SEAMLESS

Architecture for seamless road data dissemination to in-vehicle devices

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1 Introduction

ITS architecture is in flux at the present time, due to current effort on architecture for cooperative systems. But at the same time there is the promise of a groundswell of functionality on smart phones and other mobile devices that may bypass the more complex cooperative architectural definitions.

In the Joint CEN and ETSI Response to Mandate M/453[1] the following definition for cooperative ITS has been worked out together with ISO and other standardisation stakeholders:

> "Cooperative ITS (C-ITS) is a subset of overall ITS that communicates and shares information between ITS-stations to give advice or facilitate actions with the objective of improving safety, sustainability, efficiency and comfort beyond the scope of stand-alone systems."

The seamless integration of vehicles and infrastructure – including an integrated communication chain up to the end user - is a technological and organizational challenge. This challenge arises from the complexity of today's transport systems and comes from the fact that various means of communication characteristics, data formats and stakeholders are involved.

Given this state of flux, all the current efforts and these challenges, the SEAMLESS project will not spend effort in developing general architectures in detail, but state assumptions with respect to the harmonisation of protocols (WP4) as well as verify and show how emerging architectures will support seamless urban/inter-urban services. So the *Cooperative Intelligent Transport Systems* (C-ITS) model presented in this document tends to be of a generic nature with strong focus on linking legacy systems. For the two use cases “Traffic Light Phase Assistant” and “Journey times” tailored reference architectures serve as examples.

[1] April 2010

2 Architecture of Intelligent Transport Systems

In a classical sense, the term 'architecture' (from the Latin 'architectura' for art of building) means the art and/or science of a systematic approach to design and create buildings in a human-built environment.

By not only building according to functional and technical aspects, but by designing the object of observation in the context of a value system (usually the responsible contractor or a community), the term 'architecture' attained great importance in many other areas of knowledge and contexts, such as in Information Technology (System architecture), or in the business sector (Enterprise Architecture).

By the European Commission's ITS aspirations and ITS activities (ITS Action Plan and ITS Directive) a broad-based discussion on the design and concept of transport- and transportation systems was initiated. This discussion has got a high relevance for all who deal with the implementation and use of such systems. It is driven primarily by the efforts of the European Commission to renew the traditional understanding of "transport / transportation" by using the term "mobility". Therefore less attention should be drawn to the realization of systems than on the design of so called ITS services[2], which are supposed to represent as "mobility services" an entire service segment to enable and provide additional value from the perspective of territorial and cross-border applications for both the implementer and provider side as well as for the user.

Considering that those discussions are not only about ITS systems (system architectures) rather than about extensive ITS services, the understanding of architecture in the transport sector must be formed in a new way, in the sense that whenever the concept of architecture is used, it must be made clear which aspects of an ITS or mobility service are being addressed.

2.1 The ITS pyramid

As a suitable meta-model and methodological tool for manageable and comprehensible representation and description of ITS services the "ITS pyramid" [STR12] (see Figure 1) is suggested.

The ITS pyramid

- consists of **five layers**, which together span the potentially possible field of observation and display area of ITS services.
- represents the **structural design of ITS services** to better identify the characteristics of ITS, classify them and to be able to relate them to each other.
- provides necessary semantics for the description of ITS and its business models.

[2] not to be mixed up with services in the traditional sense. ITS services are services for road users and travellers provided through the use of ITS - Intelligent Transport Systems.

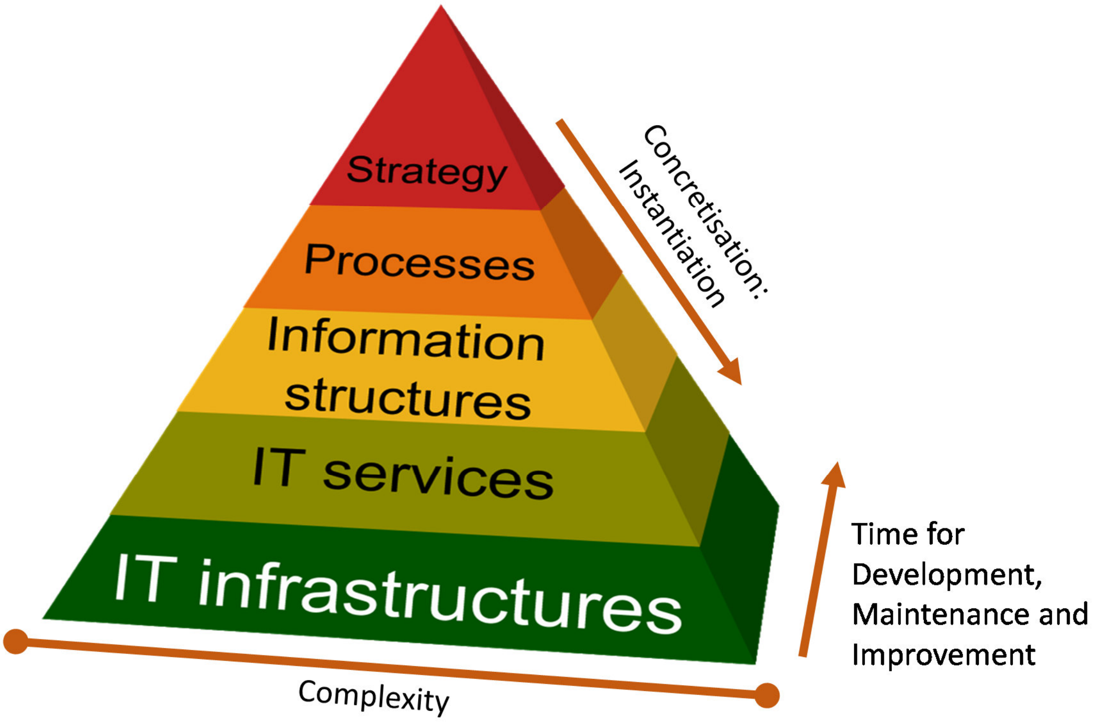

Figure 1: ITS pyramid

The basic structure of the five layers from top to bottom are described as strategy, processes, information structures, IT services and IT infrastructure:

- The **strategy layer** describes the long-term (visions), and the medium-term objectives (missions) of an ITS service, i.e. the benefits of the ITS service. The strategy is closely related to the business model of an ITS service.
- The **process layer** describes the actions of actors within their business processes and their day-to-day behaviour. Role models enable transferability by providing an abstraction from concrete organisations. Typical ITS service roles are: content owner, content provider, service provider, network provider. Typical role characteristics connected with a specific behaviour are for example public, private, external stakeholders. If networking requirements between actors are defined for the purpose of exchanging information or to act on a common basis (for example as part of a cross-regional or cross-border ITS service), then this is first form of a process description.
- The **information structure layer** deals with information that is generated by or processed in (business) processes. Information logistics, i.e. the collection and presentation of information and its distribution to relevant places where it is applicable can only be specified if appropriate information structures are mutually agreed by all stakeholders.

  DATEX II profiles serve as example for this layer.
- The **layer of IT services** (note: not to be mixed up with ITS services) describes the IT

services which have to be available to enable business processes to be "executed" and to implement the agreed information models. It focuses on the question: "How do the functions interact/ communicate with each other (specification of interfaces and data exchange mechanisms)?". The IT sector has developed proven and robust technologies to provide an abstraction from implementation details, e.g. the Service Oriented Architecture (SOA) approach. Ideally, applications use such an abstract, re-usable service mechanism to deliver their functionality.

DATEX II protocols serve as example for this layer.

- The **IT infrastructures layer** describes IT systems needed to ensure the execution of IT services and networking. In the Internet age, the execution of services can happen "somewhere" and is not bound to one specific place. An exception is the IT infrastructure for the delivery and presentation of information to users (terminals).

The ITS pyramid can be used in all phases of a content-based discussion on all relevant aspects of ITS. Above all, demands on changing role models can be identified and specified applying the pyramid. Although ITS services are implemented distributed, the ITS pyramid can always provide the logical context.

Note that SEAMLESS does not focus on the layers 4 and 5, which represent the IT world. Furthermore, layer 2 is covered by other ERA-NET ROAD projects and therefore kept to a minimum in SEAMLESS.

3 Architectures from recent projects and emerging standards

The first part of this chapter figures out C-ITS architectures of selected projects presented in the previous deliverables. The ISO outline for C-ITS standards is described afterwards. Current standardisation activities, which are going on in parallel, are described in the third part of this chapter together with their main architectures.

3.1 Recent projects

3.1.1 CVIS

The CVIS architecture consists of three subsystems, which are connected in a row

[CVS06], [2]:

- Vehicle System
    - ‘CVIS vehicles are used as a fleet of probes in order to monitor the complete traffic condition on road networks over geographical areas’.
- Roadside System
    - Traffic lights
    - Cameras
    - Variable Message Signs (VMS)
    - ….

- Central System
    - Service Centre
    - Control Centre
    - Home Agent
    - Authority Databases

The CVIS high level architecture does not explicitly highlight a kind of Roadside Station like other projects do. The connection between Vehicle System and Roadside System is done via air link; the connection between Roadside System and Central System is expressed as an IPv6 tunnel over the Internet. Although there is no direct connection between Vehicle and Central System visible in Figure 2, this connection is also intended in CVIS (V2C). Furthermore, Vehicle and even Roadside Systems can communicate with each other (V2V and I2I).

Terms like 'Service Centre' and 'Authority Database' as part of the Central System suggest some distinction between Private and Public Operators, but this is not expressed in an explicit way. Although called a 'high level' architecture, there is information about gateways, routers and hosts included. All of the three subsystems do have (different types of) these three elements; additionally, there are antennas placed on Vehicle and Roadside Systems.

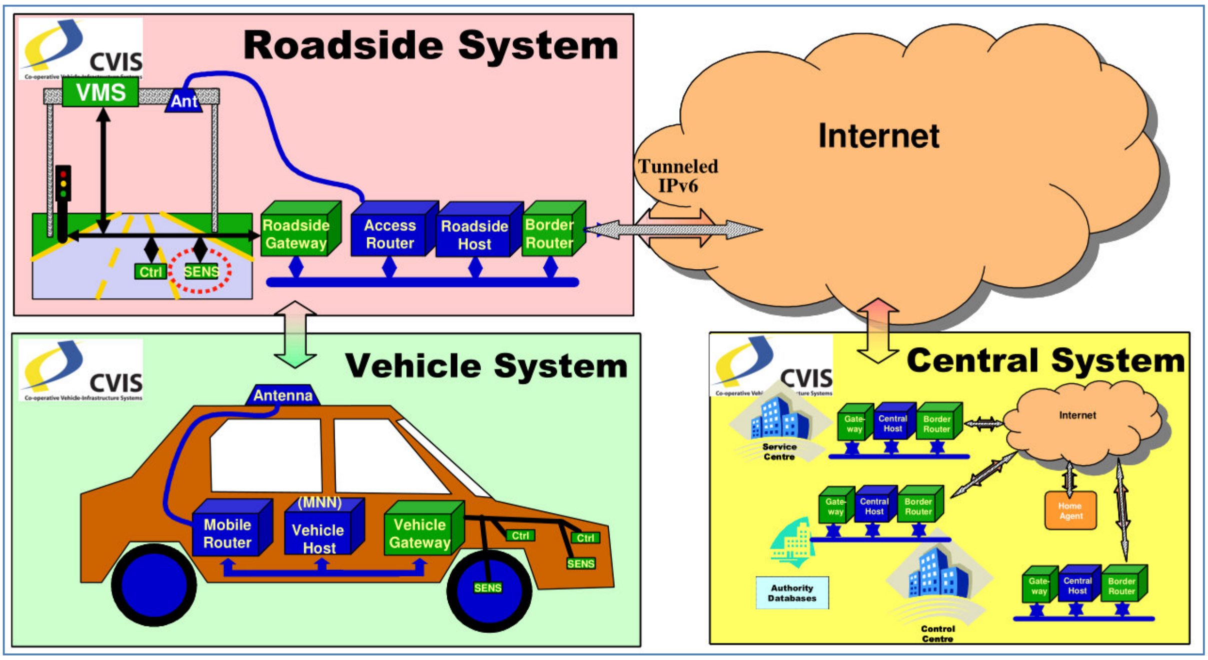

Figure 2: CVIS high-level system architecture

3.1.2 sim^{TD}

In the project Safe and Intelligent Mobility – Testfield Germany, Car-To-X Communication is used to define and to validate roll out scenarios for a couple of different traffic related functions. Key topics are efficiency, driving and safety as well as value-added services [SIM09], [10].

The sim^{TD} system architecture can be divided in these two basic subsystems:

- Vehicleside subsystem, consisting of ITS Vehicle Station and Human Machine Interface (HMI)

- Roadside subsystem, consisting of ITS Roadside Station and the so called Test Center (also called ITS Central Station)

The Test Center also incorporated the Test system, which can be seen as a third subsystem.

Figure 3 shows the main elements of the sim^{TD} architecture.

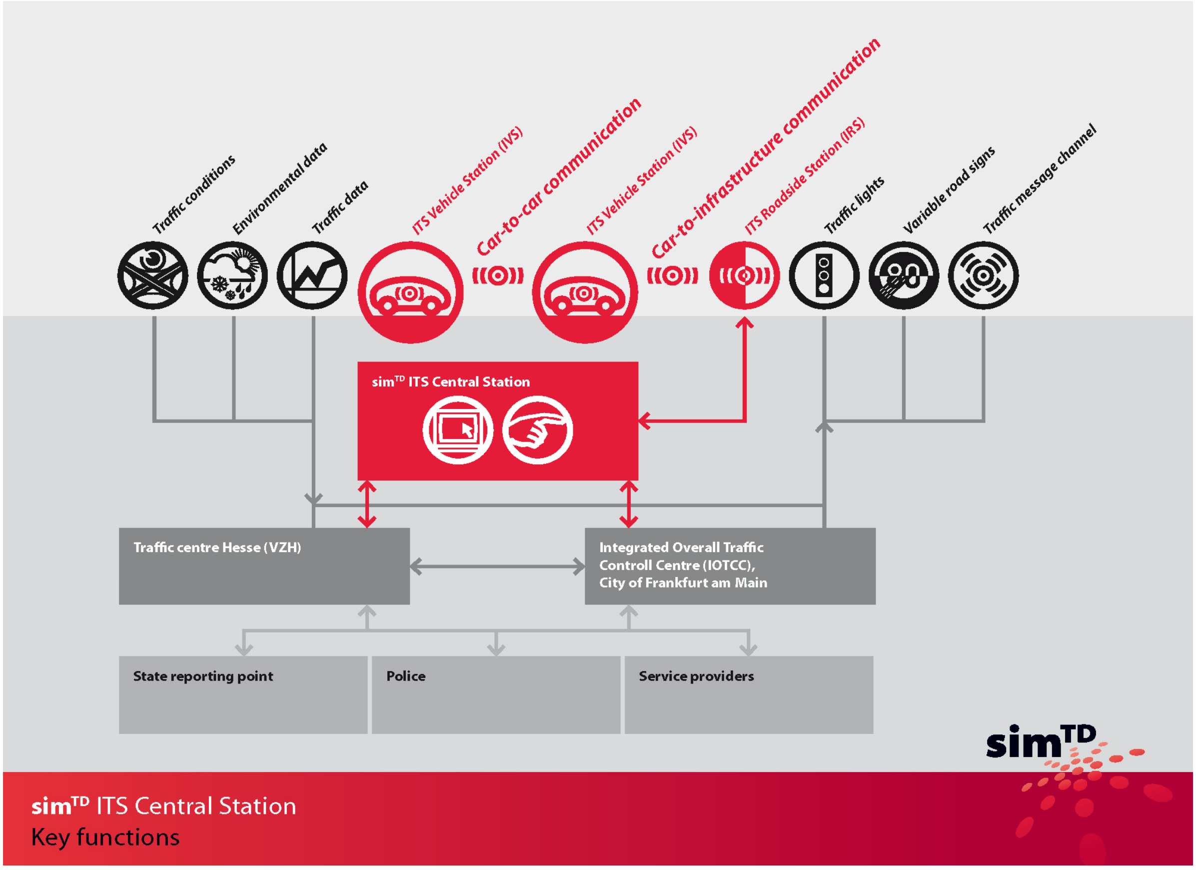

Figure 3: sim^{TD} architecture

The sim^{TD} architecture integrates basically three different communication channels that differ in technology and functionality:

- Direct communication from vehicle to vehicle and vehicle to infrastructure via communication standard IEEE 802.11p (ITS G5A). Most messages on safety and traffic efficiency require low latency and therefore are realized through this connection.
- For direct communication all vehicles are also equipped with IEEE 802.11b/g modules ("Consumer WLAN") to establish IP-based communications via the Internet with the Test Management Center or other back end services (for example used for internet or location based services or transfer of measured data).
- IP-based communication is possible all over the entire test area using GPRS, EDGE, UMTS or HSPA. Via access points for cellular networks (ETSI compliant: ITS International Mobile Telecommunications Public), forwarding and distribution of messages for safety or traffic efficiency between the highway and urban scenarios is realized. Also the Test Management Center uses mobile communication to transmit information to the drivers.

The processing of all messages up to the network layer is located within the vehicle, i.e. in the ITS Vehicle Station, to be more precise in the Vehicle Communication & Control Unit (CCU). Data from the Controller Area Network bus of a vehicle (CAN bus) can be received by a central component and provided to the functions.

