Vehicle Message Distribution	I2V applications with RSU
		RSU Application Specific Support	Priority Request, GLOSA
	RS	Roadway Traffic Monitoring	Incident Warning, Traffic Jam Ahead
		Roadway Traffic Control (e.g. via Variable Speed Limits or Signal Control status)	Shockwave Damping, GLOSA, In-Vehicle Signage
		Roadway Traffic Monitoring and Signal Control Distribution	Shockwave Damping, GLOSA, In-Vehicle Signage
Central	TMS	TMS Traffic Monitoring	Incident Warning, Traffic Jam Ahead
		TMS Traffic Control	Shockwave Damping, GLOSA
		TMS Traffic Information Distribution	Navigation related services
		TMS Application Specific Support	none
	SP/ DP/ TIS	BO Traffic Data Collection	(Extended) Probe Vehicle Data
		BO Traffic Information Distribution	Navigation related services
		BO Traveller Information Distribution	Navigation related services
		BO Application Specific Support	Smart Parking
	CP	BO Traffic Data Collection (from RSU Traffic and situation monitoring)	V2I applications with RSU
		BO Vehicle Message Distribution	I2V applications with RSU

Traveller	PID	Personal Pedestrian and Cyclist Safety	All VRU applications
		Personal Application Specific Support	Navigation related applications

6.3.1.1 Functional components at the Vehicle

The OBU / RV-OBU contain the following functional components:

1. *Vehicle V2V Safety* is the functionality to exchange current vehicle location and motion information with other vehicles in the vicinity. The information is used to calculate vehicle paths, and warns the driver when the potential for an impending collision is detected. If available, map data is used to filter and interpret the relative location and motion of vehicles in the vicinity. Information from on-board sensors (e.g., radars and image processing) is also used, if available, in combination with the V2V communications to detect non-equipped vehicles and fuse with connected vehicle data. This object represents a broad range of implementations ranging from basic Vehicle Awareness Devices that only broadcast vehicle location and motion and provide no driver warnings to advanced integrated safety systems that may, in addition to warning the driver, provide collision warning information to support automated control functions that can support control intervention. This function also includes vehicle control events that indicate a potential incident or other hazardous location warning extracted from on-board sensors (e.g. emergency brake light, slippery road, slow vehicle etc.)
2. *Vehicle Situation Monitoring* is the functionality required to collect traffic data and environmental situation data from on-board sensors and systems related to environmental conditions and sends the collected data to the infrastructure (V2I) as the vehicle travels. The collected data is a by-product of vehicle safety and convenience systems and includes ambient air temperature and precipitation measures and status of the wipers, lights, ABS, and traction control systems. Collected data is aggregated into snapshots that are reported when communications is available. Note that this application object supports collection of data for areas remote from RSUs or other communications infrastructure. A specific type of data monitoring is *Vehicle Emissions Monitoring* directly measures or estimates current and average vehicle emissions and makes this data available to the driver and connected vehicle infrastructure systems. This component is used in eco-based applications.
3. *Vehicle Roadside Information Reception* receives advisories, vehicle signage data, and other driver information and presents this information to the driver using in-vehicle equipment. Information presented may include fixed sign information, traffic control device status (e.g., signal phase and timing data), advisory and detour information, warnings of adverse road and weather conditions, travel times, and other driver information.
4. *Vehicle Traveller Information Reception* provides the capability for drivers to receive general traveller information including traffic and road conditions, incident information, maintenance and construction information, event information, transit information, parking information, weather information, and broadcast alerts.
5. *Vehicle Application Specific Support* is the representation of the functionality required in the vehicle to execute a specific application e.g. cooperative adaptive cruise control, rerouting etc.

The VEE supports the functional components

1. *Advanced Driver Assisted Systems* (ADAS) are vendor-specific assistance systems to increase safety and comfort of the driver. Examples are lane departure warning, automatic emergency brake, and advanced cruise control. These systems can in the near-future use cooperative information exchange to increase the field-of-view.
2. *Vehicle Monitoring* provides access to vehicle-specific sensor and actuator information systems of the vehicle.

6.3.1.2 Functional components at the Roadside

The RSU contains the next functional components:

1. *RSU Traffic Monitoring* monitors the Vehicle V2V safety messages that are shared between connected vehicles and distils this data into traffic flow measures that can be used to manage the network in combination with or in lieu of traffic data collected by infrastructure-based sensors. As connected vehicle penetration rates increase, the measures provided by this application can expand beyond vehicle speeds that are directly reported by vehicles to include estimated volume, occupancy, and other measures. This object also supports incident detection by monitoring for changes in speed and vehicle control events that indicate a potential incident.
2. *RSU Situation Monitoring* is a general application object that supports collection of traffic, environmental, and emissions data from passing vehicles. The data is collected, filtered, and forwarded based on parameters provided by the back office. Parameters are provided to passing vehicles that are equipped to collect and send situation data to the infrastructure in snapshots. In addition, this object collects current status information from local field devices including intersection status, sensor data, and signage data, providing complete, configurable monitoring of the situation for the local transportation system in the vicinity of the RSU.
3. *RSU Vehicle Information Distribution* receives information from the CP BO. Location-specific or situation-relevant information is sent to short range communications transceivers at the roadside. To support this function additional functions are needed in the communication network.
4. *RSU Application Specific Support* e.g.
    a. *RSU Intersection Management* uses short range communications to support connected vehicle applications that manage signalized intersections. It communicates with approaching vehicles and ITS infrastructure (e.g., the traffic signal controller) to enhance traffic signal operations.
    b. *RSU Intersection Safety* uses short range communications to support connected vehicle applications that improve intersection safety. It communicates with approaching vehicles and ITS infrastructure to alert and warn drivers of potential stop sign, red light, and pedestrian crossing conflicts or violations.
    c. *RSU Queue Warning* provides V2I communications to support queue warning systems. It monitors connected vehicles to identify and monitor queues in real-time and provides information to vehicles about upcoming queues, including downstream queues that are reported by the Traffic Management System
    d. *RSU Restricted Lanes Application* uses short range communications to monitor and manage dynamic and static restricted lanes. It collects vehicle profile information from vehicles entering the lanes and monitors vehicles within the lanes, providing aggregate data to the back office center. It provides lane restriction information and signage data to the vehicles and optionally identifies vehicles that violate the current lane restrictions. These functions are performed based on operating parameters provided by the back office managing center(s).
    e. *RSU Speed Management* provides infrastructure information including road grade, roadway geometry, road weather information, and current speed limits to assist vehicles in maintaining safe speeds and headways. It also provides speed recommendations to vehicles based on current conditions and overall speed limits and strategies established by the back office.
    f. *RSU Speed Warning* notifies connected vehicles that are approaching a reduced speed zone, providing: (1) the zone's current posted speed limit and (2) any roadway configuration changes associated with the reduced speed zone (e.g., lane closures, lane shifts) if applicable. Configuration parameters that define the applicable speed limit(s), geographic location and extent of the reduced speed zone, and roadway configuration information are received from a center or provided through a local interface. This application object works in conjunction with the 'Roadway Speed Monitoring and Warning' application object, which uses traditional ITS field equipment to warn non-equipped vehicles.
    g. *RSU Electric Charging Support* uses short range communications to coordinate with a vehicle that is being charged, receiving information about the operational state of the

electrical system, the maximum charge rate, and the percentage-complete of the charge from the vehicle.

h. *RSU Infrastructure Restriction Warning* uses short range communications to warn vehicles of infrastructure dimensional and weight restrictions
i. *RSU Parking Management* monitors the basic safety messages generated by connected vehicles to detect vehicles parking and maintain and report spaces that are occupied by connected vehicles. It also uses short range communications to provide parking information to vehicles.

The Roadside systems contain functional components to support the RSU e.g.

1. *Roadway Traffic Monitoring* monitors traffic conditions using fixed equipment such as loop detectors and cameras.
2. *Roadway Signal Control* includes the field elements that monitor and control signalized intersections/ramps and dynamic roadway signs e.g.
    - *Roadway Variable Speed Limits* includes the field equipment, physical overhead lane signs and associated control electronics that are used to manage and control variable speed limits systems. This equipment monitors traffic and environmental conditions along the roadway. The system can be centrally monitored and controlled by a traffic management center or it can be autonomous, calculating and setting suitable speed limits, usually by lane. This application displays the speed limits and additional information such as basic safety rules and current traffic information to drivers.
    - *Roadway Signal Control* includes the field elements that monitor and control signalized intersections. It includes the traffic signal controllers, signal heads, detectors, and other ancillary equipment that supports traffic signal control. It also includes field masters, and equipment that supports communications with a central monitoring and/or control system, as applicable. The communications link supports upload and download of signal timings and other parameters and reporting of current intersection status. It represents the field equipment used in all levels of traffic signal control from basic actuated systems that operate on fixed timing plans through adaptive systems. It also supports all signalized intersection configurations, including those that accommodate pedestrians.
3. *Roadway Local Traffic Monitoring and Signal Control Distribution* receive information from the *Roadway Traffic Monitoring* and send this information via a RSU to vehicles or BO systems.