Beside a few additional interfaces the same architecture (divided into CCU and AU [Application Unit]) is used for the ITS Roadside Station. Unlike ITS Roadside Stations along the highways, urban ITS Roadside Stations can control the traffic directly through a connection to the traffic light systems (see also chapter 6.2.3.1).

As a system-wide approach, the test system is deeply integrated into the vehicle and infrastructure-side subsystems.

3.1.3 DRIVE C2X

The project DRIVE C2X [11], which is still running, focuses on communication among vehicles and between vehicles, a roadside and backend infrastructure system.

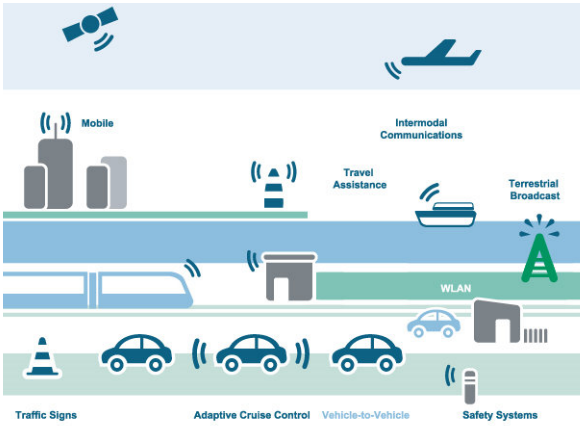

Figure 4: Drive C2X – communication between all systems

In contrast to previous projects[3], DRIVE C2X goes beyond the proof of concept of safety and traffic efficiency applications based on C2X communication. It addresses large-scale field trials under real-world conditions at multiple national test sites across Europe.

DRIVE C2X is guided by the definitions of COMeSafety, a project resulting in the European architecture for cooperative driving systems standardized in ISO 21217 and ETSI 302 665. This ensures compliance with existing and upcoming European ITS standards and a high level of long-term reliability for Road Operators and other stakeholders. Furthermore, DRIVE C2X has a successor project PRE-DRIVE C2X, which has prepared the technological basis. Thus the current project can benefit from the earlier development of specifications, hardware and software prototypes, test environments and integrated simulation tool sets.

The architecture of DRIVE C2X points out an ITS Roadside Station, which forms a central part and which is connected to an ITS Central Station Backend, and to the vehicles as well as to traffic lights and sensors. Beside that, ITS vehicle stations are also able to use an

[3] such as PReVENT, CVIS, SAFESPOT, COOPERS or PRE-DRIVE C2X

alternative communication channel, which does not involve the ITS Roadside Station.

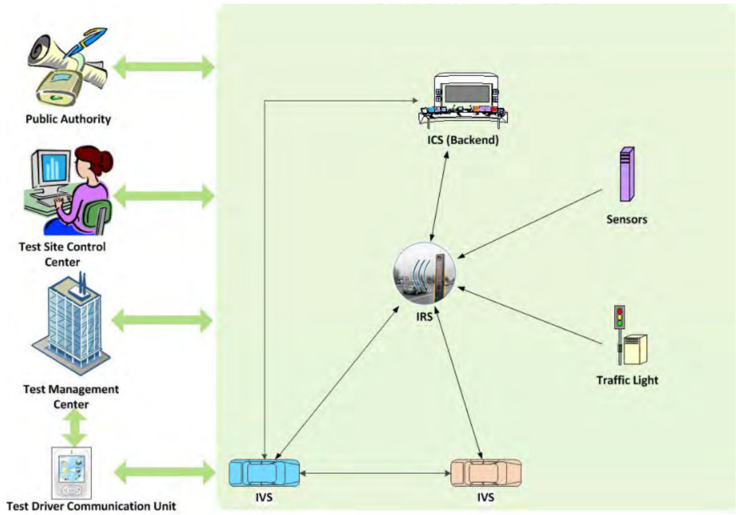

Figure 5: Drive C2X – system architecture [LYN11]

A closer look to the Roadside ITS Station (Figure 6) offers a couple of interfaces for wired and wireless communication with the internet, with sensors, with traffic lights and with other ITS Stations. In this project, the conglomerate of R-ITS and its interfaces is denoted as Road Side Unit (note that the ITS Station names come from ETSI standardisation and are introduced in chapter 3.3.2).

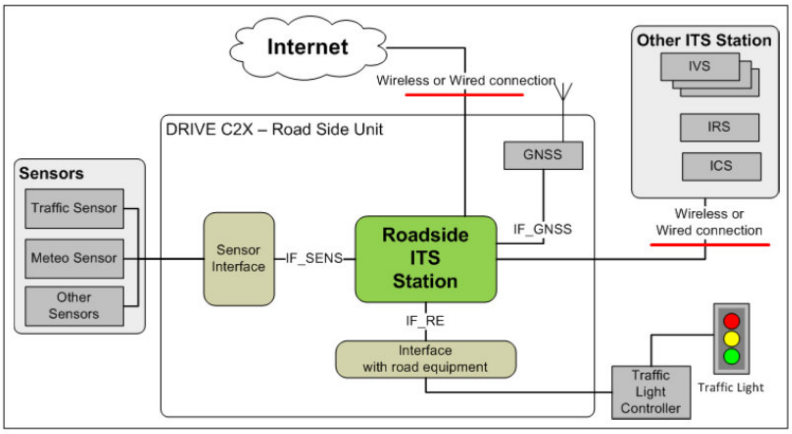

Figure 6: Drive C2X – Subsystem specification of the Roadside ITS Station

In Drive C2X, the traffic lights and its controllers are clearly separated from the R-ITS Stations / RSU. This need not be the default scenario for cooperative systems, as chapter 6.2.4 will show.

3.1.4 Score@F

This still running French project [12] aims to significantly improve traffic flow and road safety by using vehicle to vehicle and vehicle to infrastructure communication. Validating the technological choices suited for cost-optimized service and validating the economic feasibility of a deployment scenario are the main objectives. As there is a collaboration with the DRIVE

C2X project, the architecture picture found in [LON12] is quite similar to the architecture presented above. One new element is a nomadic device with connections to vehicles and the traffic management centre. For the project setting itself, an Operation Control Centre and a Technical Assessment Centre round out the picture.

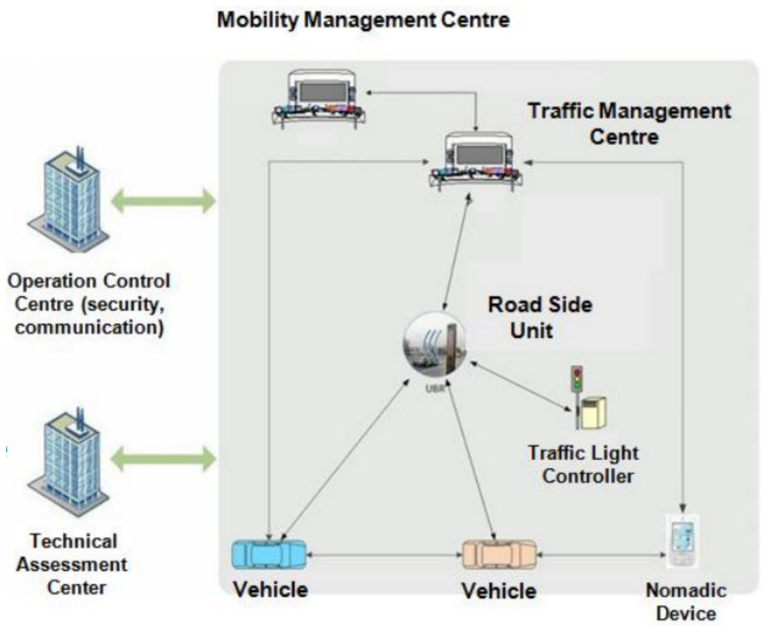

Figure 7: Score@F-Architecture [LON12]

3.2 Outline for cooperative ITS standards

ISO TR 17465-1[4] sets out terms, definitions and outline guidance for standards documents. The basic concept to describe a C-ITS application standard should follow this 10-parted manner:

Part 1	Architecture/Application Base Standard
Part 2	ITS-station Management
Part 3	Security/Privacy Set
Part 4	Data Set
Part 5	Interface Set
Part 6	Network/Protocol Set
Part 7	Identifier Set
Part 8	Facilities/API Set
Part 9	Conformance Testing

[4] under development

Part 10	Safety Set

Figure 8: Outline for C-ITS standards according to ISO TR 17465-1

The ISO TR claims cooperative ITS stations to be some kind of wireless communication resp. wireless internet platforms, but with higher demands regarding aspects like security, multiple communication media and real-time exchange. But there are also aspects of non-critical data transfer, which is usually based upon a more ‘traditional’ architecture.

Legacy ITS systems however are usually developed from independent systems or networks, which can perform a set of tasks on their own, mostly using proprietary standards. As these tasks can be fulfilled by distributed ITS services today, there is the need to include these legacy systems into the cooperative world and to standardize as many connections as possible.

This collaboration between Cooperative ITS Environments and Legacy Systems is shown in Figure 9 (for the concept of ITS stations, see chapter 3.3.2).

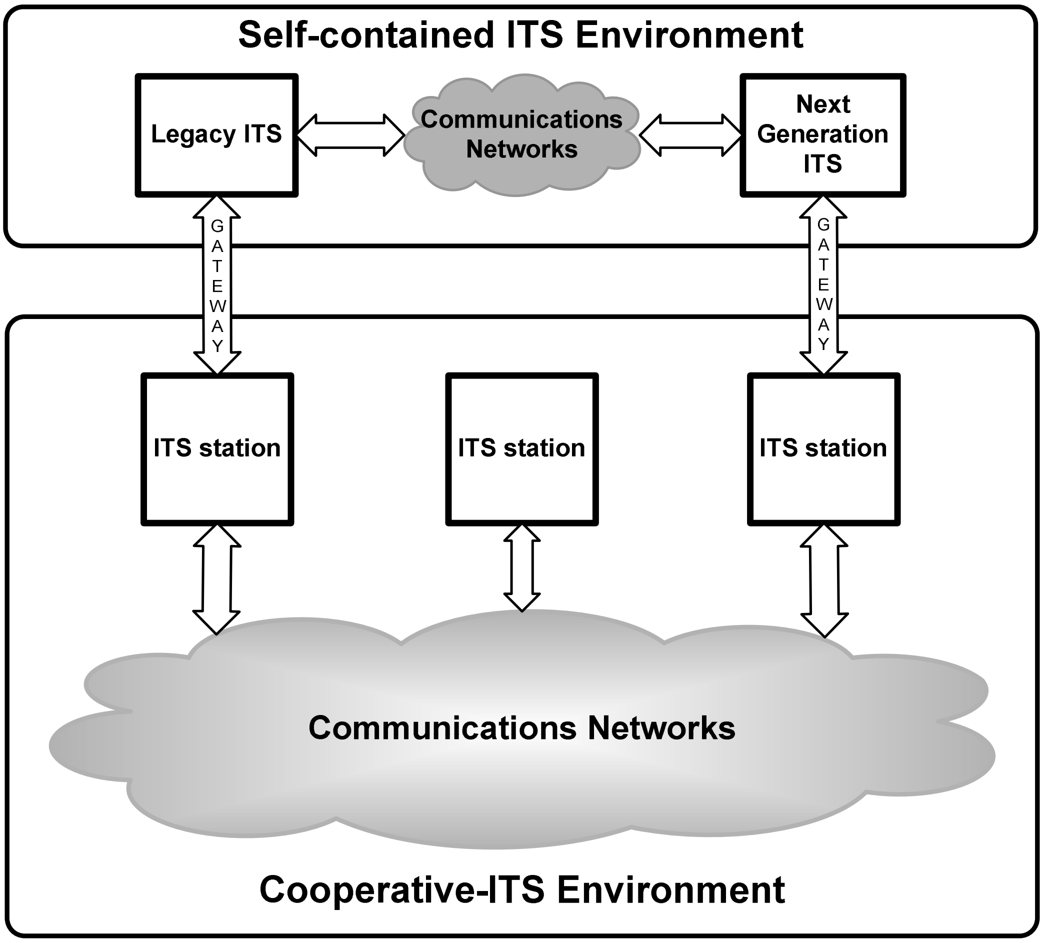

Figure 9: C-ITS Environments in a network perspective (ISO TR 17465-1)

The high-level view for the architecture of an ITS station is visualized in the following figure from ETSI EN 302 665:

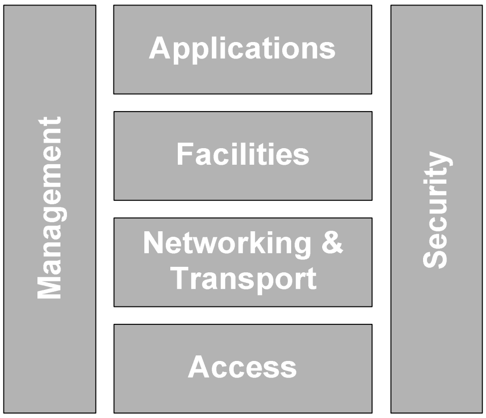

Figure 10: Reference architecture communication perspective (from ETSI EN 302 665)

Beside network and communication, *ISO TR 17465-1 also points out the following perspectives:*

- a service/application perspective - a viewpoint of sharing data between ITS applications or between services and making it available to the end users.
- a cooperative activity perspective - about the interaction between ITS stations with services and the exchange of safety related or real time information.

Typically, ITS stations cannot perform complete tasks on their own, but with the interaction of different services on different ITS stations (no matter if in vehicle, at roadside or in the centre) the cooperative ITS will be able to fulfil all the huge variety of different ITS requirements.

3.3 ITS architecture standards landscape

3.3.1 Mandate M/453

With the Mandate M/453 of the European Commission, the European Standardisation Organisations (ESO) were invited to prepare a coherent set of standards, specifications and guidelines to support European Community wide implementation and deployment of Co-operative ITS systems.

In April 2010, CEN and ETSI provided a joint response to Mandate M/453 and defined a minimum set of standards for interoperability.

In February 2012, the 2nd joint CEN/ETSI-Progress Report provides a more extensive list of standards that have been finalised and a plan with timelines and milestones for still open issues where standards are not yet finalised [ECM12].

The following table shows the arrangement of topics for the ISO and CEN working groups:

	ISO/TC204	CEN/TC278
ITS Warning & Control Systems	WG14	
Short Range Communication (DSRC)	WG 15	WG 9
"Wide area" Comm. Systems	WG 16	
Nomadic Devices	WG 17	
Human Machine Interaction(HMI)	ISO TC22	WG 10
Recovery of stolen Vehicles		WG 14
eSafety	WG16	WG 15
Nomadic Devices	WG17	
ITS Co-operative Systems	WG18	WG16

Figure 11: Topics for ISO- and CEN working groups [ITS10]

The Minimum Set of Standards defined in the Mandate M/453 is separated into

- General Standards
- Application standards
- Facility standards
- Access and media standards
- and Management standards.

Some of them are already published (Access and media, Management, some of Application and Facilities), others are yet to come within 2013. Most of them will be part of the 1st release of standards for C-ITS.

Especially some standards of interest for this project have the following perspective:

Name	Organisation	Standard	Expected
Traffic Signal Phase and Timing Message (SPaT)	CEN/TC 278 WG 16		End 2013
Intersection topology (MAP)	CEN/TC 278 WG 16		End 2013
Signal Request Message (SRM) and Signal Status Message (SSM)	CEN/TC 278 WG 16		End 2013
In-vehicle Information	CEN/TC 278 WG 16		End 2013
Localized traffic information	CEN/TC 278 WG 4		Not started
Definitions and document structures for Cooperative-ITS related standards *See chapter 3.2*	ISO/TC204 WG 1	TR 17465	April 2013

Name	Organisation	Standard	Expected
Roles and Responsibilities in the context of co-operative ITS *See chapter 3.3.1.1*	CEN/TC 278 WG 16	TS 17427	April 2013

Figure 12: Timetable for selected standards in response to M/453

3.3.1.1 Roles and Responsibilities

Currently, CEN/TC 278 WG 16 and ISO/TC 204 WG 18 are working on a standardisation of an organisational architecture for C-ITS. The Technical Specification for ‘Roles and Responsibilities’ (TS 17427) will give a guidance to build up organisational architectures within particular implementations in the field of C-ITS.

The following four top-level roles have been identified [CTS13]:

- Policy Framework
- System Management strategic and System Management operational
- Service Operation
- Using of Service

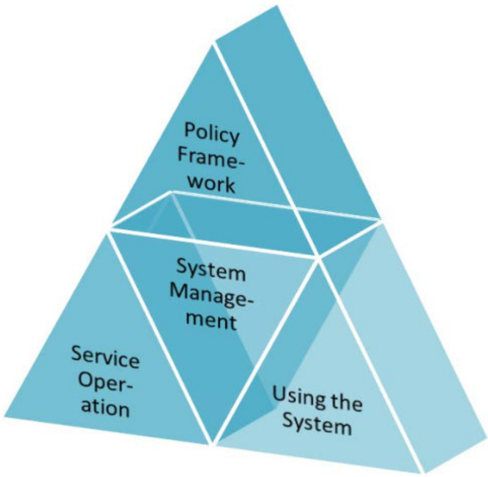

Figure 13: Top level roles for an organisational structure of Cooperative Systems [CEN TS 17427, CTS13]

For each of these roles, up to as much as seven sub roles are defined, each with a catalogue of specific tasks which allocate responsibilities. All these tasks are part of interactive processes, so there are a lot of well-defined transitions between them. Special care must be taken to legal issues, so there is the recommendation to entitle a responsible for the entity of the end-to-end service.

The technical specification is scheduled to be published in April 2013.

3.3.2 FRAME architecture

The European ITS Framework Architecture ("The Frame Architecture") was established by the project KAREN in 1998-2000. Cooperative Systems were added to the architecture in 2008-2011 in the project E-FRAME.

As the architecture is quite large, it is provided in form of a browsable html structure[5].

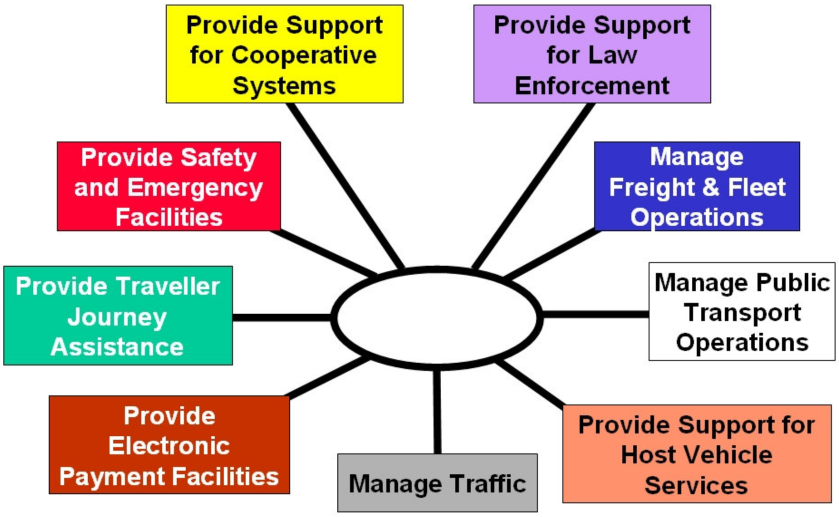

Figure 14: Functional Areas of E-FRAME Architecture[6]

The E-Frame architecture is divided into nine Functional Areas (see Figure 14). One of them is labelled "Provide support for cooperative systems". It includes management of priority for other vehicles, the use by non-public transport vehicles of any spare capacity in bus lanes, vehicle access to sensitive geographic areas within the road network, special routes for hazardous goods vehicles and urban loading zones.

Functional Areas (more precise their functionality) are able to exchange data with some of the others, therefore, a hierarchy of in- our outgoing data flows is defined between the nine elements.

A lot of 'Terminators' are defined, to interact with the surrounding world (see elements arranged in a circle in Figure 15). A Terminator may consist of a number of Actors, each of which represents a specific sub-set, e.g. the 'Driver' Terminator has an actor to represent a driver of each type of vehicle such as private car, public transport, emergency, goods, etc.

[5] http://www.frame-online.net/node/33

[6] From http://www.frame-online.net

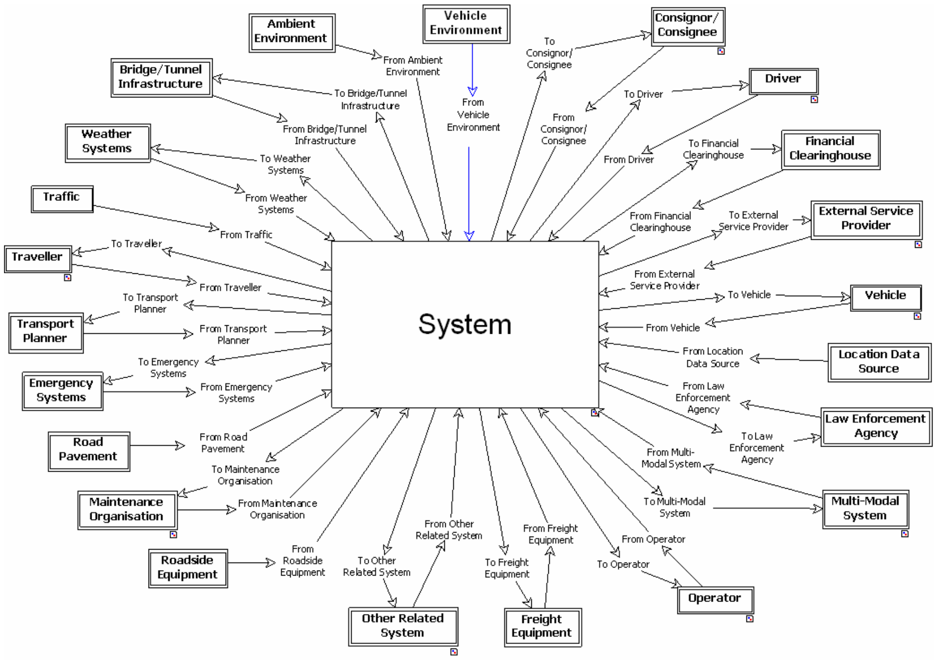

Figure 15: The FRAME architecture context diagram

Furthermore, there is a process defined to create sub sets out of the frame architecture, which considers especially user and stakeholder needs (see Figure 16).

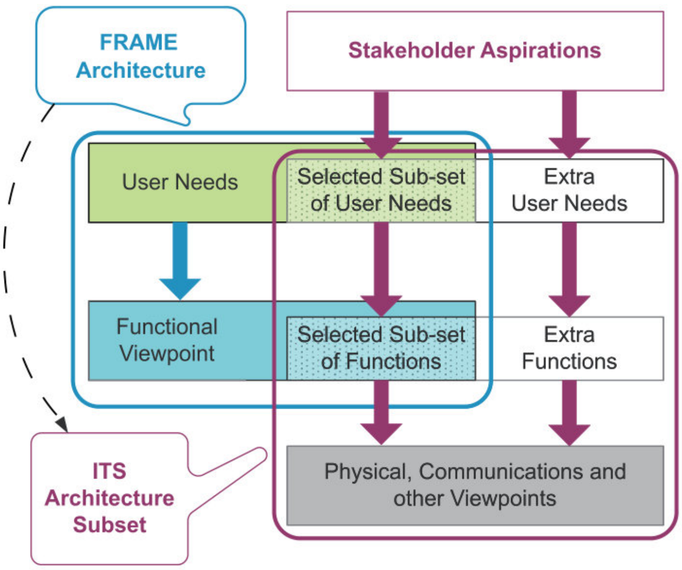

Figure 16: Process for creating sub sets of FRAME Architecture [FRA11]

3.3.3 ETSI

The key architectural standard is EN 302 665 [ETS10]. The ETSI ITS architecture consists of four subsystems:

- Personal ITS subsystem (Hand held devices)
- Vehicle ITS Station
- Central ITS sub-system

- Roadside ITS sub-system

Figure 17 shows these subsystems within an architectural view, connected by the ITS peer-to-peer communications.

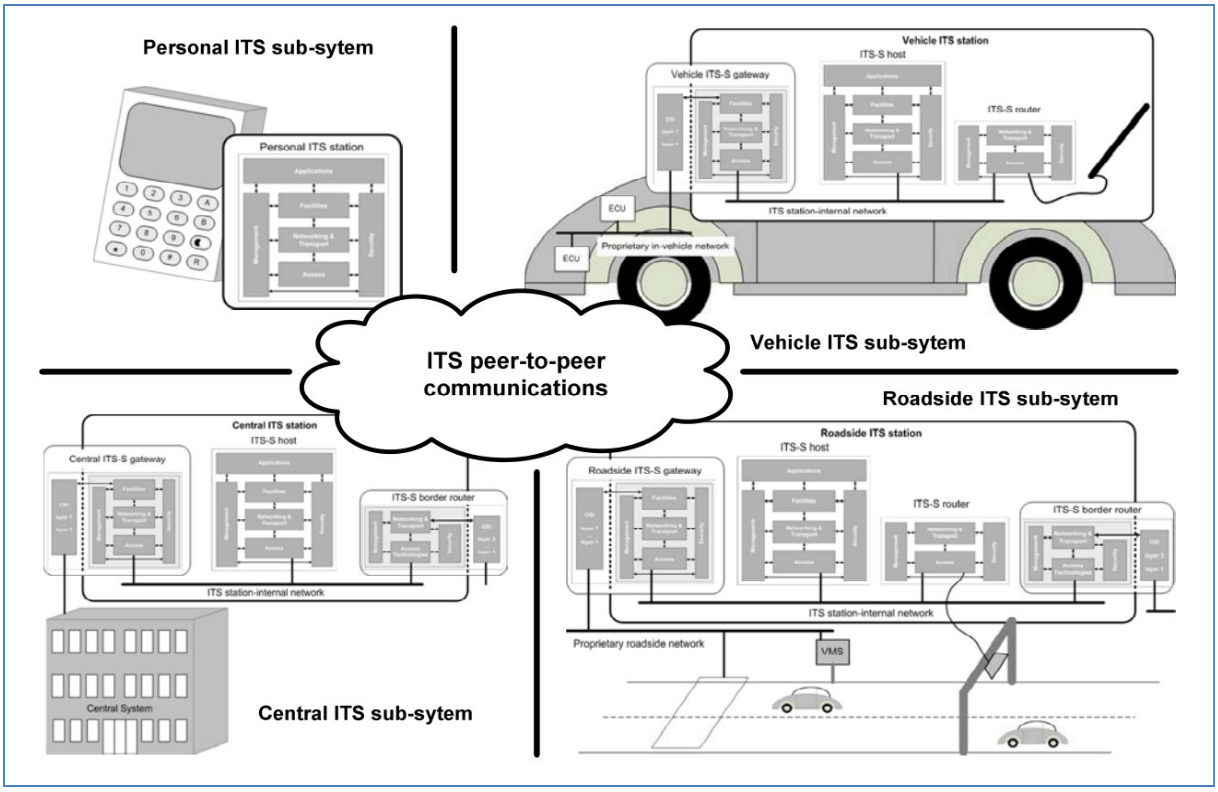

Figure 17: Illustration of ITS sub-systems

The next Figure shows a specific interpretation of the Roadside ITS subsystem (RIS) of the ETSI ITS-Station architecture developed by the DriveC2X project. It contains all elements needed for the implementation of the Traffic Signal Assistance use cases, namely the application logic and the SPAT message. In the Drive Project the link to the existing traffic lights ("legacy system") is realised by the Road Equipment Management as part of the facility layer.

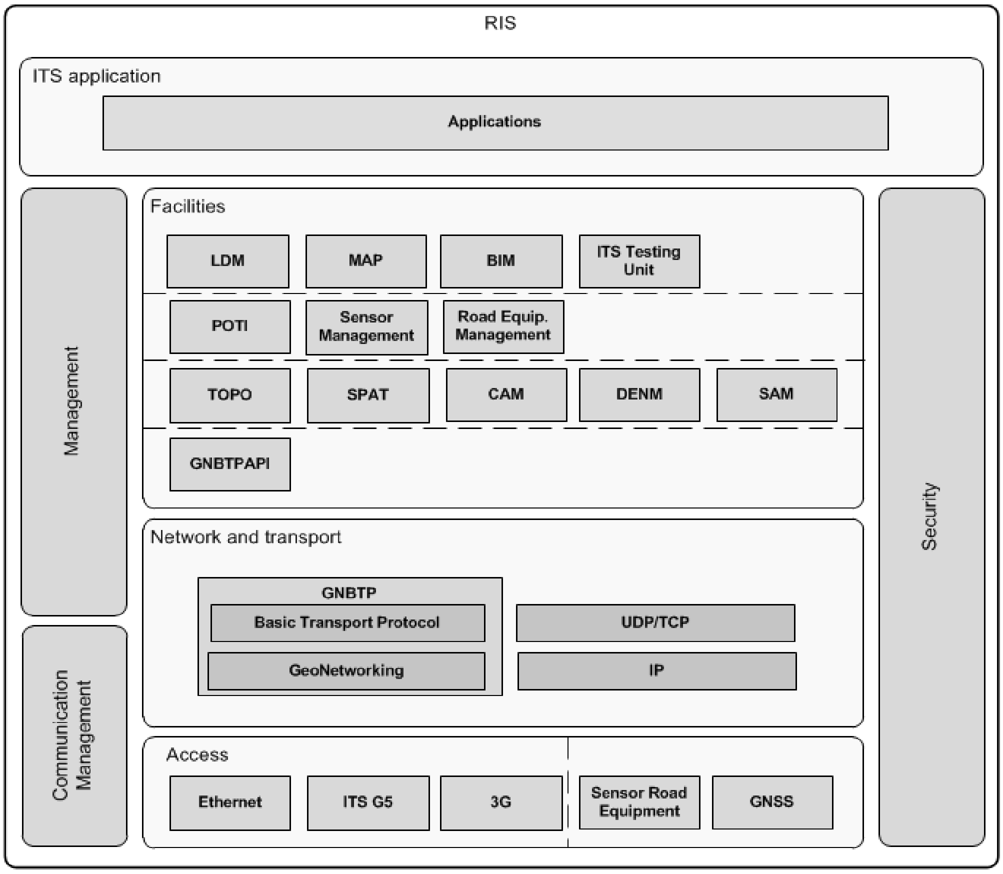

Figure 18: ETSI ITS-Station RIS

An ETSI-compliant interpretation of OCIT-Outstations will be shown in chapter 5.2.3.

3.3.4 CALM architecture

To remove technology barriers between different regions, ISO TC 204, Working Group 16 worked out the Communications access for land mobiles (CALM). It is supporting user transparent continuous communications and an open way to combine GPRS with vehicle-optimized WLAN technology.

The cooperative concept of CALM relies on seamless communication, support of multiple media and the possibility to adapt latest communication technologies. The corresponding applications can be designed independent of their communication (common API support), and furthermore elements like security and facility support as well as improved traffic safety communications are included in the concept.

Basic communication scenarios of CALM are depicted in the following figure:

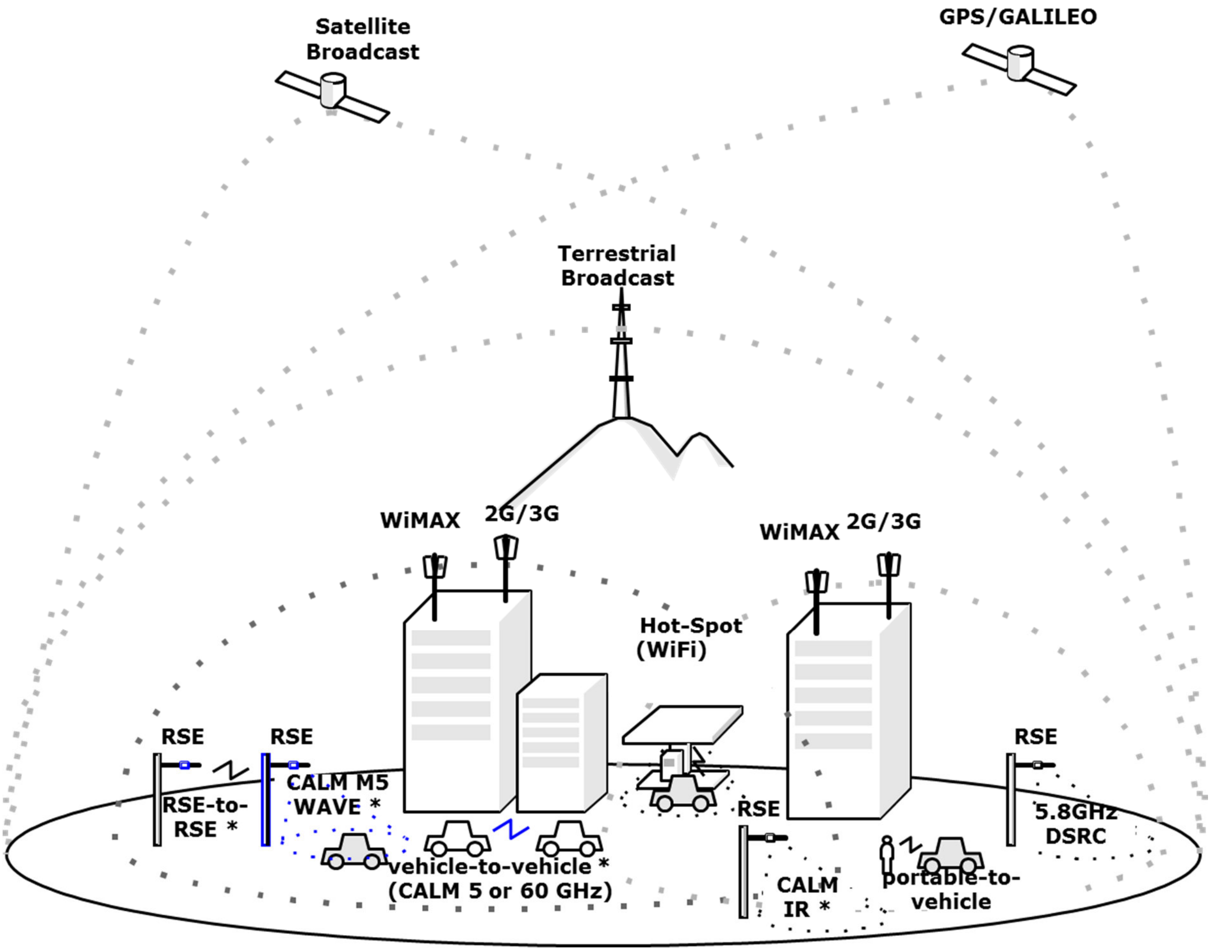

Figure 19: CALM communication scenarios

CALM architecture is defined in ISO 21217:2010 (currently being harmonized with ETSI EN 302 665), with conformance and testing the subjects of a current ETSI work item to lead to the Technical Specifications TS 102 984-1 and TS 102 984-2.