6.3.1.3 Functional components at the Center

The TMS contains the next functional components:

1. *TMS Traffic Monitoring* remotely monitors traffic sensors and surveillance equipment (cameras), and collects, processes and stores the collected traffic data. Actual traffic information and other real-time transportation information are also collected from other centers. The collected information is provided to traffic operations personnel and made available to other centers. The collected information is used in scenario management in TMS Application Specific Functions to decide on traffic control measures.
2. *TMS Traffic Control* controls driver information system field equipment including dynamic message signs, managing dissemination of driver information through these systems.
3. *TMS Traffic Information Distribution* disseminates traffic and road conditions, dynamic speed limits, closure and detour information, incident information, driver advisories, and other traffic-related data to other centers, the media, and driver information systems. It monitors and controls driver information system field equipment including dynamic message signs and highway advisory radio, managing dissemination of driver information through these systems.
4. *TMS Application Specific Functions*, e.g.
    a. *TMS Dynamic Lane Management* remotely monitors and controls the system that is used to dynamically manage travel lanes, including temporary use of shoulders as travel lanes. It monitors traffic conditions and demand measured in the field and determines when the lane configuration of the roadway should be changed, when

intersections and/or interchanges should be reconfigured, when the shoulders should be used for travel (as a lane), when lanes should be designated for use by special vehicles only, such as buses, high occupancy vehicles (HOVs), vehicles attending a special event, etc. and/or when types of vehicles should be prohibited or restricted from using particular lanes. It controls the field equipment used to manage and control specific lanes and the shoulders. It also can automatically notify the enforcement agency of lane control violations.

b. *TMS Incident Dispatch Coordination* formulates and manages an incident response that takes into account the incident potential, incident impacts, and resources required for incident management. It supports dispatch of emergency response and service vehicles as well as coordination with other cooperating agencies. It provides access to traffic management resources that provide surveillance of the incident, traffic control in the surrounding area, and support for the incident response. It monitors the incident response and collects performance measures such as incident response and clearance times.
c. *TMS Infrastructure Restriction Warning* controls and monitors RSUs that support Infrastructure Restriction Warnings. It configures the RSUs to define tunnel/bridge geometry and design and temporary size and weight restrictions. Information that is currently being communicated to passing vehicles and the operational status of the field equipment is monitored by this application.
d. *TMS Intersection Safety* controls and monitors RSUs that support stop sign, red light, and pedestrian crossing violations. It configures the RSUs for the current intersection geometry and traffic signal control equipment at the intersection. Information that is currently being communicated to passing vehicles and the operational status of the field equipment is monitored by this application.
e. *TMS In-Vehicle Signing Management* controls and monitors RSUs that support in-vehicle signing. Sign information that may include static regulatory, service, and directional sign information as well as variable information such as traffic and road conditions can be provided to the RSU, which uses short range communications to send the information to in-vehicle equipment. Information that is currently being communicated to passing vehicles and the operational status of the field equipment is monitored by this application. The operational status of the field equipment is reported to operations personnel.
f. *TMS Roadway Warning* remotely monitors and controls the systems used to warn drivers approaching hazards on a roadway. It monitors data on roadway conditions from sensors in the field and generates warnings in response to roadway weather conditions, road surface conditions, traffic conditions including queues, obstacles or animals in the roadway, and any other transient events that can be sensed.
g. *TMS Variable Speed Limits* provides center monitoring and control of variable speed limits systems. It monitors data on traffic and environmental conditions collected from sensors along the roadway. Based on the measured data, it calculates and sets suitable speed limits usually by lane. It controls equipment that posts the current speed limits and displays additional information such as basic safety rules and current traffic information to drivers
h. *TMS Work Zone Traffic Management* coordinates work plans with maintenance systems so that work zones are established that have minimum traffic impact. Traffic control strategies are implemented to further mitigate traffic impacts associated with work zones that are established, providing work zone information to driver information systems such as dynamic message signs.

The next functional components can be used on several central systems like TIS, SP BO, DP BO:

1. *BO Traffic Data Collection* collects, processes and stores the traffic data. Current traffic information and other real-time transportation information are collected from several sources like TMS, and connected vehicles.

2. *BO Traffic Information Distribution* disseminates traffic and road conditions, closure and detour information, incident information, driver advisories, and other traffic-related data to other centers and the media (e.g. radio, service providers). Location-specific or situation-relevant traveller information is sent to short range communications transceivers at the roadside.
3. *BO Traveller Information Distribution* disseminates traveller information including event information, transit information, parking information and weather information. Also information such as lodging, restaurants, and service stations can be distributed. Tailored traveller service information is provided on request that meets the constraints and preferences specified by the traveller. This application also supports reservations and advanced payment for traveller services.

The Communication Provider BO contains the next functional components:

1. *CP Traffic Data Collection* collects, processes and stores the traffic data from RSU traffic and situation monitoring. Current traffic flow information and other real-time information are collected from equipped cooperative vehicles passing the roadside station of the communication provider.
2. *CP Vehicle Information Distribution* receives information including traffic and road conditions, incident information, maintenance and construction information, event information, transit information, parking information, and weather information. Location-specific or situation-relevant information is sent to short range communications transceivers at the roadside.

The SPES contains the next functional components:

1. *Service Directory* (SD) provides basis capabilities to manage and search service descriptions
2. *Identity Manager* (IM) provides capabilities to manage common identities and to handle all security and privacy related concerns
3. *Billing* is a support system that handles all financial transactions and provides a neutral instance which monitors the transactions between different parties.

6.3.1.4 Functional components for Traveller / VRU

The PID contains the next functional components

1. *Personal Pedestrian and Cyclist Safety* improves pedestrian and cyclist safety by providing pedestrian and cyclist location information to the infrastructure that can be used to avoid collisions involving pedestrians/cyclists. The application may also alert the pedestrian/cyclist of unsafe conditions, augmenting or extending information provided by signals and signs. The information provided and the user interface delivery mechanism (visual, audible, or haptic) can also be tailored to the needs of the user that is carrying or wearing the device that hosts the application.
2. *Personal Application Specific Support* e.g Personal Interactive Traveller Information provides traffic information, road conditions, transit information, yellow pages (traveller services) information, special event information, and other traveller information that is specifically tailored based on the traveller's request and/or previously submitted traveller profile information. The interactive traveller information capability is provided by personal devices including personal computers and personal portable devices such as smart phones.

The VRU OBU contains similar application objects as Vehicle OBU, but with specific VRU vehicle parameters for the functional components.

6.4 Communication view – detailed descriptions

A general communications reference architecture for a **single** ITS system is described in ETSI EN 302 665. The ITS station reference architecture is shown in Figure 6-6. This reference communication architecture is valid for all ITS systems, i.e. OBU, RSU and BO systems. In the ETSI definitions these elements are named Vehicle ITS Station (V-ITS-S), Roadside ITS Station (R-ITS-S) and Central ITS (C-ITS-S).

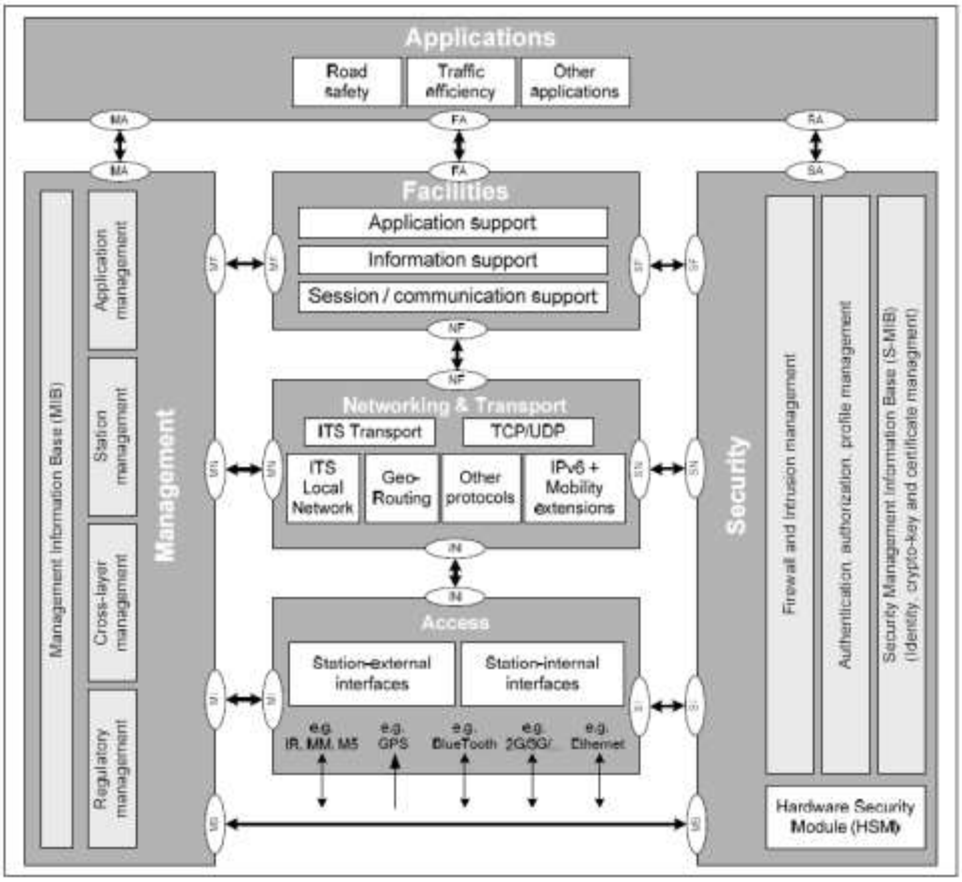

Figure 6-6 ITS station reference architecture / ITS-S host with examples of functional elements

This ITS station communication reference architecture is used to define different 'types' of ITS-Stations (ITS-S) e.g. ITS-S host, ITS-S gateway and ITS-S (border) router. Each type indicates the functions that are implemented and the interfaces to other elements, i.e. no ITS stations. The ITS station architecture can also be used to define the communication interfaces between ITS-S hosts and towards non-ITS-S station at Applications, Facilities, Network & Transport layer or Access through so-called SAP reference points (IN-IN, NF-NF, FA-FA, see Figure 4 8). It should be noted that most of the reference points are defined in the current ETSI ITS standards as internal reference points and are not designed with interoperability in mind, e.g. the specification of these interfaces is informative and additional design effort is needed to implement them. This is a main issue, especially for roadside networks that need to be interconnected to back-office systems of different stakeholders.