4 Reference model for C-ITS architectures

4.1 Generic model with focus on linking legacy

The subsequent figure shows a generic architecture for ITS. It covers all relevant C-ITS compontents and communication channels. Starting with this overall view, explicit and detailed architectures can be tailored from it for specific situations and systems.

The generic model is divided into components mostly driven by Service Providers and components mostly driven by Road Operators. For Central ITS station (C-ITS-S) as well as for Roadside ITS stations (R-ITS-S) both parties might operate instances of these components in suitable system environments.

According to their main task and behaviour, all components are clustered in layers named Central, Field and Mobile. Each of the components can be seen as an independent system including different subsystems and back ends. Usually, these subsystems contain different services or back ends, which can be seen as black boxes. They need to provide several services or functionalities, but their inner structure or even implementation is not part of this generic architecture.

There are still a lot of legacy systems, on the Service Provider side as well as on the Road Operators side. Usually, those systems do not yet communicate with vehicles directly, so it is a challenge to connect them to new vehicle services. One possibility is to establish communications between the new Service Provider systems and the Road Operators' legacy systems, which can be seen right in the middle of Figure 20.

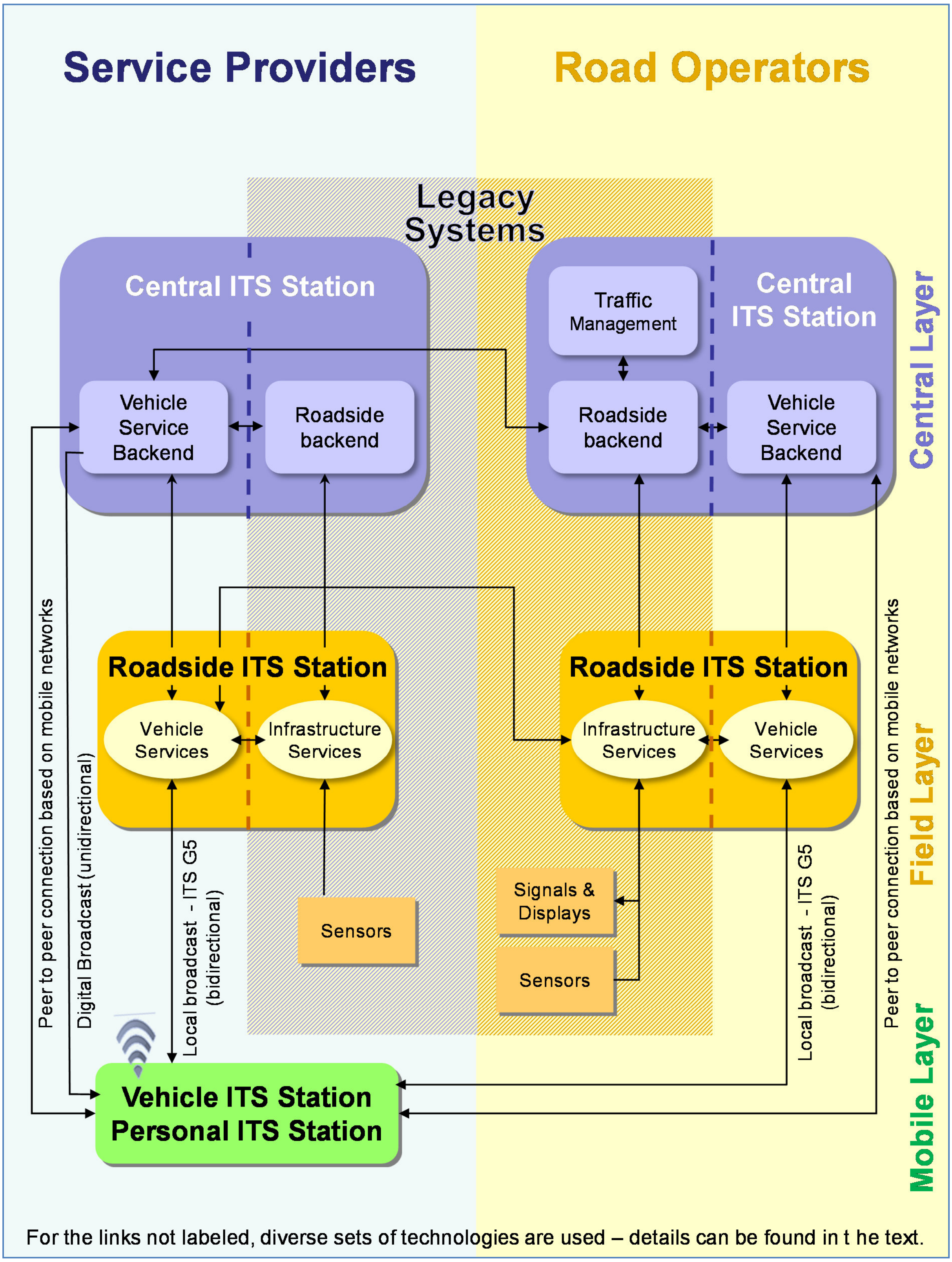

Figure 20: A generic ITS model

The connections from and to the Vehicle ITS Station (V-ITS-S), and also the Personal ITS station (P-ITS-S, mobile devices of end users), are designed as air links. Usually all ITS stations are able to communicate with other ITS stations, i.e. a V-ITS-S can exchange data with other V-ITS-S (with or without using an R-ITS-S, for example).

4.1.1 Central ITS Station (Central Layer)

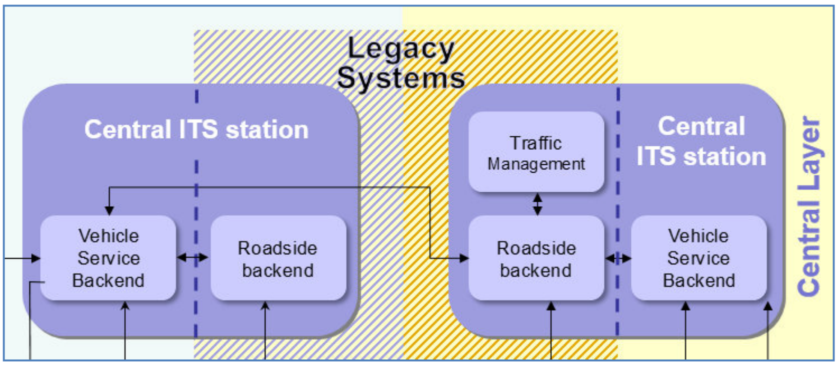

Figure 21: Central ITS-Station (Central Layer)

Central ITS Stations can be driven by Service Providers as well as by Road Operators. In the latter case, the services running on a C-ITS-S can be named Central System Services (for example represented by traffic computers). For the private sector, the services on the C-ITS-S can be named Private Services.

Cooperative Systems enable the direct communication between C-ITS-S and vehicles (rightmost arrow in the image section above) and therefore enable a connection between Traffic Management Centers (as part of a C-ITS-S) with vehicles. It is a powerful tool to establish new services in the field of traffic management. From a business viewpoint it extends the concept of public RDS/TMC-services. Future TMC-system-architectures must be extended by a vehicle service backend.

In general, a C-ITS-S should be able to communicate with a Roadside Station as well as with vehicles, using appropriate back end systems.

4.1.2 Roadside ITS Station (Field Layer)

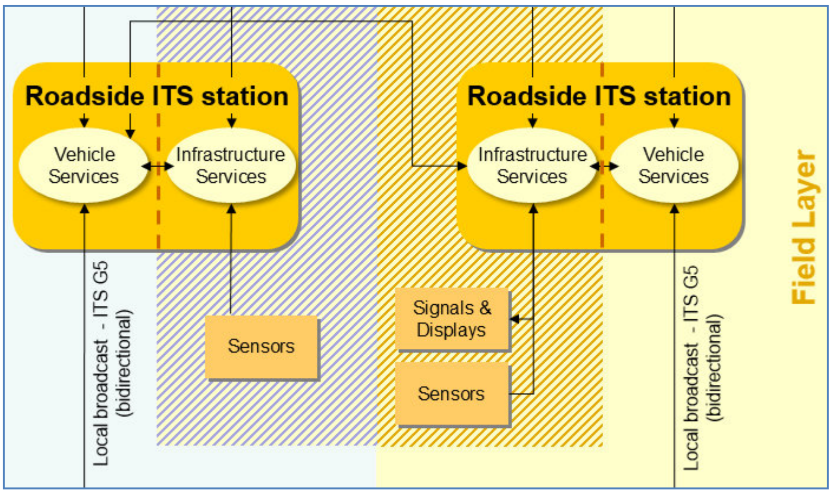

Figure 22: Roadside ITS Station (Field Layer)

The R-ITS-S has a link to C-ITS-S and V-ITS-S. But likewise it possible (with appropriate interfaces) to act as a link between legacy systems and new cooperative system components – depending on architectural decisions. More than for all other components of the generic

ITS architecture, exact role, placement and operator of an R-ITS-S are not entirely clear. Those aspects may vary a lot in different situations, circumstances or implementations. That is why the R-ITS-S is located on the Public Authority side as well as on the Service Provider side in Figure 20:

- R-ITS-S driven by Service Providers
  Operation and control of the R-ITS-S is done by private service providers. Examples include systems on private motorways.
- R-ITS-S driven by Road Operators
  Operation and control of the R-ITS-S is done by Road Operators. Examples would be R-ITS-S connected to traffic signal controllers which are also operated by Road Operators.

The R-ITS-S typically covers services for infrastructure and services for vehicles. The communication connection between these two parts is a very interesting one, as it forms the link between legacy and 'new' cooperative systems features – it might be also available across the different ownerships of the R-ITS-S (see Figure 22). Nevertheless, the shape of the infrastructure services can vary in real system environments:

- Infrastructure services located in independent systems
  (field devices, e.g. traffic light controller)
  - without any link to the vehicle services (i.e. the legacy system cannot communicate with the Mobile Layer directly, but only with the Central Layer)
  - with an external link to the vehicle services (i.e. the legacy system can use this connection to communicate with the Mobile Layer)
- It is also conceivable to combine infrastructure services and vehicle services in one system with an internal interface between them.

Examples for these different architectures can be found in chapter 6.2.3 and 6.2.4.

4.1.3 Vehicle ITS Station / Personal ITS Station (Mobile Layer)

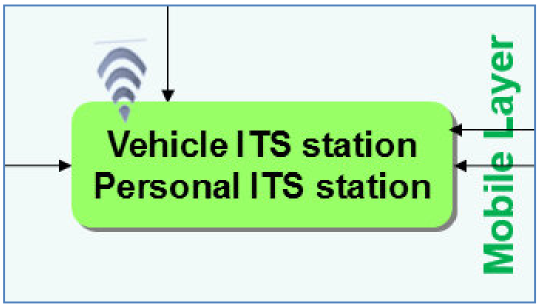

Figure 23: Vehicle ITS Station / Personal ITS Station (Mobile Layer)

In the Mobile Layer, vehicles on the one hand and mobile end systems on the other hand are conglomerated (note that R-ITS-S can also be 'mobile', e.g. for dynamic usage in case of roadwork, but even then they are not part of the Mobile Layer, as the Mobile Layer focusses on the mobility of the end-user).

These systems are connected via air link. Typical communication forms are the unicast cellular mobile communication (point-to-point) or broadcasts (as well uni-directional). For the communication between ITS-S, ETSI defines the medium range communication technology

ITS G5 (harmonised with ISO CALM M5, WAVE, and IEEE802.11p).

4.1.4 Test viewpoint

It is good practice to include consideration of testing and testability within architectures. In the Seamless generic architecture each component boundary uses defined interfaces and should be testable. Each layer within a layered framework architecture such as that developed by ETSI also presents a test point.

4.2 Hybrid communication

The architecture presented in the chapter above shows that there is not just a single solution for the delivery of data to the end user. This becomes even clearer in chapter 6.2.4, where the reference architecture is tailored with the use of different communication chains.

In fact, a Road Operator has to decide very carefully which kind of communication media he likes to use to spread his information. In most cases it will turn out that the best solution is to use more than one communication channel. Reasons might be:

- Higher reliability (redundancy) → ensuring quality
- Better coverage (service is available in a wider area)
- Different type of end-uses (e.g. mobile devices vs. in-car-signage)
- Different type of data (e.g. data amount), which forces different technologies

To examine these (dis)advantages and different types of technologies, testing is an important activity in a pre-operational phase.

Even though it might be the case that different sorts of data are published (see bullet point #4), it is more interesting to have a closer look at the distribution of the same sort of data through different channels:

The most important requirement for this case must be to provide the customers with a consistent set of information – consistent in terms of content as well as in terms of timing issues, i.e. information must not be outdated and must match to information sent out through other channels. A customer whose mobile phone gives travel times which differ from those on the fixed installed VMS for the same trip will not rely on either information. This may lead to damaged perceptions of the quality of the road operator's service.

In consequence, the Road Operator must utilise reliable channels with adequate[7] latency, where data must not be modified during transport[8]. Usually, parts of the communication chain are not under full control of the Road Operator (think of Service Providers or maybe other Road Operators), which make this requirement even more crucial.

On the other hand, the decision on which communication channel to use cannot be made in a haphazard way. A lot of restrictions and interactions have to be considered:

- Real time (-like) information has to be delivered via as few hubs as possible, and of course, with low latency. The channel has to have a good quality and reliability;

[7] A guaranteed maximum latency which is adequate for the respective application

[8] This must not be wilful. Several transformations from one data format into the other, maybe accompanied by rounding issues, might led to different outputs, just like in Chinese Whispers.

usually, no acknowledgements are sent. The data structure has to be very small, so the amount of data is limited. It is a good practice to transmit only offsets or only changed values. Examples could be the remaining seconds of green or red on a traffic light.

- Structural data requires a high bandwidth for a huge amount of data. The frequency of update is low, and the requirements for latency are not difficult. Because of the data's size, it can be useful to send only on request and/or to give acknowledgements after receiving. Examples could be the transfer of geospatial information for an intersection (see chapter 6.3.5) or the complete signal program information of a traffic light controller.

There are shades of grey between these two examples, and a detailed strategy is required to best distribute all information:

- The target application determines the sort, amount and frequency of required data.
- Also the other way round: The available data affects the application format.
- The source and the provider must have this data available; extra care is needed if several sources need to be tapped.
- The sort of data determines the communication channel and gives requirements for its characteristics (bandwidth, latency, point-to-point or broadcast, …)

  Note that there is usually more than one channel in the communication chain, so the lowest quality standard of all used channels must match the requirements.
- The required chain of communication channels must be available for this task[9] and all involved stakeholders / service providers need to agree on it (including legal and financial issues for this data transfer)
- The sort of data determines the data model, which must match to the required channel characteristics
- The data model must be represented in the used communication standard, which must be available for this link.
- The applications must support the respective standard used on the connected link (or taking use of some gateway)

Furthermore it must be considered that especially the Service Providers are in competition. Different types of channels are used to set them apart from the other competitors. Thus a strong and healthy market exists, but it forces Road Operators even more to do precise checks on the technologies offered.

5 Mappings to existing standards

Specifications for seamless traffic data dissemination have to consider trans-national requirements and also national adaptations to fit with well-established national architectures such as those defined by UTMC [3] and OCA [4]. Further basis is DATEX II [5] (recently adopted as CEN Technical Specification 16157) and the TMC and TPEG specifications (see

[9] Also including the question of free capacities due to other services on the same link.

TISA [6]). This also takes into account the currently agreed common work between EasyWay [9] and TISA on consistent modelling of data along the value chain, especially the interoperability between DATEX II and TPEG.

In consequence, this chapter maps the reference architectures for UMTC as well as for the OTS standard against the SEAMLESS reference model introduced in chapter 4. Furthermore, the DATEX II – TPEG cooperation is described.

5.1 UTMC mapping to SEAMLESS reference model

5.1.1 UTMC reference architecture

Background to UTMC was described in Seamless Deliverable 1. To describe architecture, UTMC uses a "logical reference model" and a "functional reference model".

The logical reference model is illustrated in Figure 24.

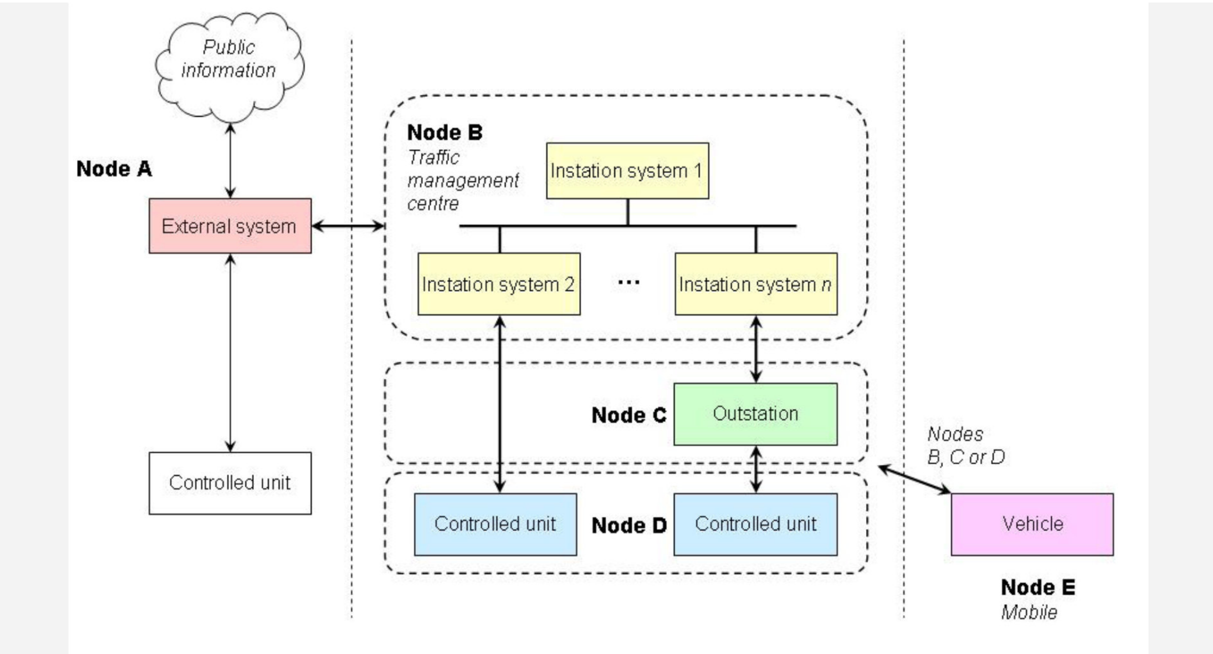

Figure 24: UTMC logical reference model

The UTMC "functional reference model" distinguishes:

- user interface
- applications
- system management services
- communications services
    - information level
    - application level
    - transport level
    - sub-network level
    - plant level

and arranges these concepts in the following layered model:

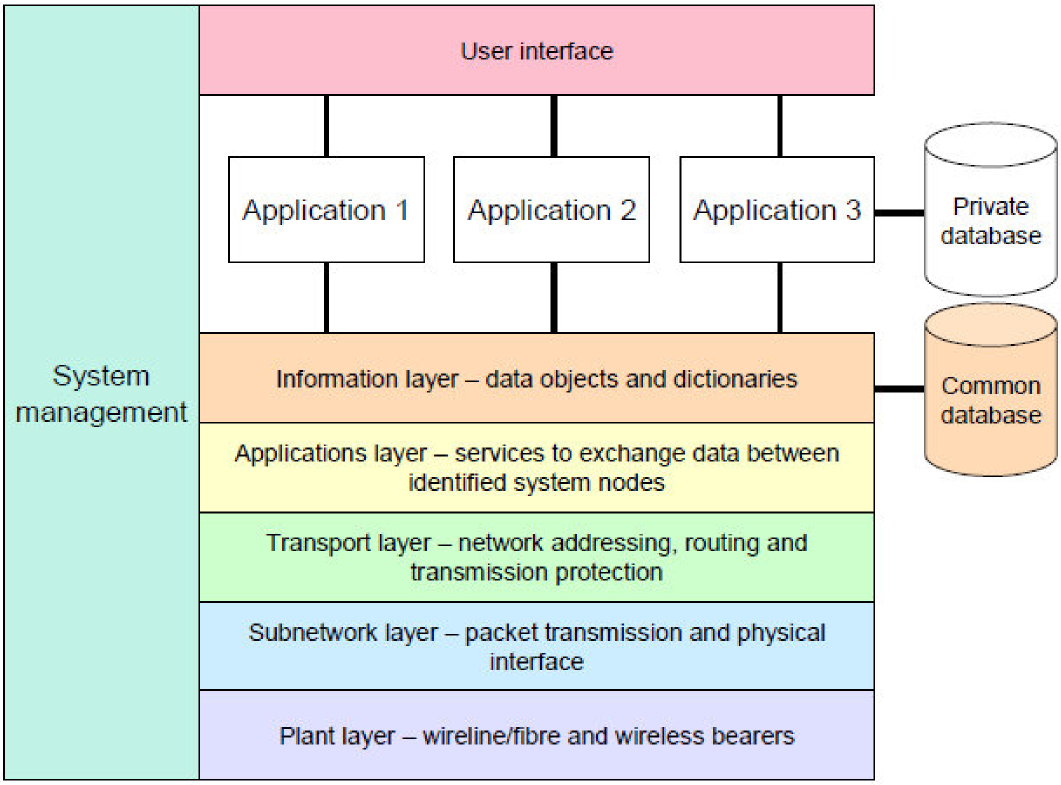

Figure 25: UTMC functional reference model

(Please note that the meaning of the colours used in Figure 24 and Figure 25 do not correspond).

There is further specification for each of these layers and areas available. Despite the wide scope of these specifications, the notion of UTMC compliance is defined primarily for communications interfaces – which must individually comply with the aspects of UTMC specifications that are relevant for that interface.

In practice systems often have a mixture of UTMC and legacy interfaces, i.e. only some of the connections shown in the "logical reference model" are UTMC-compliant.

5.1.2 Mapping to SEAMLESS reference model

The UTMC logical reference model can be understood to relate to the Seamless generic model as shown in Figure 26.

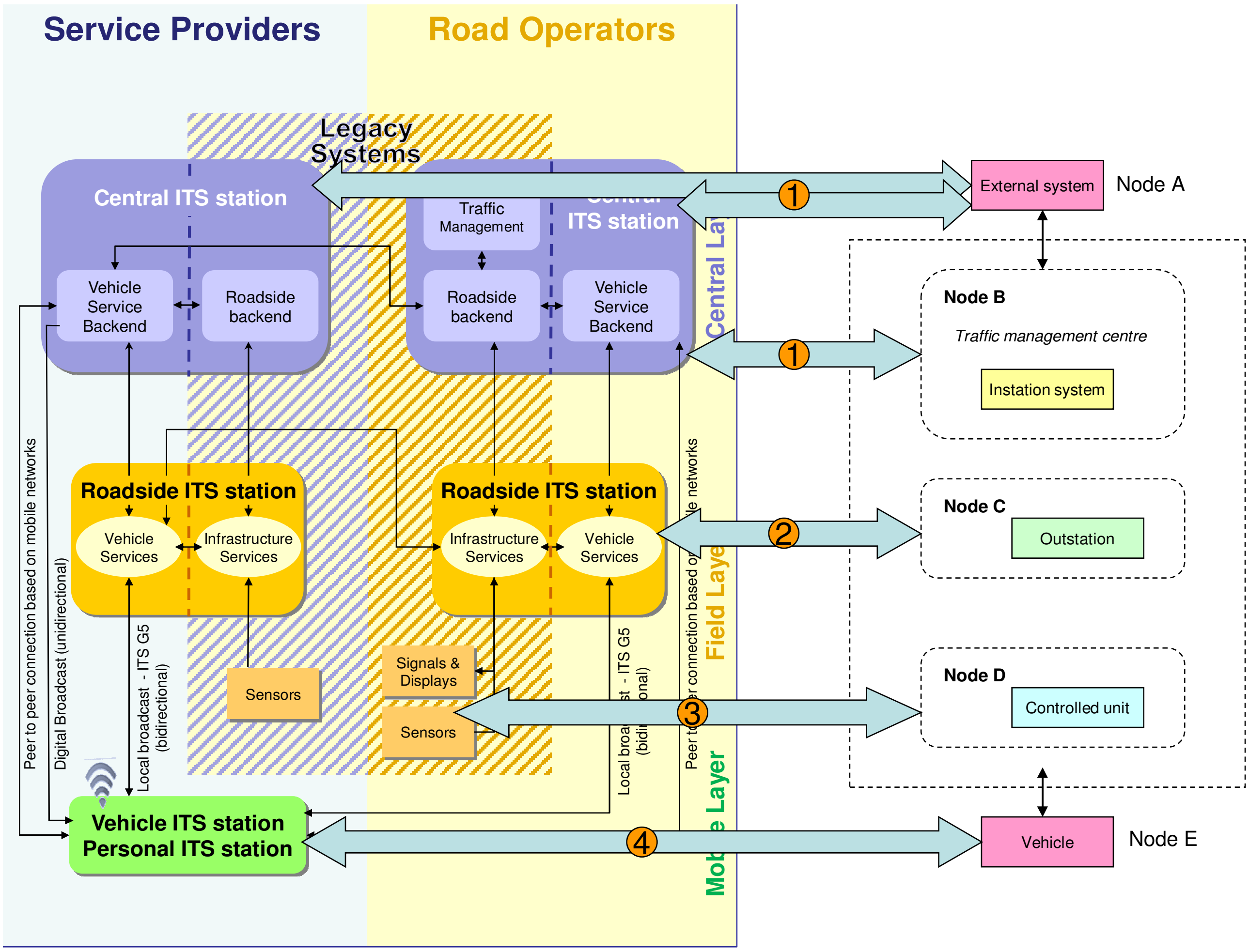

Figure 26: Seamless – UTMC architecture mapping

1. Although the public/private ownership is not a question of architecture (and UTMC may not be fully explicit on this) there is a clear implication that nodes B, C and D are public; node E is usually private, while node A (external system) could be either public or private. In SEAMLESS/ETSI terms, UTMC Node B is a road operator's C-ITS-S and Node A is another C-ITS-S which could be public sector (e.g. another operator's system) or private sector. Node B is allowed to be physically distributed at several locations as long as it acts as a single logical node.
2. A UTMC Node C (outstation) is an example of an R-ITS-S. Node C may be capable of acting autonomously, taking higher level control decisions. Node C may be permanent or temporary installations.
3. A UTMC Node D (controlled unit) is an item such as a signal, display or a sensor. The UTMC architecture also includes controlled units that are external to the UTMC

system, which could equate to service providers' sensors. A Node D cannot act autonomously but may be controlled by any of Nodes A-C. If a Node C is controlling a Node D, it shall inform Node B of its actions. Node D may be permanent or temporary installations.

4. UTMC Node E equates to V-ITS-S/P-ITS-S.

Given current UTMC specifications, a UTMC system (as indicated by the dashed rectangle) at present maps approximately to the "Legacy System" in the Seamless architectural reference model.

5.1.3 Mapping to ETSI ITS Station reference architecture

The UTMC functional reference model maps approximately to the ETSI ITS Station reference architecture as shown in Figure 27.

However, a fundamental difference is that the UTMC functional model is a model of an *overall* UTMC system, whereas the ETSI model applies to an ITS Station. Although the diagram shows similarities in detail, the two sides are not identical in overall purpose and scope. Nevertheless the comparison is helpful to identify commonality (which could give a common foundation for harmonisation) and differences (which may require harmonisation).

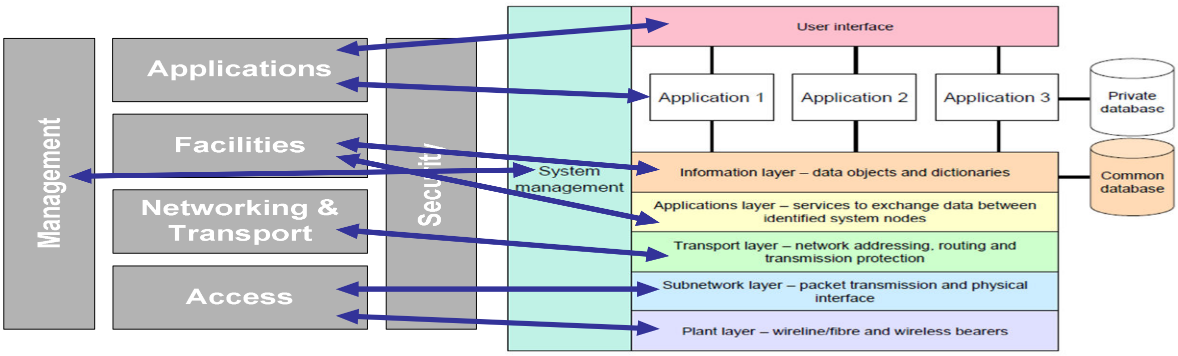

Figure 27 ETSI-UTMC functional mapping

The UTMC functional model by itself is not really constraining, just a way of viewing the suite of specifications, but within each layer there are further specification statements.

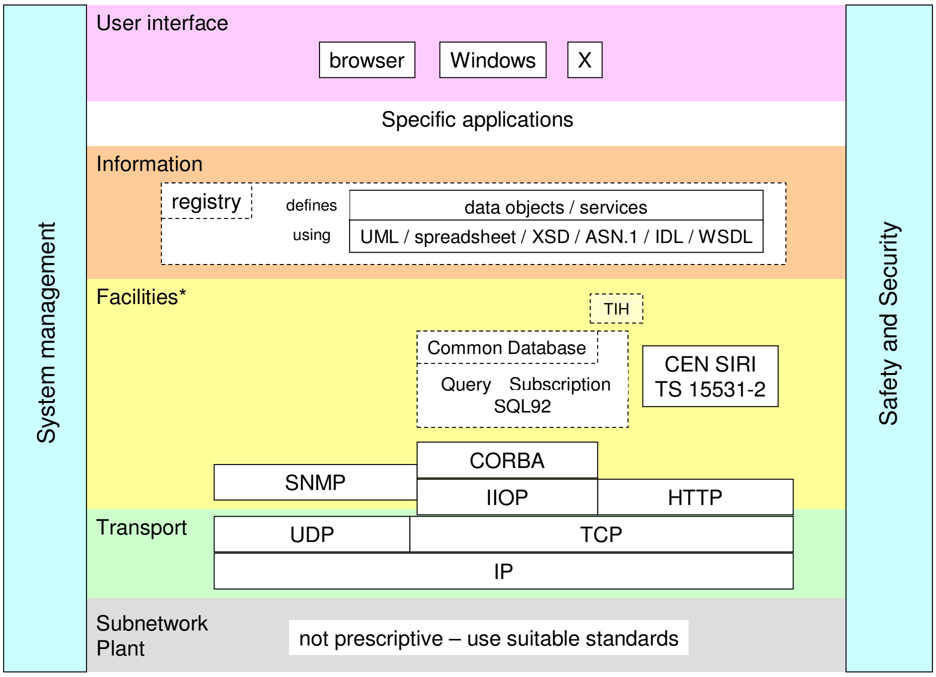

Figure 28 UTMC functional model with details (illustration by the Seamless project)

Figure 28 is an attempt to illustrate the principal choices specified by UTMC within each layer. To help comparison with ETSI reference architecture, some minor renaming and repositioning has been performed.[10]

Figure 28 represents an overall UTMC system rather than every UTMC node, but at least the Transport and lower layers should apply to every node. So for example UTMC-compliant communications with the vehicle (Node E with Node B/C/D) currently must be IP-based.

Figure 29 summarises the current contents of the UTMC Objects Registry (located in information layer). This includes both application data definitions and middleware service definitions.

[10] The UTMC layer between Information and Transport is named "Applications" layer but "Facilities" is perhaps a better description – specific applications have their own layer above the Information layer. The UTMC Common Database is illustrated in the functional model as part of the Information layer but specifications for its scope and services appear in the Applications (i.e. Facilities) layer specification.

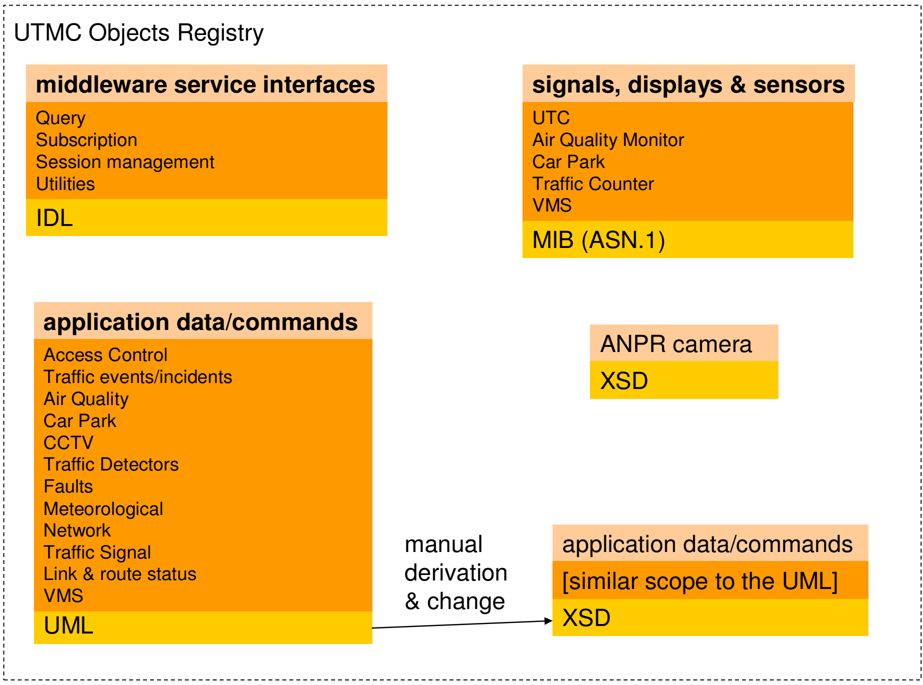

Figure 29: Contents of UTMC Objects Registry

The more detailed ETSI specifications may not be seen as presenting any conflict with UTMC specifications: although the vehicle-infrastructure communication would not be considered UTMC compliant, it may simply be considered out of scope of UTMC.

Nevertheless it may be desirable in future to define how the ETSI and UTMC specifications plug together.

Applications – similarities and differences

Although the scope of applications is different, there is overlap in subject matter. ETSI TR 102 638 defines a “basic set of applications” for vehicular communications. UTMC does not define a list of applications, but UTMC specifications show that there are overlaps in subject matter with the ETSI applications e.g. in roadwork and traffic event information. There are traffic management applications in which both UTMC scope and the ETSI cooperative ITS scope would apply – therefore further study and harmonisation of UTMC and ETSI ITS specifications is a candidate work item for SEAMLESS WP4.