In the architecture report [1] several technical descriptions are given on ITS-G5 based deployments for:

1) V2V with single vehicle unit: this this deployment is useful when no
2) V2V with split in application and communication unit in vehicles: this deployment is useful to split the ITS-G5 based communication with existing in-car information systems and/or smart phones that are used for applications;
3) I2V with stand-alone roadside unit: in this deployment one single unit is used to send I2V messages. This is e.g. used for moving roadside ;
4) I2V with roadside unit with back-office integration via three types of gateways:
    a. Facility Layer Gateway: this gateway acts as gateway at the back-office for applications from other third parties and 'translates' messages between the Application and Facilities layer. This type of gateway can be used e.g. to translate information from e.g. DATEX-II to DENM and vice versa.
    b. Access Layer Gateway: this gateway acts on the
    c. Proxy Layer Gateway: similar to Access Layer Gateway, but with additional function on geographical distribution of messages

In this deployment scenario, the communication between a centralized component and roadside station is implemented by a Facility Layer Gateway. The benefit of this approach is that the application developers do not need to provide their own implementation of the Facilities and GeoNetworking (and ITS-G5) layer of the ITS communication stack. Multiplexing between different roadside ITS stations is done by the facility layer gateway (Figure 6-7).

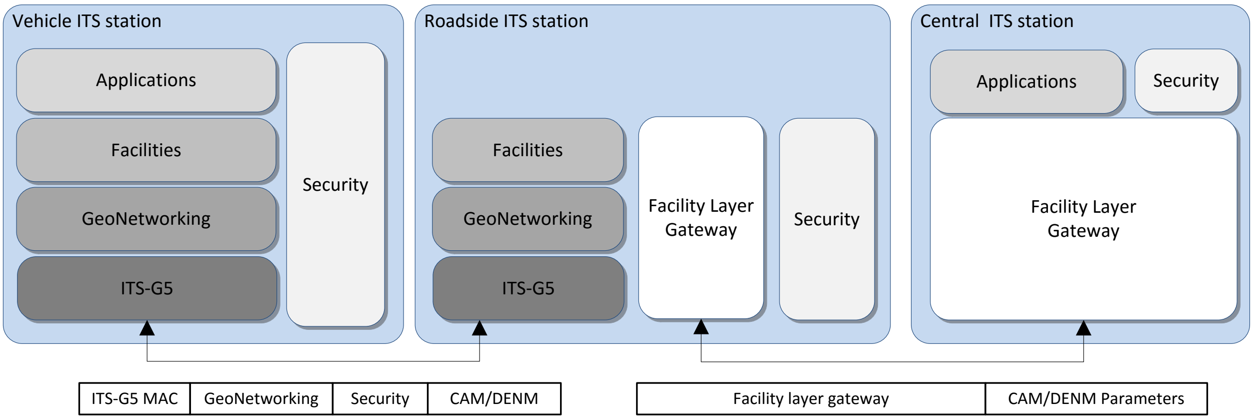

Figure 6-7 Facility Layer Gateway deployment[5]

As the security specifications of ITS dictate that the messages are to be signed at the GeoNetworking level, the certificates of the roadside ITS station provider are used for signing.

Facilities Layer Gateways are currently not standardized. Facility Layer Gateway deployment is currently being implemented in the *Shockwave Traffic Jams A58* project.

6.4.1.1 Access Layer Gateway deployment

In the Access Layer Gateway deployment scenario, GeoNetworking frames are tunnelled over IP to the different roadside stations connected to the central ITS station and then threated as a normal GeoNetworking frame (Figure 6-8). This approach is different from the facility layer gateway as in that case the internal interface between the Facilities and the Applications layer is used.

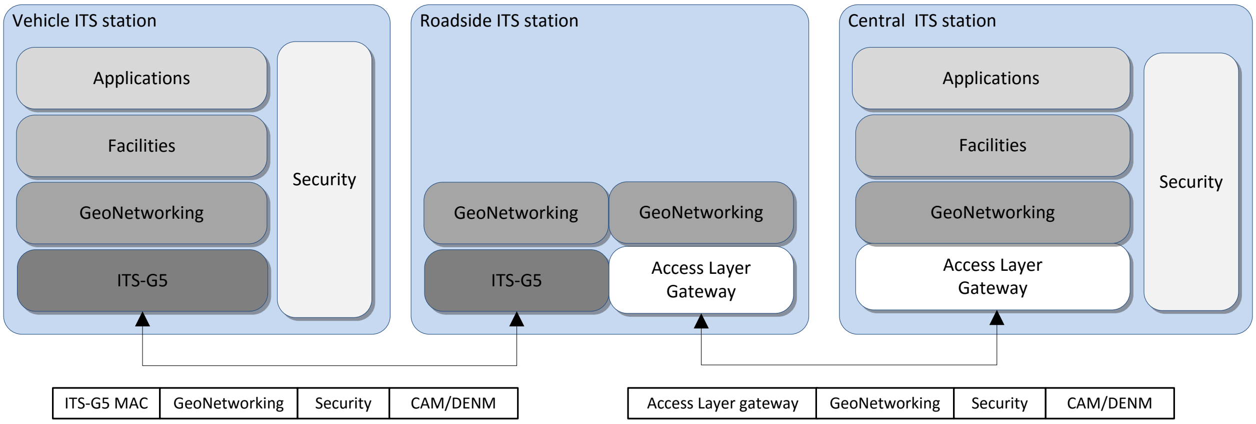

Figure 6-8 Access Layer Gateway deployment[6]

The advantage of the Access Layer Gateway scenario is that the new facilities and applications can easily be introduced at vehicle and central ITS station components without interference of the roadside

[5] The C-ITS station can also be another R-ITS station
[6] The C-ITS station can also be another R-ITS station

ITS network. Also the security certificates of the implementer of the application can be used to sign the GeoNetworking frames.

The tunnelling of GeoNetworking frames over IP (or other transport methods) is currently not standardized. The Access Layer Gateway deployment is currently being implemented in the Converge project.

6.4.1.2 Proxy Access Layer Gateway deployment

In the Proxy Access Layer gateway deployment scenario the same tunnelling mechanism as in the Access Layer Gateway deployment scenario is used (Figure 6-9). In this case an additional station is introduced (Proxy ITS station) that directs tunnelled GeoNetworking messages to the right roadside ITS stations.

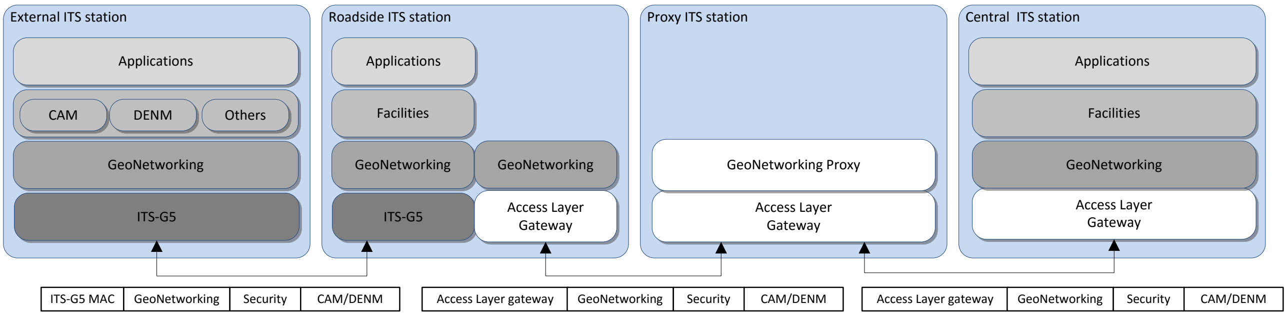

Figure 6-9 Proxy Access Layer Gateway (Tunnel) deployment

Multiple proxies can be chained together to create a tree-like hierarchic structure - similar to DNS - from which wider geographic areas can be addressed. This concept is also explained in more detail in section 6.5.6. More detailed descriptions can be found in [1].

6.5 Architecture view for V2V, I2V, V2I and I2I applications

6.5.1 Introduction

In this section different functional architectures are shown for groups of applications. Via this aggregation for a group of applications - with specific information flows - a more simplified architecture is shown, with information exchange between a subsets of physical systems.

The architectures are shown for:

- V2V applications with direct communication between vehicles => *specific focus of C2C CC profile*
- V2I applications for information collection from vehicles
- I2V applications for intersections with Traffic Light Controllers => *specific focus of iTLC project*
- I2V applications for road segments / highways => *specific focus of A58 and ITS Corridor projects*
- I2I applications with a e-Market place: support for automated discovery, registration and use of ITS applications => *specific focus of MOBiNET and Converge project*
- I2I applications for distributed cooperative networks: support for “geocast” i.e. message distribution via broadcast via selected geographical networks from different stakeholders => *specific focus of Converge project*
- VRU applications => *specific focus of VRUITS project*

6.5.2 V2V applications with direct communication between vehicles

The architecture view for the V2V applications described in detail in section 6.1.1 is shown in Figure 6-10.

The selected V2V applications are Hazardous Location Warning, Emergency Brake Light, Slow Vehicle Warning and Cooperative Adaptive Cruise Control.

Awareness information on location, speed, heading and event-based information (e.g. emergency brake warning) are exchanged between on-board ITS units of vehicles.

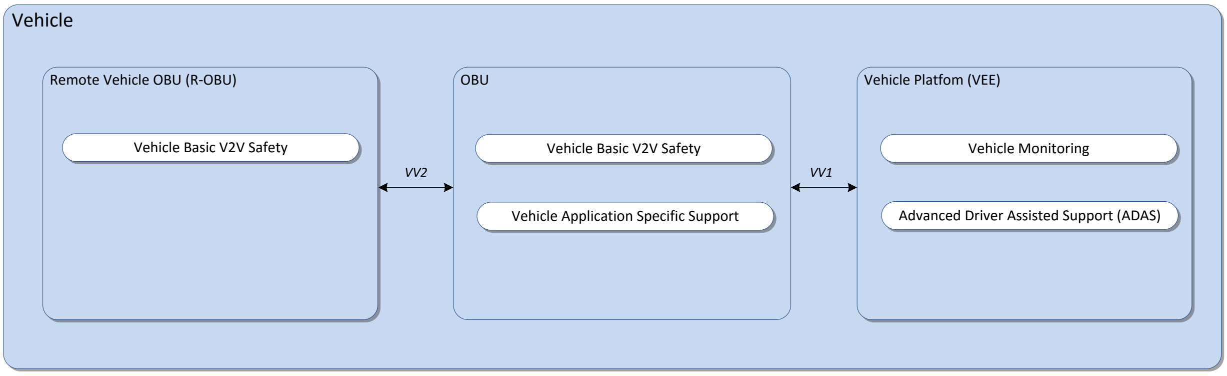

Figure 6-10 Architecture view for V2V applications

The interfaces are given in
Table 4 with details on the information exchanged for the selected V2V applications between source (sender) and destination (receiver), the information type (generic description) and a reference to a standard.

Table 4 Interfaces with reference for selected V2V applications

Id	Source	Destination	Information Type	Reference	Remark
VV1	VEE	OBU	Vehicle State	EOBD standard	OEM specific
VV1	OBU	VEE	Risk	None	OEM specific
VV2	OBU	R-OBU	Situation Awareness	ETSI CAM	ETSI EN 302 637-2
VV2	OBU	R-OBU	Warnings	ETSI DENM	ETSI EN 302 637-3
VV2	R-OBU	OBU	Situation Awareness	ETSI CAM	ETSI EN 302 637-2
VV2	R-OBU	OBU	Warnings	ETSI DENM	ETSI EN 302 637-3

The integration with vehicle or existing information systems is not specified. This is left to corresponding parties (e.g. Car2Car Consortium, Amsterdam Group) to include in application white papers and/or profiles.

6.5.3 V2I applications for information collection from vehicles

The selected V2I applications are:

1. Probe Vehicle Data from cooperative cars: the broadcast information from cars equipped with ITS-G5 unit is collected (CAM, DENM) and used;
2. Probe Vehicle Data from connected cars: information from cars equipped with mobile equipment (connected cars or smart phones of driver) is collected via a service/data provider. The end-user has a direct relation to this service/data provider and agrees to share this information;
3. Priority Request : a priority request is sent by special vehicles (public transport, emergency vehicles) to a traffic light controller, to request for early green;

The aggregated architecture view for these V2I applications is shown in Figure 6-11. This architecture gives an example with physical and functional components to support the Probe Vehicle Data application via connected and cooperative communication. Information is exchanged directly from OBU to the Data Provider BO when the connected communication channel is used, whereas information is exchanged from OBU via an RSU and Communication Provider BO to the Data Provider BO when the cooperative communication channel is used. This figure illustrates how the PVD application can be created by combining a limited number of functional components and which interfaces are required. This figure also illustrates that if the connected variant of PVD is implemented, the physical component roadside is not needed. Optionally, other “probe vehicle” data from loops used in a RS can also be used in a TMS and/or distributed to DP/SP via a TIS (shown in Figure 6-11 via interfaces CC1 and CC4) can be integrated to improve traffic monitoring.

For priority request CAM messages of a specific type of vehicles (public transport, emergency vehicle) can be used to initiate a priority request for a signalized intersection).

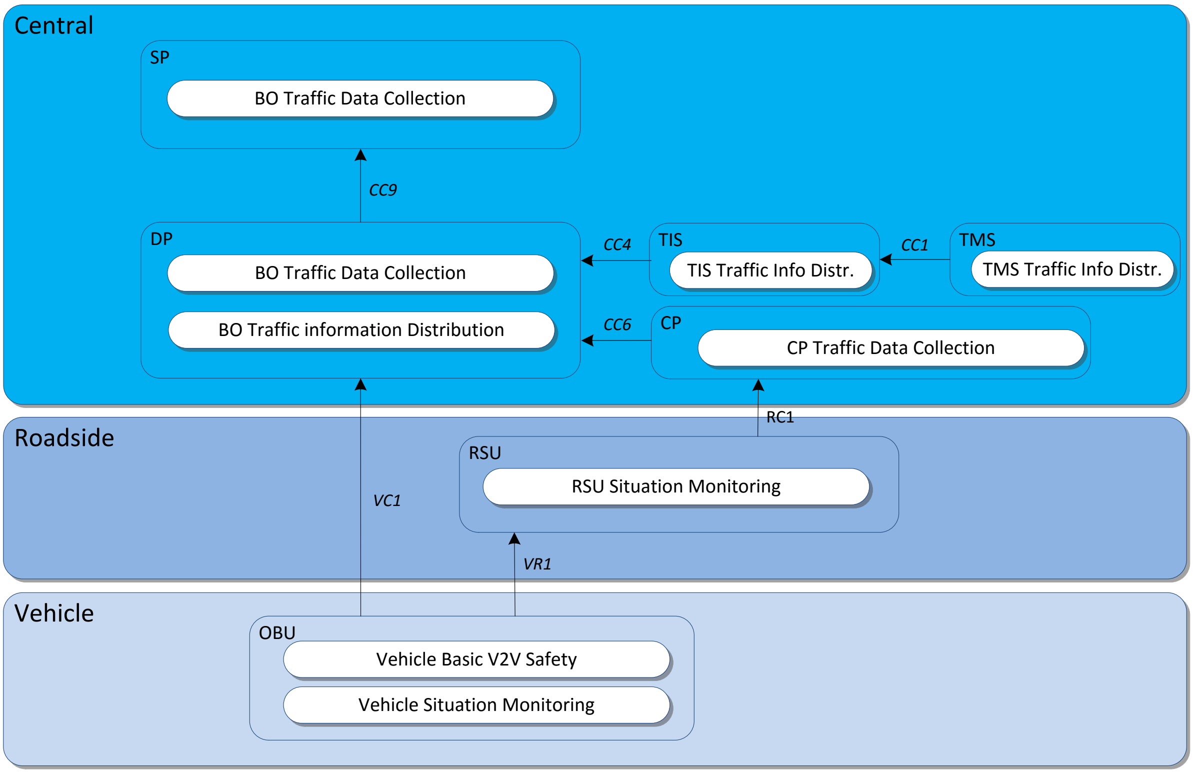

Figure 6-11: Architecture View for V2I applications for Probe Vehicle Data

The interfaces and the information exchange are shown in Table 5.