Communications layers – similarities and differences

The use of IP, UDP and TCP gives a common basis to UTMC and ETSI communication architectures.

The ETSI architecture depicted in Figure 18 also permits GeoNetworking. In fact ETSI GeoNetworking includes a requirement to support transparent routing of IPv6 packets, so any potential mismatch arises only for non-IP applications using GeoNetworking.

Facilities – similarities and differences

Facilities in the UTMC and ETSI specifications are quite different. ETSI has specified details for the internals of ITS Stations[11], for which UTMC is neutral, only constraining communications between nodes. However, the ETSI facilities specifications also include functionality that does require communications between nodes. For example the Cooperative Awareness Messages (CAM) service is a mandatory component in an ETSI ITS Station, and the functionality originates in the facilities layer. Messages are exchanged between ITS Stations such as R-ITS-S, V-ITS-S, P-ITS-S. These messages are not UTMC-compliant, and although as vehicle-infrastructure communications they may simply be considered out-of-scope, there would be potential benefit in clarifying how the suites of specifications plug together.

Data definition – similarities and differences

UTMC and ETSI use different techniques to define data elements and the composition of messages.

UTMC defines UML models for most information concepts. A precise systematic mapping can be applied to the UML to produce the relational data structures that are communicated via CORBA. Another precise systematic mapping can be applied to produce the SNMP MIBs (in ASN.1) that are used for roadside communications. There are also XML Schemas, some derived loosely from the UML model, and others produced from scratch without any corresponding UML. For a few updates, a tabular description in a spreadsheet has been used instead of a UML model update.

ETSI defines individual data element meaning in text. It has hierarchical illustration of message contents (message, containers, elements), tabular description with byte layout specified, and ASN.1 definition. All these appear to be written in parallel rather than one being generated from the other.

Emerging Detail

ETSI is currently working on TS 102 723 (11 parts) which are expected to specify detailed APIs for the interfaces between each of the layers in their ITS Station Reference Architecture. This promises to make the layers more than an abstract functional reference model, rather a specific protocol that is different to protocols used in UTMC. This would mean that a UTMC node cannot be considered an ETSI-compliant ITS-Station without adding an implementation of this protocol stack in parallel to the existing UTMC-compliant aspects. This situation is illustrated in the Seamless generic architectural reference model, and further highlighted in Figure 30 below.

[11] For example the ETSI TS 102 723 specifications define details of the interfaces within the ITS Station Reference Architecture. The ETSI specification set is very detailed; as discussed in Seamless deliverable 2 when considering the P-ITS-S/V-ITS-S it is possible that certain elements could be overtaken by mass market groundswell.

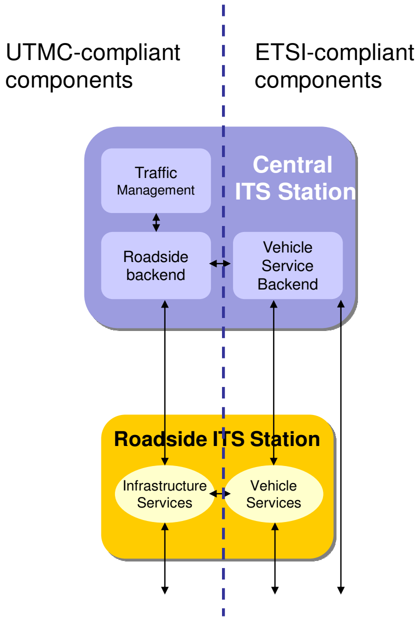

Figure 30: UTMC integrating ETSI components

5.2 OTS mapping to SEAMLESS reference model

5.2.1 OTS reference architecture

To specify a traffic control and / or traffic management system especially with multiple vendors involved, it is helpful to compare the prospective design with acknowledged system structures. This idea is met by the OTS system model. It identifies subsystems which are interdependent in a system landscape for the performance of different tasks. The OTS system model is depicted in Figure 31 [OTS09].

With the help of the OTS system model, OTS communication standards can be identified, which are suggested for use for communication between subsystems. In the illustration of the OTS system model, nine sub-systems of control and traffic management level can be seen (red and yellow area). All of them are able to communicate with OCIT or OTS standards.

For the seven identified components of the field level (green area), only traffic signals can claim to base on a common standard, namely OCIT-Outstations.

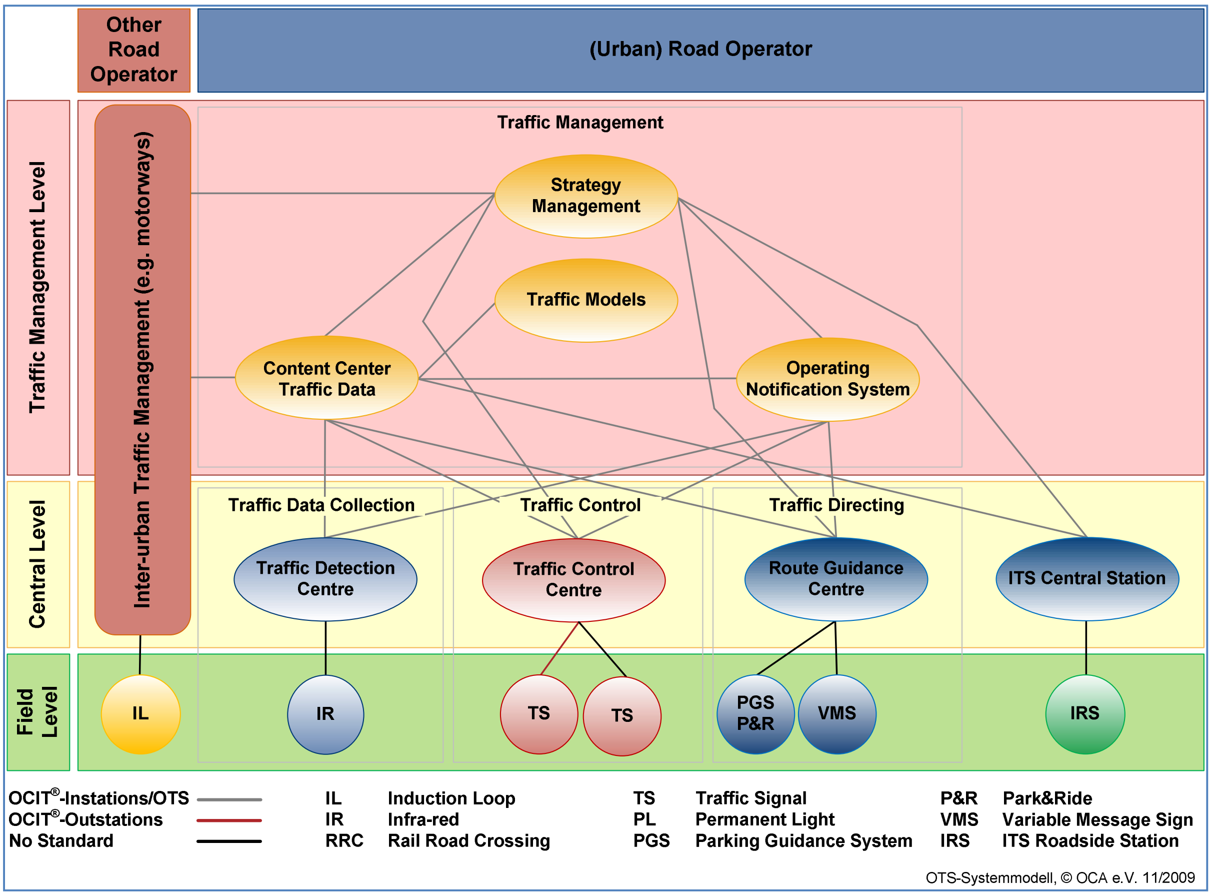

Figure 31: OTS system model

5.2.2 Mapping to SEAMLESS reference model

A mapping from the OTS system model to the SEAMLESS reference model is shown in the next figure. It can be emphasized that the OTS model includes a component named ‘ITS Central Station’ on the central layer, whereas several components from the management layer correspond to the SEAMLESS namesake (Central ITS Station).

There is no correspondence for the R-ITS-S of Service Provider side in the OTS model, only the R-ITS-S of Road Operator side has a corresponding element. This element (‘IRS’ in the OTS model) does not have any connections to other field devices. Without any further connections, the element is quite useless, so it can be assumed that there are connections missing in this representation.

The equivalent of the SEAMLESS Service Provider can be found in the left column (dark red) of the OTS model, called ‘Other Road Operator’.

Furthermore missing in the OTS system model is a corresponding element for the Vehicle and Personal ITS stations – this should be due to the quite new history of these components or due to a different focus of the OTS model (which is very much concentrated on the management scene). These missing elements are another reason for the absence of connections on the ‘IRS’ component in the OTS model.

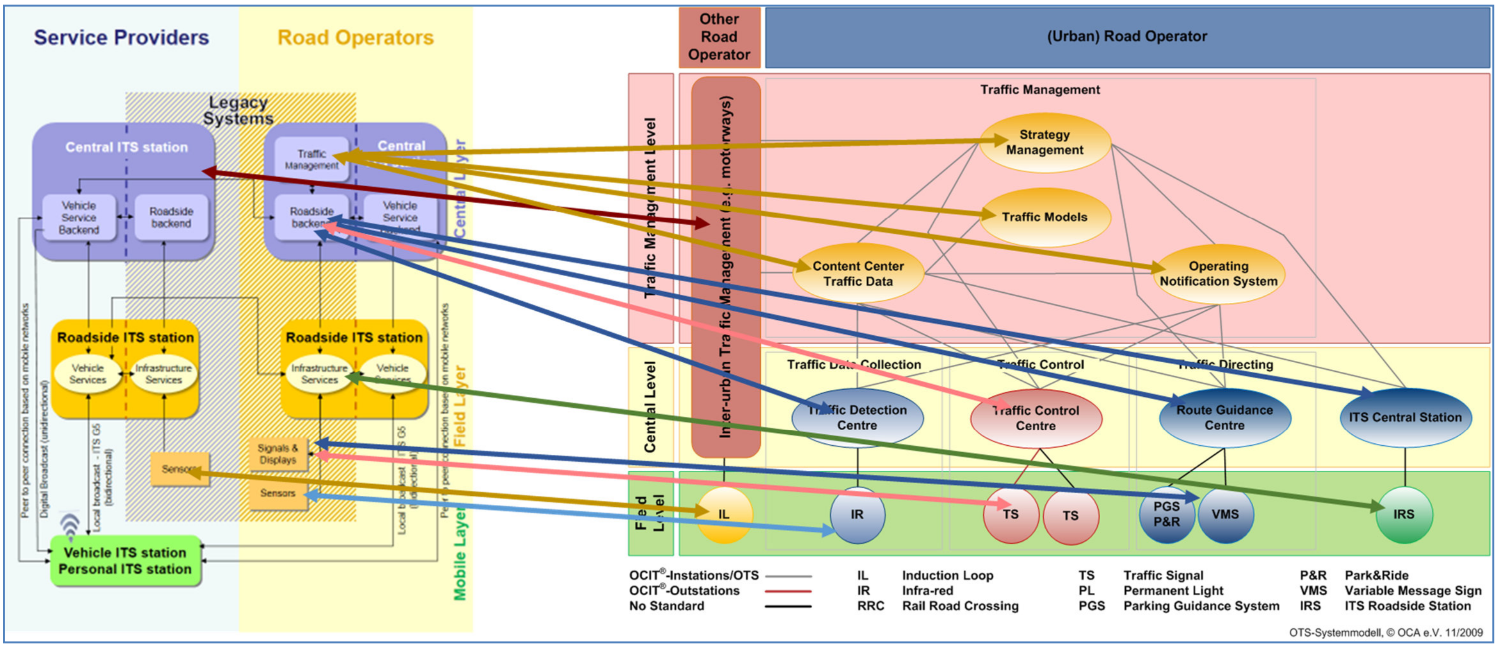

Figure 32: Seamless – OTS architecture mapping
(the colour of the arrows corresponds to the colour of the OTS components)

5.2.3 ETSI-compliant interpretation of OCIT-Outstations

The design of a future type of RIS/R-ITS-S has to match the existing architecture for traffic lights and the ETSI station architecture. For Germany OCIT-Outstations (OCIT-O, [14]) defines the communication between centres and road-side controllers. Figure 33 gives an overview of the architecture concept. Depending on the communication access the OCIT standard set provides different profiles. Furthermore the communication between roadside controllers and LED displays is standardised.

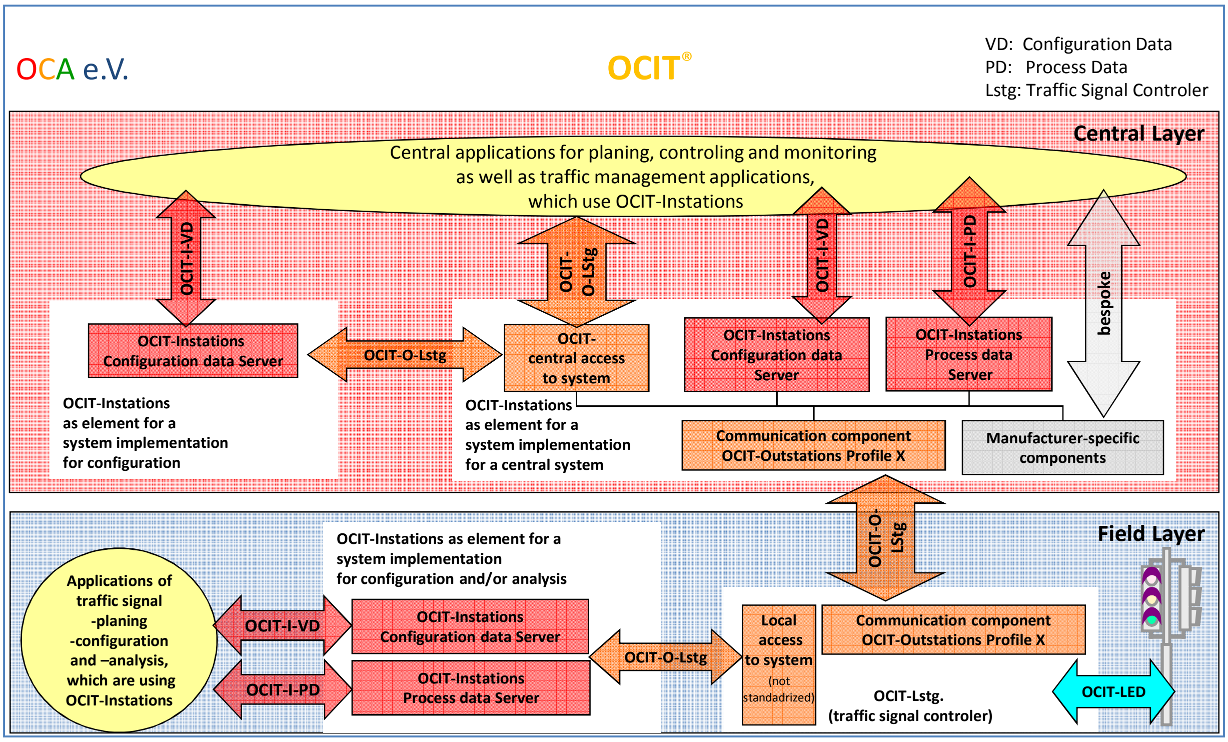

Figure 33: OCIT-O

For an ETSI-compliant interpretation of the German OCIT-O architecture, the following aspects must be considered:

Access Layer: As mentioned before OCIT-O is open regarding the access channels. It is the same for ETSI. Besides 3G communication, traffic controllers equipped with V.34 modems or Ethernet connections are in place. Both can be added to the ETSI-conformant architecture in figure 1.

Network and transport layer: On this layer no modification is needed. Both OCIT-O and the current ETSI-conform developments are using UDP, TCP and IP.

Facility layer: This layer is providing basic functions for the R-ITS-S which can be used by one or more application. Protocol-related data structures form one segment of the facility layer. As a consequence OCIT-O must be added to the data structure list. The interface OCIT-LED should be part of the facility layer too.

Application layer: The control logic itself will be placed on the application layer. Depending on the specific realisation of the RIS/R-ITS-S future control logics will use the capabilities provided by the upper layers in order to make the traffic light control more intelligent.

In general the matching is possible and opens a new and innovative view on roadside traffic light controllers. But in parallel to this communication and software-oriented view, traffic light-specific requirements must be considered. At least in Germany some hardware-based security mechanisms are required to ensure traffic safety of the traffic signal control program.

5.3 Further activities

5.3.1 Cooperation in using DATEX II and TPEG

By establishing wider communication chains the problem arises to get data transferred using different standards in a row. Especially DATEX II and TPEG are addressing different parts of the communication chain, but have similarities regarding their traffic data content. EasyWay ESG5 and TISA have collaborated to develop a strong synergy between these two fields of applications and see significant benefits by improving message exchange efficiency and quality to provide improved value and safety for the end-user.