Table 5 Interfaces with reference for selected V2I applications

Id	Source	Dest.	Information Type	Reference	Remark
VR1	OBU	RSU	Situation Awareness	ETSI CAM	ETSI EN 302 637-2
VR1	OBU	RSU	Warnings	ETSI DENM	ETSI EN 302 637-3
VR1	OBU	RSU	Warnings	Project ITS Corridor	Eco-AT IF4 spec. plus profiles for RWW and other Hazardous Location Warnings
VC1	OBU	DP BO	Probe Vehicle Data	project A58	A58 spec. G
RC1	RSU	CP BO	Probe Vehicle Data	project A58	A58 spec. F / F*
RC1	RSU	CP BO	Probe Vehicle Data	Project ITS Corridor	Eco-AT IF3 spec; CAM aggregation (minute); DENM aggregation
CC1	TMS	TIS	Local Traffic State Data	project A58	A58 spec. H*
CC4	TIS	DP BO	Local Traffic State Data	project A58	A58 spec. H*
CC6	CP BO	DP BO	Probe Vehicle Data	project A58	A58 spec. G

CC9	DP BO	SP BO	Traffic Info (macro/micro)	project A58	A58 spec. A / A*

Notes on V2I

- *In the project A58 a difference is made on the collection of micro and macro data. Micro data is defined as (raw) individual vehicle data; macro data is aggregated data on a road segment; aggregation can be*

6.5.4 I2V applications for intersections with Traffic Light Controllers

For I2V applications information is distributed from infrastructure objects (back-office or roadside systems) to vehicles. To support this location-based information distribution several options exist to use hybrid communication networks. In this section, the intersection-based applications with traffic light controllers (TLC) are shown. For this a stand-alone RSU-RS system can be used for applications like:

1. Green Light Optimal Speed Advice
2. Green Wave (via Speed Advice)
3. Stopping Behaviour Optimization
4. Red Light Violation Warning

An example architecture for the GLOSA application is depicted in Figure 6-12. The GLOSA application contains the Roadside System, which provides signal state data via the RSU to the OBU. This architecture shows a cooperative solution with a stand-alone roadside system.

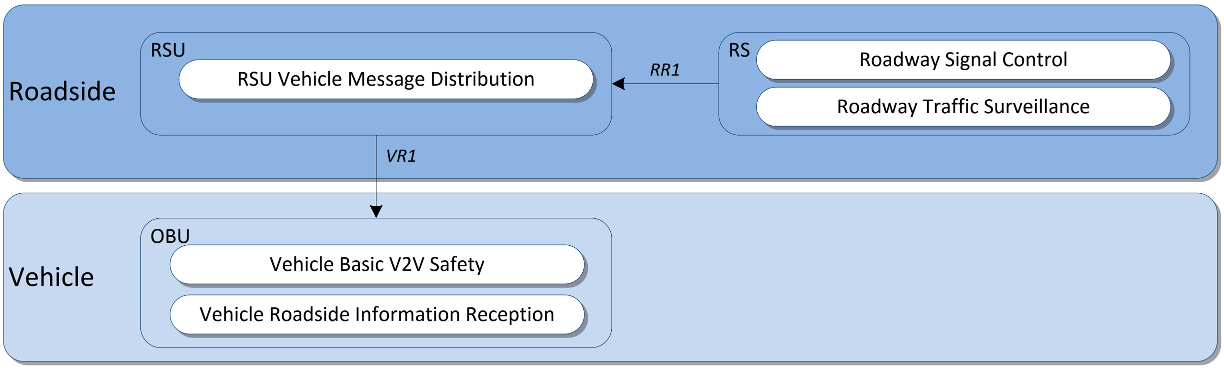

Figure 6-12 Architecture View for cooperative I2V applications for intersections with stand-alone RS-RSU

Optionally, the signalling phase (part of Roadway Signal Control information) from the TLC can be distributed via back-office systems to Service Providers, and - depending on the time constraints - this information can be used for connected applications. This is shown in Figure 6-13.

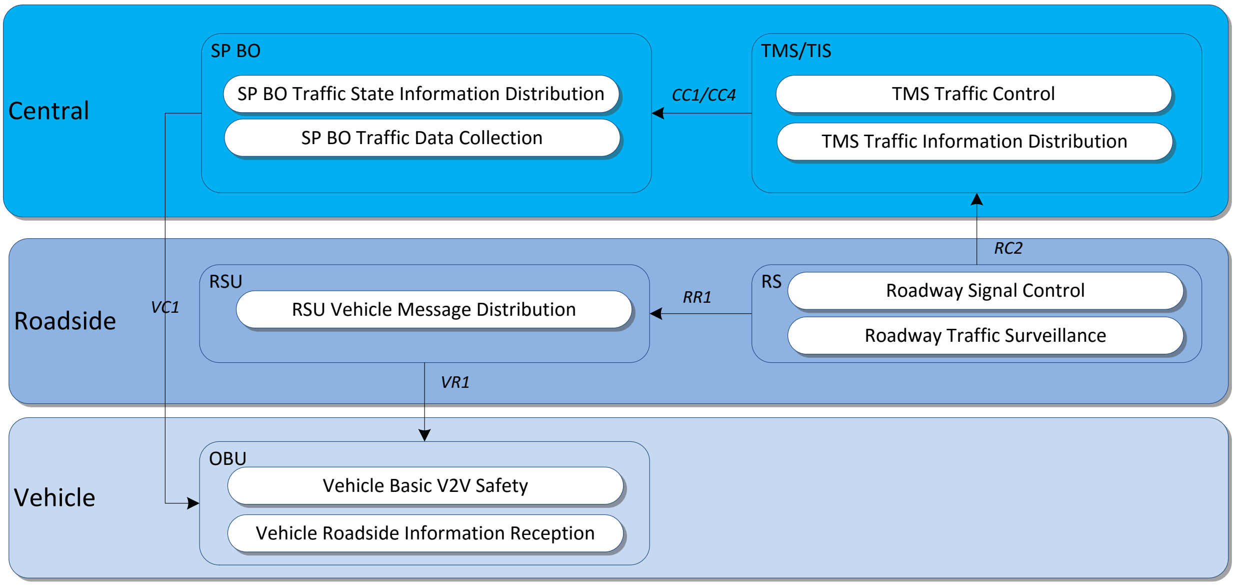

Figure 6-13 Architecture View for I2V applications for intersections with BO integration

The interfaces and the information exchange are depicted in Table 6.

Table 6 Interfaces with reference for selected I2V applications

Id	Source	Destination	Information Type	Reference	Remark
VR1	RSU	OBU	Road Topology of intersection	ETSI spec.	MAP: in progress
VR1	RSU	OBU	Signalling Phase and Time	ETSI spec.	SPAT: in progress
VR1	RSU	OBU	Warnings	ETSI standard	DENM: ETSI EN 302 637-3
RR1	RS/TLC	RSU	Green time	IVERA/OCIT	candidates
RR1	RS/TLC	RSU	Green time	Project Eco-AT	IF-6: proprietary interface to TLC
RR1	RS/trailer	RSU	Warnings	Project Eco-AT	IF-7: proprietary interface to trailer
RC2	RS	TMS	Green time	IVERA	candidate
RC2	RS	TMS	Warnings	ETSI standard	DENM: ETSI EN 302 637-3
CC1/ CC4	TMS (via TIS)	SP BO	Green time	none	
VC1	SP BO	OBU	Green time	none	

6.5.5 I2V applications for road segments / highways

In this section the architecture for the remaining I2V applications is shown:

1. Incident Warning
2. Road Works Warning
3. Traffic Jam Ahead Warning
4. In Vehicle Signage
5. Shockwave Damping (via Speed Advice)

In this architecture, it is assumed that the TIS is the central provider generating the safety warnings for incidents, road works and traffic jam ahead. For speed advice in shockwave damping or in-vehicle signage a service provider might generate advices to individual end-users.

Figure 6-14 gives an example how the architecture for road work / incident / traffic jam ahead warning can be composed out of physical and functional components, where we combined the cooperative and connected versions into a single architecture. The difference is that the connected version communicates directly between SP BO and OBU, whereas the cooperative version communicates via

CP and RSU to OBU. This architecture shows the required functional components, their interfaces and the flow of data only directed towards the OBU.

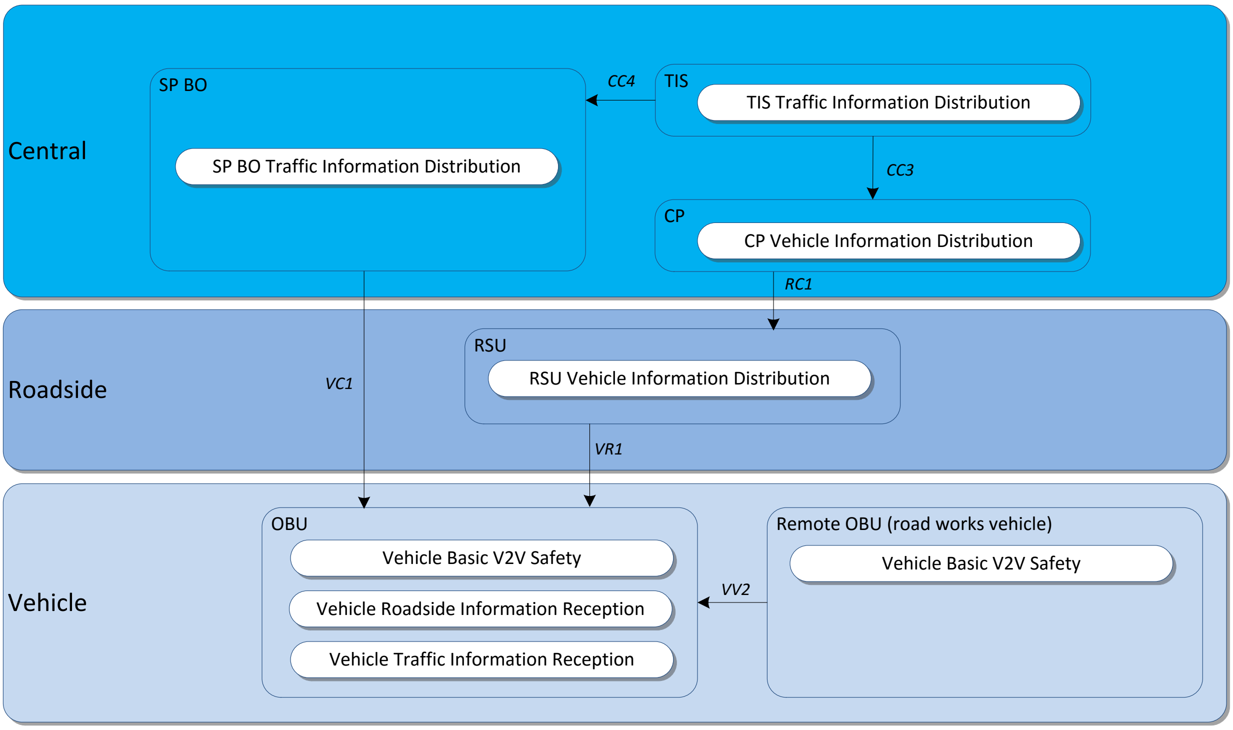

Figure 6-14: Architecture view for I2V applications for road segments/high-ways

The interfaces and the information exchange are depicted in Table 7:

Table 7 Interfaces with reference for I2V applications for high-ways

Id	Source	Destination	Information Type	Reference	Remark
VR1	RSU	OBU	Warning	ETSI standard	DENM: ETSI EN 302 637-3
VV2	R-OBU	OBU	Situation Awareness	ETSI standard	CAM: ETSI EN 302 637-2
VV2	R-OBU	OBU	Warning	ETSI standard	DENM: ETSI EN 302 637-3
RC1	CP	RSU	Warning	ETSI standard	CAM: ETSI EN 302 637-2
RC1	CP	RSU	Warning	ETSI standard	DENM: ETSI EN 302 637-3
RC1	CP	RSU		project ECo-AT	ECo-AT IF3 spec.
CC3	TIS	CP BO	Warning	project ECo-AT	ECo-AT IF1 spec. (DATEX-II-to-DENM)
CC4[7]	TIS	SP BO	Warning	DATEX-II	Used by NDW
VC1	SP BO	OBU	Warning, Speed Advice	project A58	A58 spec. B (speed advice, JAM)

Other I2V applications can also be supported by the architecture in Figure 6-14, but only require the interface between SP BO and OBU:

1. Navigation related applications: e.g. Rerouting / Smart routing / Traffic Information, Intermodal Route Planner, Eco Route Planner, EV Charging Point Planner and Smart Parking Assistant
2. Pay How You Drive

[7] The Dutch Ministry of I&M has initiated a Data Top 5 project to improve data quality on road works information, dynamic and static speed limits, dynamic traffic management measures, expected resolve time after incidents and map accuracy (via OpenLR).

6.5.5.1 I2I architecture for e-Market place

To support a scalable and open eco-system with multiple service providers, data providers and communication providers a distributed Service Provider Exchange System (SPES) is needed. It should be noted that both public (e.g. road operator) and private entities (e.g. commercial company) can fulfil the different roles of service provider, data provider and/or communication provider. The split in roles – with corresponding interfaces – enables a flexible eco-system with a split in roles and underlying business models.

This SPES system is described in projects like MOBiNET (MOBiCENTER) and Converge (Service Directory in Car2X network). On the SPES platform service providers can publish their (ITS) services and subscribe to other services. These services are registered in a (distributed) service directory, which provides a search interface to lookup relevant services. This concept is globally shown in Figure 6-15.

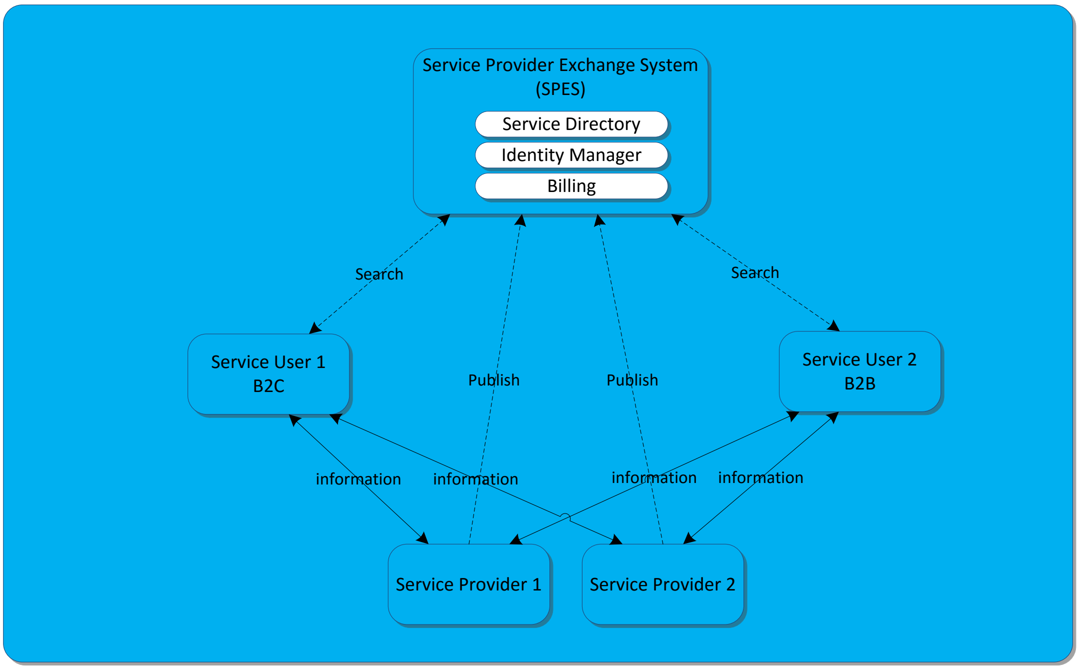

Figure 6-15 Architecture for Service Exchange.

Service Providers publish their ITS services in a Service Directory. Service Users (both B2C and B2B) can search this Service Directory and subscribe to these services (either in the Service Directory, with Billing option) or with Service Provider directly. After a subscription information can be exchanged between Service Provider and Service User. A Service Description and Information Model is needed to publish and search services. In both MOBiNET and Converge concepts of these (USDL-based) models are presented.

In Figure 6-16 this model is applied in an eco-system with several BO systems, related to different business roles. These interfaces can be established by pre-arranged bi-lateral agreements or be based on the above concept with a (distributed) service directory.

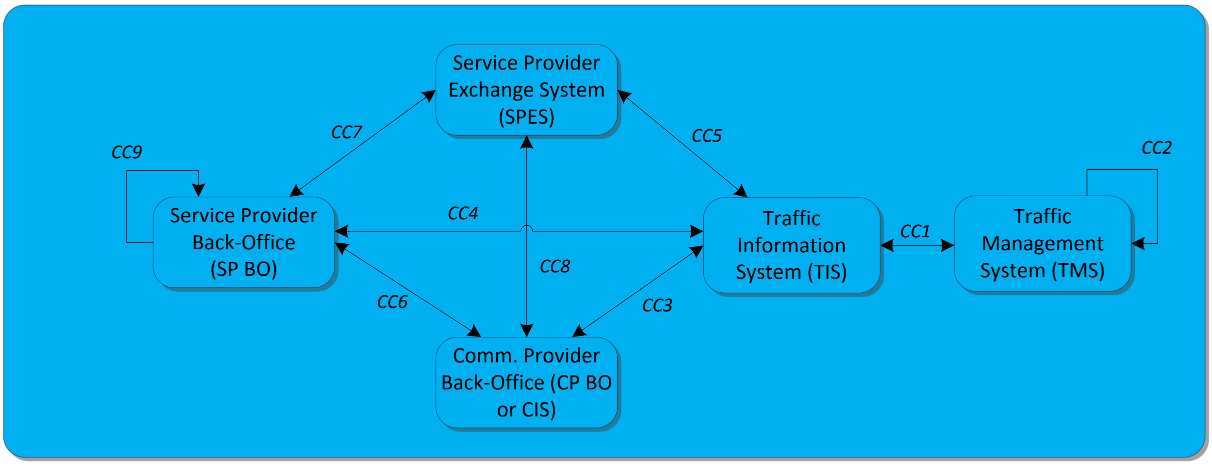

Figure 6-16 Architecture with different business roles, CP, DP, SP and TIS

In the above figure also the Communication Provider of the road-side ITS network publishes his communication services (i.e. the supported messages types, applications and the geo-graphical coverage). In this figure it is assumed that a (central) Traffic Information System is the interface to and from Traffic Management Systems of road operators. A TMS can also – via a TIS – use the Communication Provider network to receive and send messages from cooperative vehicles.