For this reason, first attempts to map the information from one service to the other started in 2010, starting with DATEX II to TPEG-TEC. Beside the wider structure and the individual arrangement of data and information, special interest is spent to compare the attributes of both standards. Basically, three different cases can occur:

- Attribute from one standard is not covered by the other
- One attribute has to be mapped to more than one attribute
- Attributes are quite similar on both standards (maybe only some naming issues)

Of course, the third point is the easiest one, as a mapping can be defined straightforwardly; the other points require more effort. It turned out that especially enumerations (lists of predefined literals) are subject of big differences – the definitions for every single literal have to be compared carefully. Even if the wording appears to match, the intended scope can be very different and in some cases not be matched accurately.

DATEX 2 Payload - SituationPublication					TPEG TEC Message					
Class Name	Attribute Name	Definition	Multiplicity	Data Type	Class Name	Attribute Name	Definition	Multiplicity	Data Type	Set Value to
OverallPeriod [1]	overallStartTime	Start of bounding period of validity defined by date and time.	[1]	DateTime	Event	startTime	Date and time at which an event began or is scheduled to begin (used for presentation to the end-user). If startTime is missing first time of reception is used instead.	[0..1]	DateTime	If D2 "validityStatus" = "active" or "suspended" value = time of message reception Else value = D2 attribute value
	overallEndTime	End of bounding period of validity defined by date and time.	[0..1]	DateTime		StopTime	Date and time at which an event, or status information, ended or is scheduled to end (used for presentation to the end-user). If stopTime is missing stopTime is set to startTime plus default duration, which is defined per main cause. In case of multilple causes the highest default duration shall be taken.	[0..1]	DateTime	If D2 "validityStatus" = "active" do not send this attribute If D2 "validityStatus" = "suspended" value = time of message reception Else value = D2 attribute value
Impact [0..1]	capacityRemaining	The ratio of current capacity to the normal (free flow) road capacity in the defined direction, expressed as a percentage. Capacity is the maximum number of vehicles that can pass a specified point on the	[0..1]	Percentage						
	numberOfLanesRestricted	The number of normally usable lanes on the carriageway which are now restricted either fully or partially (this may include the hard shoulder if it is normally available for operational use, e.g. in hard	[0..1]	NonNegativeInteger	DirectCause	numberOfLanes	Specifies how many lanes are closed or opened. If this element is not given, the plural form shall always be used.	[0..1]	IntUnTi	if TEC laneRestriction type set to 1 then value = D2 value (numberOfLanesRestricted) if TEC laneRestriction type set to 2 then value = D2 value (numberOfOperationalLanes) Else do not set
	numberOfOperationalLanes	The number of usable lanes in the specified direction which remain fully operational (this may include the hard shoulder if it is being used	[0..1]	NonNegativeInteger						
	originalNumberOfLanes	The normal number of usable lanes in the specified direction that the carriageway has before reduction due to roadworks or traffic events	[0..1]	NonNegativeInteger						
	residualRoadWidth	The total width of the combined operational lanes in the specified direction.	[0..1]	MetresAsFloat						
	trafficConstrictionType	The type of constriction to which traffic is subjected as a result of an event or operator action.	[0..1]	TrafficConstrictionTypeEnum		laneRestrictionType		[0..1]	tec004:LaneRestriction	If D2 "trafficConstrictionType" populated OR "numberOfLanesRestricted" populated value = 1: "lane(s) closed" Else If D2 "numberOfOperationalLanes" populated value = 2: "lane(s) open" Else do not set

Figure 34: Mapping table from DATEX II to TPEG-TEC (extract, 2010)

In summer 2011, a first demonstrator was shown in the 8th European ITS Congress in Lyon[12]. In 2012, a complete scenario was introduced in the 19th ITS World Congress in Vienna[13]:

Starting from a content provider (which could be a traffic management system), the traffic messages were sent along the complete delivery chain to the end user, i.e. to some in-car or mobile devices. For demonstrating purposes, the messages could be created by the user on a web interface in form of DATEX situation records (for example an accident on the Brenner pass); the result – sent in form of a TPEG message – could be seen on a tablet PC (for example a suggestion for an alternative route along the Tauern motorway). Even the limited set of functionality for the demonstration already pointed out benefits that the stakeholders should experience in case of a closer collaboration in the near future between the DATEX and TISA communities. Figure 35 shows the setup for this inter-standard communication.

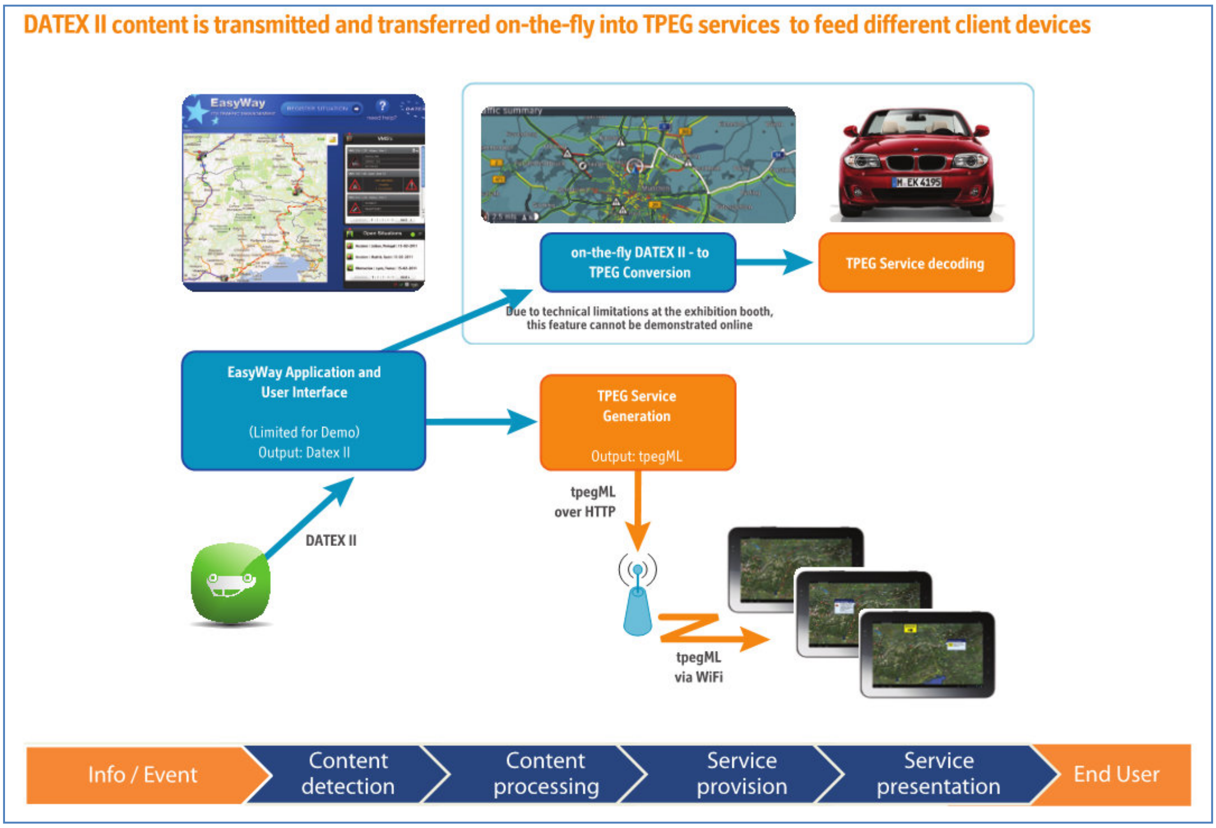

Figure 35: DATEX II – TPEG pilot communication (from ITS World Congress 2012 flyer)

[12] see http://www.ertico.com/tisa-and-easyway-esg5-cooperate-to-deliver-coherent-traffic-information/ and http://www.ertico.com/lyon-2011/

[13] see http://www.itsworldcongress.at/

6 Use Cases "Traffic Light Phase Assistant"

6.1 Description and Requirements

6.1.1 Description

Within the last 90 years, traffic signals have become a significant part of traffic infrastructure (in fact the very first traffic signal was set up 1868 in London[14]).

The main reasons (from a 'traditional' point of view) for installing traffic lights are:

- Serving the optimization of traffic flow.
- Contribution to mitigate risks on complicated or confusing intersections.
- Reasons of space (e.g. when no roundabout can be set up).

Especially, terms like 'driver', 'vehicle' or 'information (to drivers)' are not yet mentioned here. So the main task of urban traffic management in the last years has been to control intersections and traffic streams – by using infrastructure (traffic lights, detectors, …) and operator actions (speed limits, structural measures, …). There was no focus on detailed information management and mostly no knowledge about individual cars. In particular, it is worth mentioning the main interaction between traffic signal and driver is still based on a unidirectional visual communication (sometimes the other direction might exist in form of detectors and traffic adapted signalling).

With the rise of cooperative ITS, these paradigms are going to change. Road Operators and traffic managers will get the chance to individualize their information on the one hand and to get more detailed data themselves on the other hand. Road users will be better informed and will gain better understanding of current traffic situations. Obviously, road users will also change their behaviour, i.e. they might try to avoid intersections with waiting times or they drive in a more economical way, when they have knowledge about a traffic light being several more seconds red. This is an important change Road Operators have to be aware about: in former times, drivers reacted in answer to traffic situations; today (or in near future) they will react in answer to information about prospective traffic situations.

To reflect this development, this chapter will focus on cooperative communication issues with respect to traffic signals. All of these can be subsumed as part of the use case "Traffic Light Phase Assistant" (which is actually more than just one use case):

- Information flow towards the road user
    - Visualisation to the driver
        - Current State of signal
        - Time to Green / Time to Red
        - Speed Advice (economic driving)
        - Green Wave visualisation
        - Red light violation (warnings)
        - Reminder on Green

[14] See http://www.bbc.co.uk/dna/h2g2/A9559407

        - More exact calculation of navigation routes
        - …..
    - Vehicle behaviour
        - Red light violation (automated braking)
        - Adapted speed control (economic driving)
        - Adapted fuel consumption
        - Improvement of start/stop automatic
        - Automated driving
        - …
- Information flow towards the traffic light
    - Improvement of control by precise information about traffic (for single traffic light controller or net wide control)

Especially with respect to the first block of information flow, the topology information of the intersection is an important piece of information. The automated exchange of this topology can be also seen as part of the use case "Traffic Light Phase Assistant".

6.1.2 Requirements

The term Traffic Light Phase Assistant is used collectively for different objectives and applications (including some not yet known or developed). The common characteristic is their need for information describing the near-future behaviour of traffic signals. Usually this should cover:

- Operating state of controller (e.g. if working in regular or in an exceptional mode like "switched off",)
- Current signal program and/or sequence of the next signal programs (and also the specification of the signal programs as part of static information)
- Current signal state including information which allows to relate it to the targeted traffic streams
- Time to green and time to red for controlled traffic streams

both for the current situation ('real-time') and often also for the future (short term prediction, 'next changes' or schedule).

But even more detailed control information can be required:

- Traffic adaptive or fixed time control
- Cycle-time (if fixed time control applies)
- Special operation control (for emergency vehicles)
- Public transport priority active or
- Manual control.
- Queue length of the waiting vehicles

This dynamic data might need to be enriched by static information about the controller (type and control method, signal groups, quantity and design of signals, etc.).

In most scenarios of this use case, detailed geographical information about the whole junction (topology information) and especially its stop lines need to be present. At least an assignment of the information to the affected traffic streams must be enabled somehow.

The source of information can vary between the controller itself or some central system (when the central system has knowledge about the signals and knows their states).

6.1.2.1 EasyWay Deployment Guidelines

The EasyWay Deployment Guidelines[15] do not focus on traffic lights. There is only one Guideline [EWD12] about Ramp Metering with even a little correlation to this use case. Ramp metering signals are installed on the on-ramps of motorways to regulate the flow of joining traffic during peak or congested periods. The signalling depends on the measured main stream flow to which the side stream shall be merged. So the measurement captures the in-coming traffic and the algorithm by nature tries to minimise the impact of the merging traffic. For this reason, ramp metering signals are usually connected to their surrounding infrastructure by detectors or the use of VMS, but a communication with cooperative ITS, especially with vehicles, is not (yet?) mentioned..

6.2 Technical Approach

6.2.1 Constraints

What is written above already implies that there are different possibilities for design of the communication chain. From the signal controller to some vehicle, information transfer can use hops on different central systems on the one hand (which might lead to latency problems) or use field devices for communication, such as an R-ITS-S (Roadside ITS Station). For the latter one, new communication protocols and data models need to be developed, like in the project sim[TD].

6.2.2 Existing Standards

Depending on the chosen approach and processing chain, different standards are applicable.

In a first step the basic traffic signal information must be collected.

In the case of static information (geo-reference and logical topology layout of the intersection) manual collection and processing is required. Some modern traffic control and management centres might already hold appropriate information electronically – which allows a semi-manual data preparation based on data exports from these systems.

To access dynamic information, the traffic signal control related standards help to supply the data. UTMC, OCIT, DATEX II or SAE are relevant for this processing step.

After the static and dynamic information is acquired, it must be processed and transferred to the vehicles.

In case of approach 1 – the infrastructure to vehicle communication – standards such as the following are available:

- SPAT (Signal Phase and Timing Data, SAE J2735 [SAE09]):
  This message determines the state of the signal phasing and when the expected

[15] See http://www.easyway-its.eu/deployment-guidelines/

next phase will occur. Also part of this SAE standard is the MapData message which gives a full geometric layout of the intersection in question. With a SignalRequest message, a vehicle can ask for prioritization and with a SignalStatus message the R-ITS-S can reply with information about the prioritization ranking.

- CAM (Cooperative Awareness Message, ETSI TS 102 637-2 [CAM11]):
  The CAM message can transfer a ‘traffic light priority’ element for the treatment of certain traffic streams, usually PT or emergency vehicles.
- DENM (Decentralized Environmental Notification Message, ETSI TS 102 637-3 [DEN10]):
  DENM also covers the traffic light priority (see above) and furthermore can communicate information about traffic signal violation, i.e. a warning sent out to other vehicles, if some red light violation was detected.

In case of approach 2 – a centre to vehicle communication – standards such as DATEX II and TPEG are applicable. Germany is defining a DATEX II profile for cities to provide signal control and intersection information for the regarded use cases[16]. In TISA the TPEG-TSI application (Traffic Signal Information) is under development for disseminating the needed data to vehicles.

6.2.3 Examples

6.2.3.1 sim^{TD}

There are several functions in sim^{TD} handling with traffic light communication and therefore can be associated to the term Traffic Light Phase Assistant as a whole:

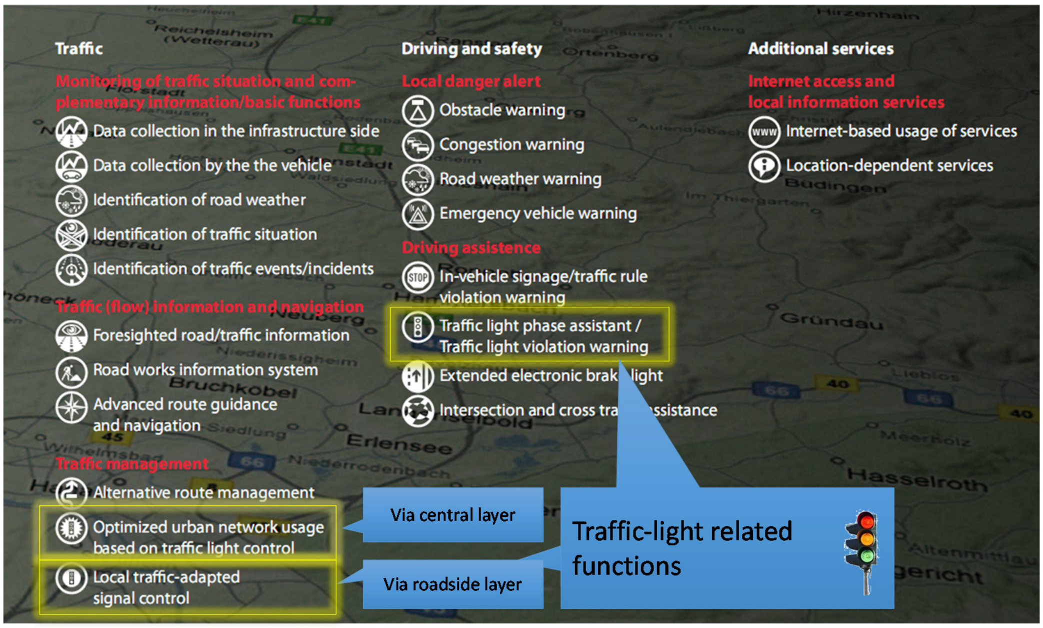

Figure 36: Overview about sim^{TD} functions and focus on traffic light communication

Optimized urban network usage based on traffic light control

[16] Should be available shortly in the Profiles section of www.datex2.eu.

In an urban scenario, this function uses traditional sensors/detectors as well as vehicle data provided by car-to-infrastructure communication to detect the current network-wide traffic status. It is fused into a traffic model with time- and local based representation. Several traffic signal controlling scenarios are computed out of this information with a prognosis of 5 to 15 minutes. They are optimized to minimize the loss of time for individual traffic (motorized or non-motorized) as well as for public transport.

The vehicle information (especially position and speed) is collected via 802.11p protocol by R-ITS stations, which are each adjacent to a traffic signal. The information is transferred via an OTS 2 link into the local traffic management centre of the City of Frankfurt am Main. After processing the network-wide computation, the centre transfers resulting control frames to the traffic signals. For this purpose, the existing OCIT-Outstations communication chain (from central system to traffic signal) had to be upgraded to be capable to transfer new communication elements of OCIT-Outstation 2.0 version.