Examples of the interfaces and information exchange are:

Table 8 Interfaces with reference for selected I2I applications

Id	Source	Dest.	Information Type	Reference	Remark
CC1	TMS	TIS	Traffic Info	DATEX-II	See NDW
CC1	TMS	TIS	Local Traffic State Data	project A58	A58 spec. H* (loop data)
CC1	TMS	TIS	Local Traffic Control Data	project A58	A58 spec. H (dynamic speed)
CC1	TIS	TMS	Traffic Info	DATEX-II	See NDW Data Fusion Project
CC2	TMS	TMS	Coordinated Traffic Management info	DVM-Exchange	See PPA roadside
CC3/6	CP	TIS/SP	Probe Vehicle Data	project A58	A58 spec. F/F*
CC4	TIS	SP	Traffic Info	DATEX-II	See NDW
CC4	TIS	SP	Local Traffic State Data	project A58	A58 spec. H* (loop data)
CC4	TIS	SP	Local Traffic Control Data	project A58	A58 spec. H (dynamic speed limits)
CC5/7/8	TIS	SP	Publish/Search/Subscribe	project MOBiNET/ Converge	See project documents
CC9	SP BO	SP BO	Any	none	

6.5.6 I2I architecture for distributed cooperative networks

For a scalable communication infrastructure with multiple CPs and SPs different architecture options are possible. A CP with an RSU-based network can 'disclose' this network to external service providers, including road operators, in several ways:

1. Single CP, multiple SPs: multiple SPs have access to one single CP, where the CP sends his topology (area of reach) to the SP. Based on this info a SP can decide to send message to cooperative cars via the CP GeoMessaging server (Geom-S, see [39]). This Geom-S is aware of the internal topology of the RSU-based network and forwards messages to the correct RSU. A SP can also send peer-to-peer messages to connected OBUs via cellular networks.

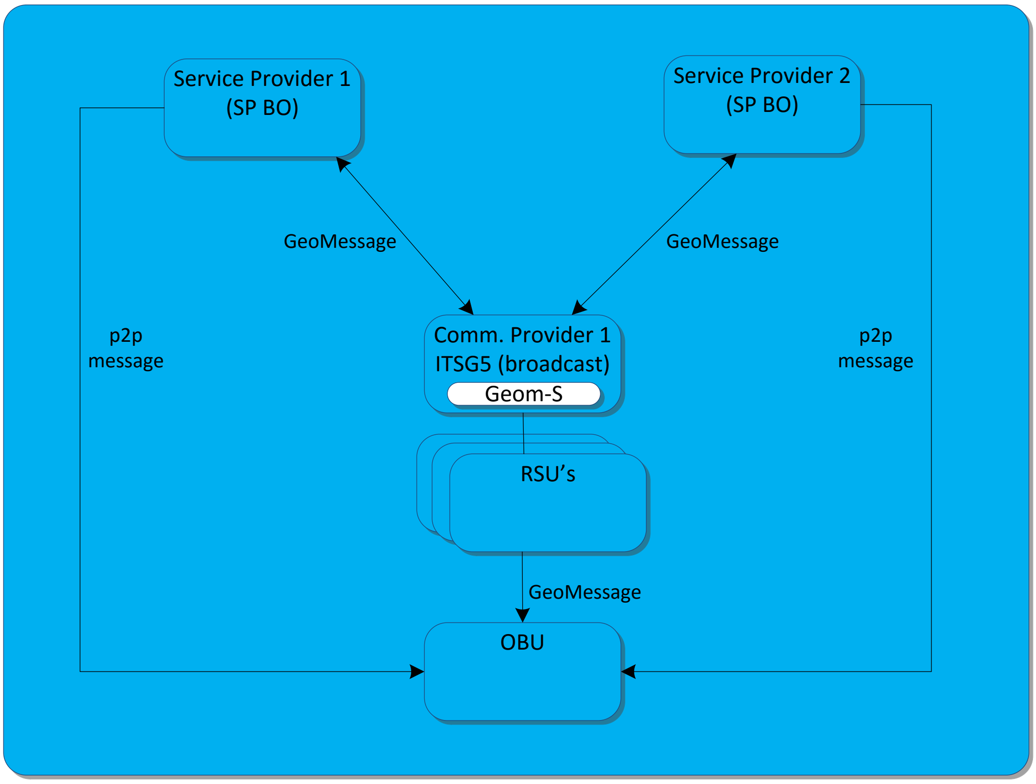

Figure 6-17 Architecture for single CP - multiple SPs

2. Multiple connections between SPs and CPs, without service directory: a SP has access to multiple CPs. The CPs send their topology (area of reach) to the SP. The SP's stores this info and uses an own GeoMessaging Proxy (Geom-P) to send message to the correct Geom-S of the CP. Also other non-ITS-G5 broadcast networks of mobile network operators (e.g. with LTE broadcast) can be integrated in this concept, as shown by CP 1 and CP 4 in the next figure.

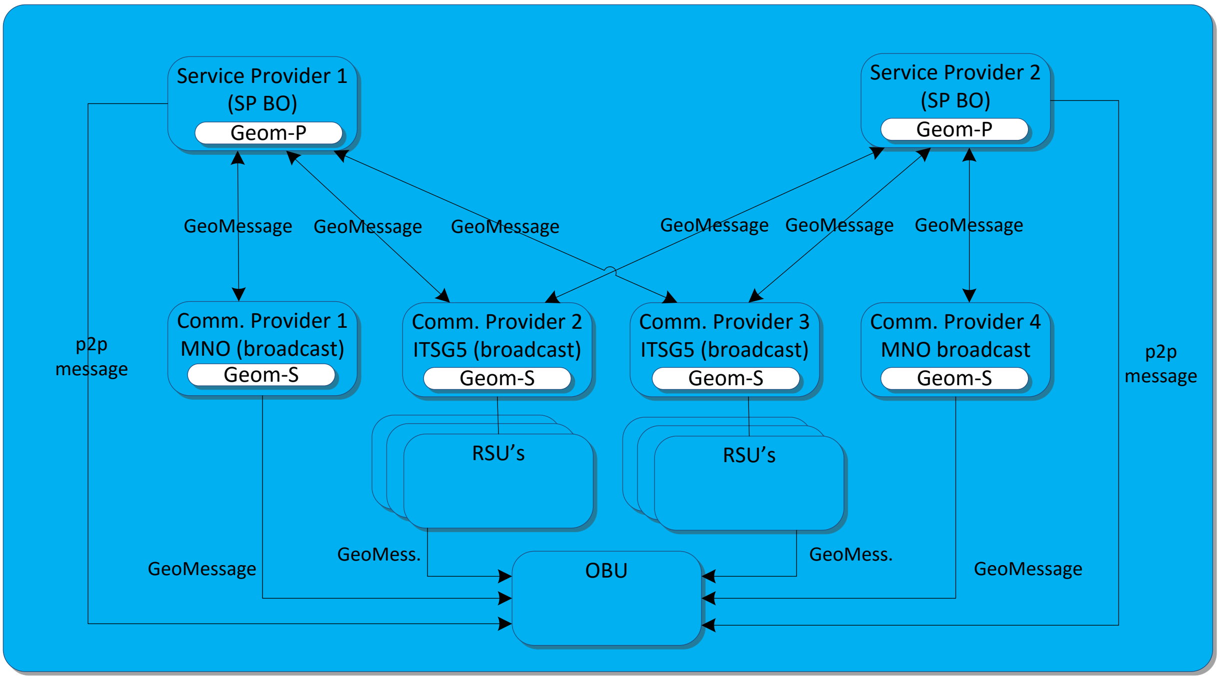

Figure 6-18 Architecture for multiple CPs - multiple SPs, without service directory

3. Multiple connections between SPs and CPs, with Service Directory: a SP has access to multiple CPs. The CPs send their topology (area of reach) to the central SD. The SP's retrieves this info and uses a GeoMessaging Proxy (Geom-P) to send message to the correct Geom-S of the CP.

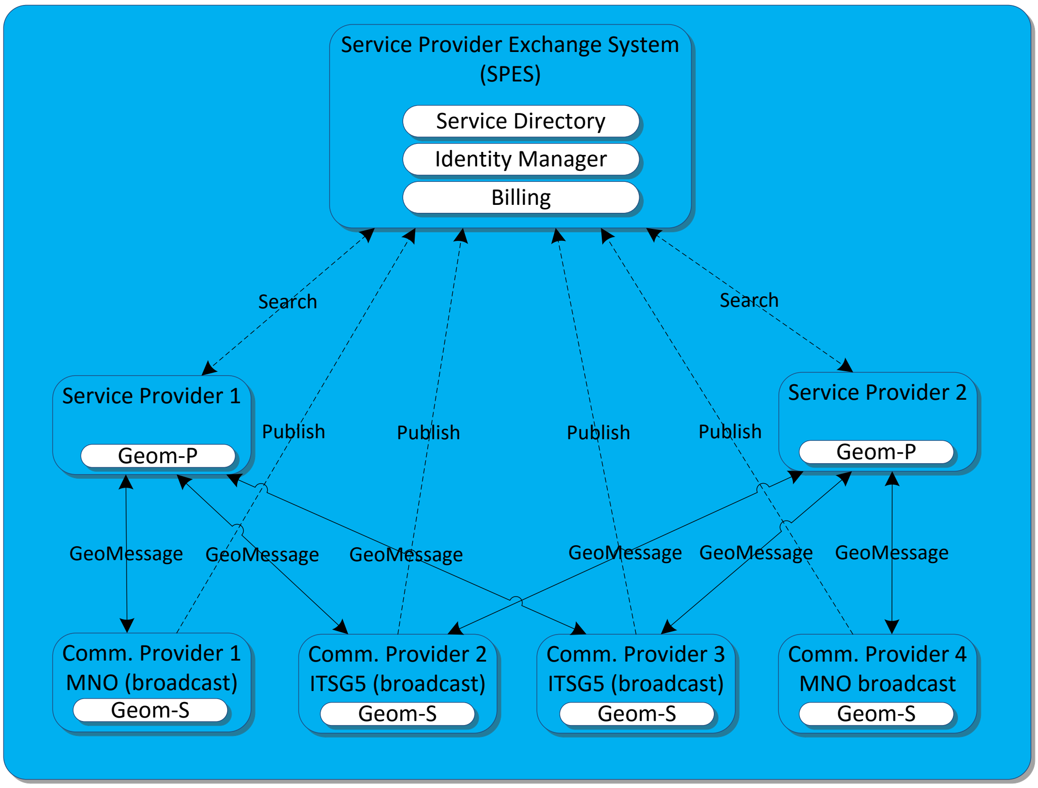

Figure 6-19 Architecture for multiple CPs - multiple SPs, with service directory

4. Multiple connections between SPs and CPs, with a central CP: a SP has access to multiple CPs via a central CP. This CP acts as communication broker for all SPs. The CPs send their topology (area of reach) to the central CP. The SP's forward all message via the central CP.

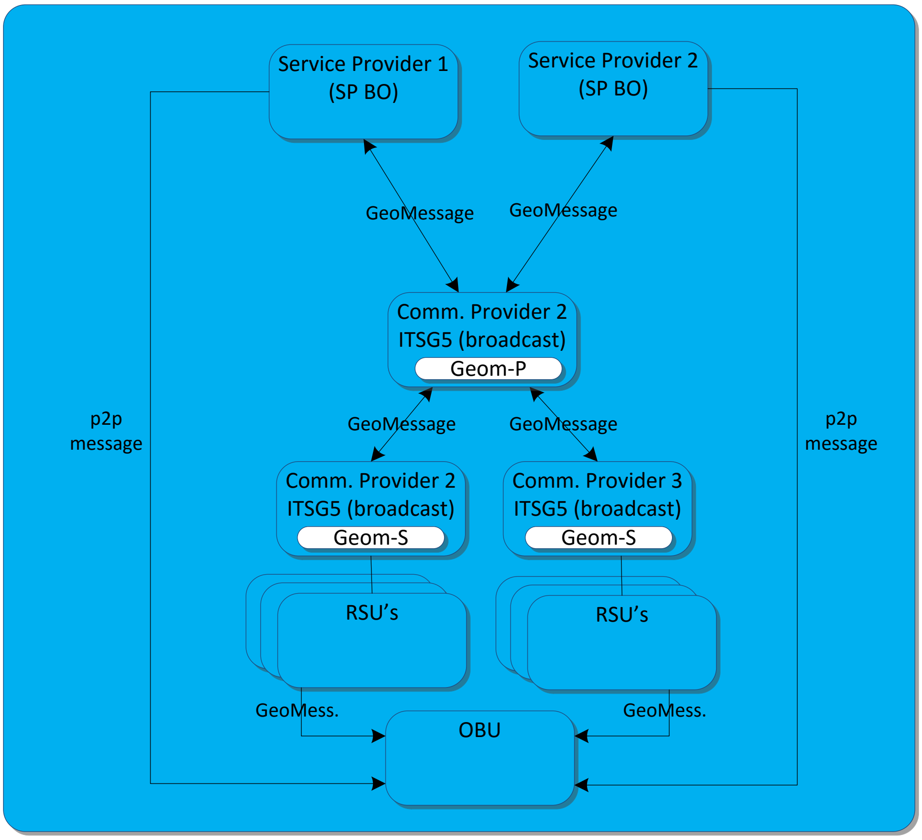

Figure 6-20 Architecture for multiple CPs - multiple SPs, with central CP proxy

6.5.7 Architecture for VRU applications

The VRU safety applications rely on accurate localization of VRU's via either (i) in-vehicle or roadside sensors (camera, radar), (ii) a tag-based system (VRU-transponder with a vehicle or roadside VRU localization system) or (iii) VRU's with a VRU-OBU capable for ITS-G5 communication or a personal information device.

The solutions differ in the system that performs situation assessment (i.e. roadside, vehicle or VRU) and in the road users that are warned i.e. driver and/or VRU. The aggregated architecture for the selected VRU applications is shown in Figure 6-21.

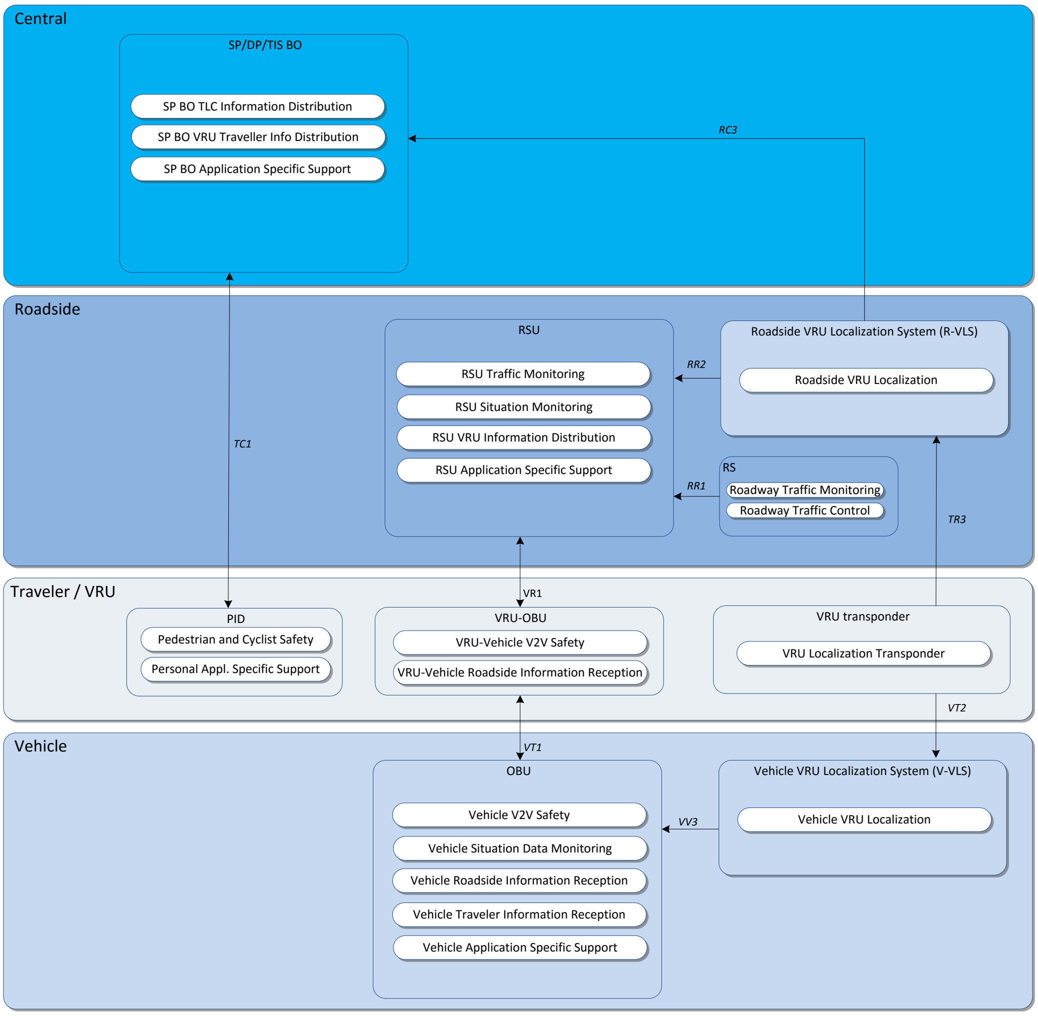

Figure 6-21 Architecture for VRU applications

Examples of use of the interfaces are depicted in Table 9.

Table 9 Interfaces with reference for selected VRU applications

Id	Source	Dest.	Information Type	Reference	Remark
VT1	OBU	VRU-OBU	Vehicle State/Warning	ETSI CAM/DENM	
VT1	VRU-OBU	OBU	Vehicle State/Warning	ETSI CAM/DENM	
VT2	VRU-T	V-VLS	VRU Location	Project VRUITS	
VR1	RSU	VRU-OBU	Warning, Intersection State	ETSI DENM, SPAT, MAP	
VR1	VRU-OBU	RSU	Vehicle State	ETSI CAM	
TR3	VRU-T	R-VLS	VRU Location	Project VRUITS	
RR1	RS	RSU	Intersection State, Detected VRU	Project VRUITS	
RR2	R-VLS	RSU	Detected VRU	Project VRUITS	
VV3	V-VLS	OBU	VRU Location	Project VRUITS	
TC1	PID	SP BO	Extended green time request	Project VRUITS	
TC1	SP BO	PID	Intersection Info	ETSI SPAT/MAP	
RC3	R-VLS	SP BO	VRU Location	Project VRUITS	
RC3	SP BO	R-VLS	Extended green time request		Similar to Priority Request

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