Local traffic-adapted signal control

In contrast to the network-wide function just explained, the local traffic adapted control function uses the vehicle information sent to the R-ITS-S to compute a local traffic model. Via a geospatial model of the intersection and with map matching, the occupancy rate for each traffic stream is computed. The information is directly sent to the traffic light controller, which is forced to adjust the controlling within its frame, to maximize the local throughput of traffic. There are two scenarios (a separated test field and an urban test area) in which the communication is solved slightly differently due to technical reasons: The communication between R-ITS-S and traffic signals is done either by a direct DATEX II communication or by electrical impulses (in the second case, the computation of the traffic model is done inside the traffic signal controller).

In the urban test scenario, it is essential to get knowledge about the necessary penetration of equipped vehicles within the total amount of vehicles in order to achieve satisfying results of this function.

Traffic light phase assistant / Traffic light violation warning

These two functions use traffic signal data to display in-vehicle information. For the traffic light phase assistant, the frequently incoming information about the traffic light status is filtered to the appropriate vehicle-relevant signal (the estimated driving direction, for instance in case of a turn tight signal, is determined out of position [with exact lane, if possible], navigation information and turn signal). The remaining green or red time is shown to the driver. The system can also compute optimized speed advices, which allow the driver to pass the signal in a most economical way[17]. It turned out that most exact time synchronisation is essential between traffic signal and IRS. As the vehicle is calculating with relative values of signal seconds, a very low latency is required. In case of traffic adapted controlling, the counting of remaining seconds might be irregular (with gaps or doublings), because the signal control calculation can change in a rapid manner.

For the traffic light violation warning, the driver itself and/or surrounding cars are informed in case a red traffic light is going to be ignored. For this function, again a precise geospatial

[17] Advanced approaches beside sim^{TD} are even dealing with fully automated fuel saving, for instance by linking the vehicle start-stop-technology directly to the traffic light information.

model of the intersection is required.

6.2.3.2 UR:BAN VV

One of the UR:BAN-VV project use cases is targeting to provide information on predictable traffic signal status.

In general two approaches can be distinguished so far:

- the provision of detailed near future traffic signal state directly from the intersection to the vehicle;
- the central based collection and dissemination of expected signal changes between red and green.

The second approach aims to cover the majority of fixed time controlled signal intersections as well as any dynamically controlled intersections which still have no 'last second decision changes' so that it is feasible to disseminate their most likely status even up to a minute ahead.

The first approach requires to equip each intersection locally on one hand side while on the other hand side highly dynamic decision changes of locally adaptive control can be communicated within a second.

In UR:BAN the second approach is implemented using a DATEX2 profile for supplying the forecast information to a (national public) service provider (called MDM) and further dissemination to the vehicles is achieved using TPEG.

6.2.3.3 UTMC readiness

As described in section 3, UTMC does not currently include any specifications for communications with the vehicle. The existing specifications for traffic signal control involve the use of SNMP between roadside stations and the centre, and a set of MIBs are defined to allow getting and setting of many detailed traffic signal control parameters. These specifications are not well suited to direct use for the traffic light assistant application, but they do indicate the presence of an IP-equipped roadside station that contains the signal phase information necessary for the application.

6.2.4 Role of the R-ITTS

Considering traffic light related functions using a R-ITS-S, it becomes clear that a lot of different scenarios are possible. Especially the physical occurrence of the R-ITS-S, its tasks and its control authority are by no means preassigned.

Depending on different stakeholders, a variety of concepts are favoured:

- An R-ITS-S in form of a plug-in card for the traffic light controller:

  This solution would reduce the R-ITS-S interfaces to the air-interface, because the internal link would be most probable on a non-standardized basis.

  The functionalities of the R-ITS-S would be reduced to dedicated traffic light operations.
- No explicit R-ITTS, but all applications inside the traffic light controller, but with one (or even several?) radio modules:

  Similar to the solution above, but this time there will not even be a link between controller and R-ITS-S functionality. Note that in this case extension of functionality most often needs to go along with a complete upgrade of the traffic light controller.

- One individual R-ITTS for every application on the intersection:

  This solution might happen, if several vendors want to participate in the ITS communication, but did not concentrate on a common platform or standard. Although there are different owners, some management seems to be necessary (usage of radio frequencies, placement in public space, …)

- Multifunctional approach:

  A kind of open platform for the R-ITS-S, as seen in the ETSI architecture or in sim^{TD}. Multiple applications, maybe even from different vendors can place their functionality into a framework.

  This approach provides a flexible solution for different protocols and different applications. Even non-traffic light information can use this equipment, like information on roadwork, VMS, ….

The role of the R-ITS-S is in flux, depending on the projects and stakeholders involved. There is not yet a standard or a well-accepted realization, but there are a lot of possibilities to cover the R-ITS-S topic. Road Operators should be aware of these different approaches and contrast all advantages and disadvantages of each solution.

6.3 Tailored Reference Architectures

Based on the generic architecture introduced in chapter 4 and the examples shown in this chapter, different shapes of the use case Traffic Light Phase Assistant can be depicted in the form of derived architectures. It is not the intention to express specific approaches of implementation, but to show a variety of constructional different approaches to realize the communication chains. Advantages and disadvantages of these approaches are also discussed.

6.3.1 Local Communication

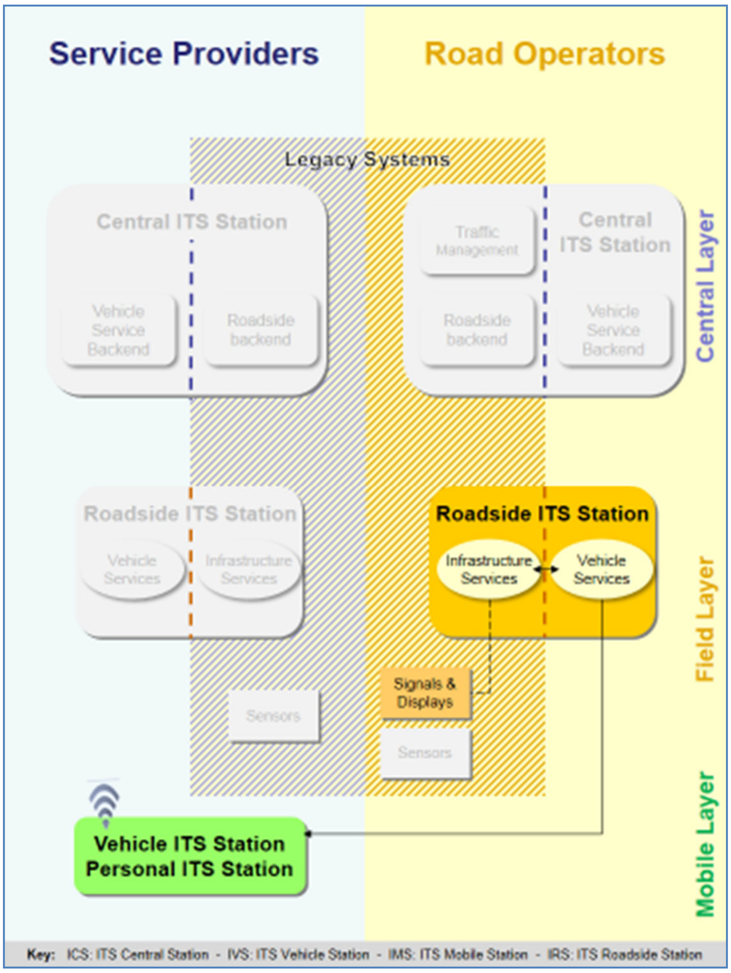

Figure 37: Scenario I: Traffic Light Phase Assistant via Field Layer

The signal information is available inside the traffic signal controller, which is usually located inside the subcomponent ‘Infrastructure Services” (the connection to the component ‘Signals & Displays’ is dashed in the upper figure, because it is not the controlling element). The information is broadcasted out of the R-ITS-S vehicles services via air link. Although there is an interface between Infrastructure Services and Vehicle Services, this is a very fast connection to the vehicles (low latencies). So the type of information can be real time like (current state, next change in … seconds). Of course an appropriate concept for synchronising the different systems on a common time base is needed. Since the information is broadcasted (maybe with 1 or even 2Hz), the quantity of information must not be too large. Usually the range is restricted geographically by some radius around the corresponding intersection.

6.3.2 Using the central network

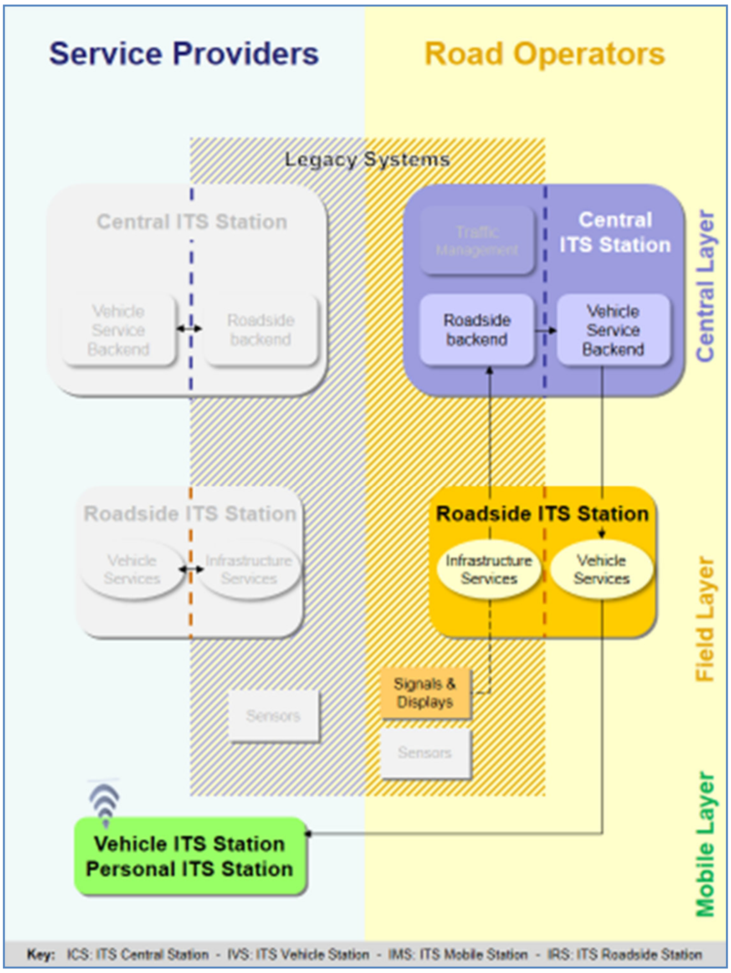

Figure 38: Scenario II: Traffic Light Phase Assistant via Central Layer

In scenarios where the interface between Infrastructure Services and Vehicle Services cannot be realized – note that these can be two physical independent components – it is possible to route the data via Central Layer, Roadside Backend and Vehicle Services to the Vehicle Stations. In this approach, the latency must be considered carefully – it might be too high. Hence it is useful not to transfer the same kind of data as in the local approach, but to use data, which does not have to restrictive real time requirements (e.g. sequences of signal programs instead of current time to green).

6.3.3 Service provider distribution

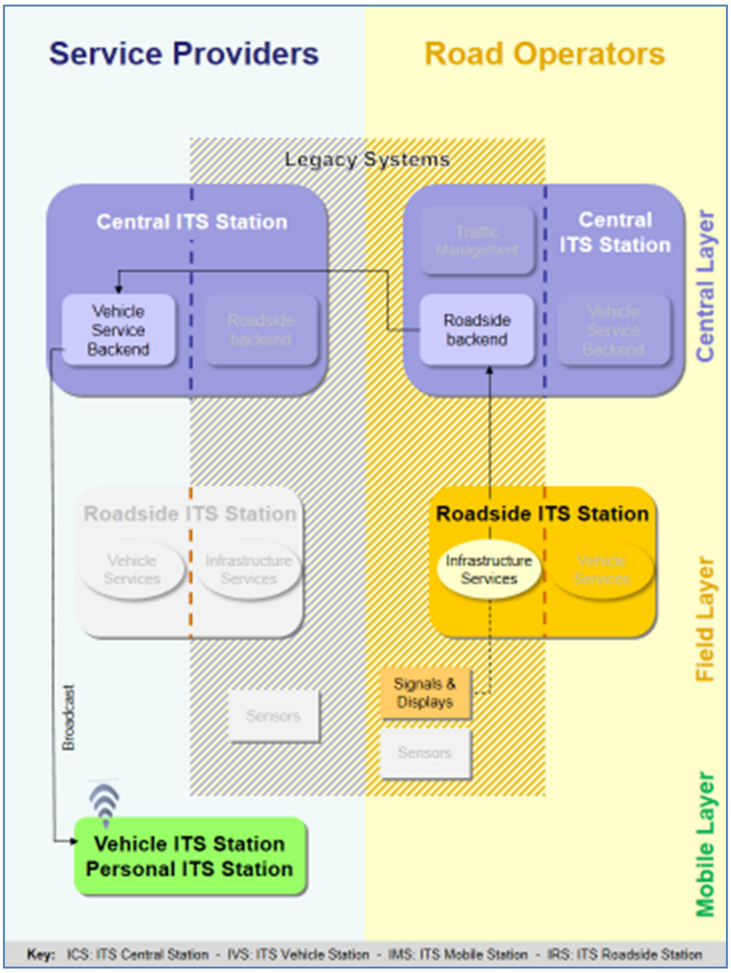

Figure 39: Scenario III: Traffic Light Phase Assistant via Service Provider

In Scenario III, the traffic light information is gathered from the central component of a Road Operator. Usually, the Road Operators system has a direct connection to and from its field devices, but the central system might also already store all relevant information itself. Customer for the information is a service provider. The link between these two C-ITS stations might be build-up of a DATEX II connection; an example for this interface will be provided in a deliverable from workpackage 4 of SEAMLESS.

The service provider will prepare the information and broadcast it to the vehicles. As in the approach before, this communication chain should not be used for real time data. Useful information would be next sequences of signal programs, content of signal programs or current changes in the pre-calculated sequences. It would be also possible to transfer the geospatial information of the intersection (see chapter 6.3.5).

6.3.4 Publishing Vehicle Information

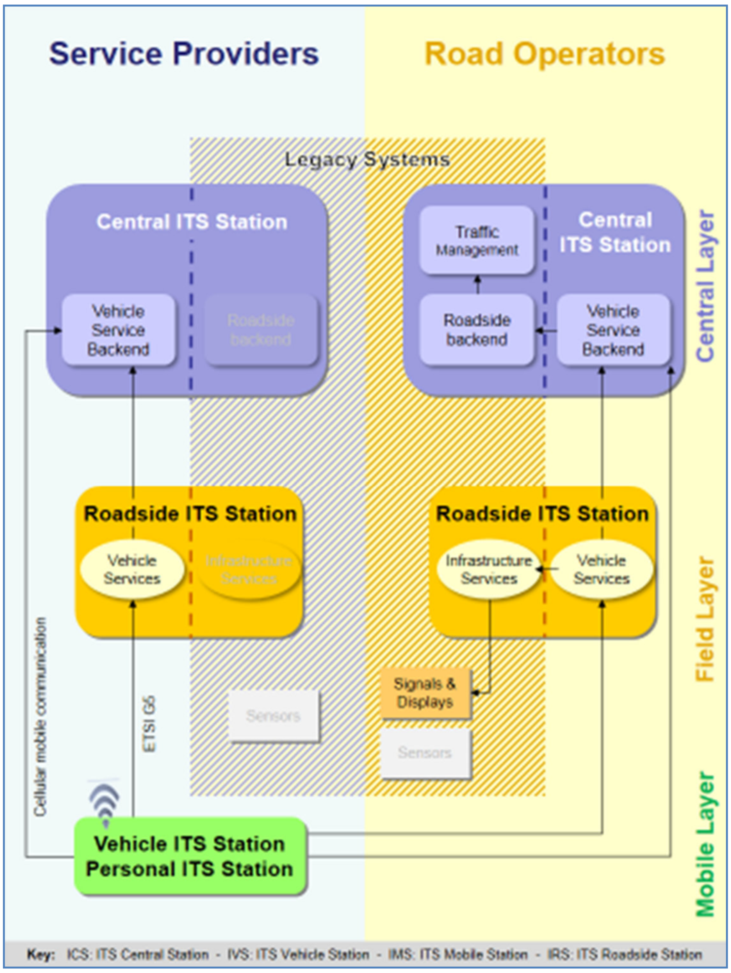

Figure 40: Scenario IV: Publishing Vehicle Information to different recipients

As the term Vehicle-To-Infrastructure Communication states, there can be also communication that comes from the vehicles. Depending on the definition, it is possible to add this scenario to the concept of a Traffic Light Phase Assistant.

The information processed will be usually speed, position and orientation of vehicles, but it can be enriched by the type of vehicle, information about emergency or public transport vehicles or trajectories. Usually, a Cooperative Awareness Message (CAM) is used for this purpose, and also Decentralized Notification Messages (DENM) can come into operation for further information about the vehicle's environment (take in mind chapter 6.2.2).

There are multiple possibilities to spread this information to different recipients – for instance in a point-to-point communication to some service provider, or via broadcast to some R-ITS-S or C-ITS-S. The information can be variously used – please refer to the examples in chapter 6.2.3.

6.3.5 Exchanging Intersection Topology

For various scenarios, the vehicles or at least the R-ITS-S need to have detailed knowledge about their structure of their surroundings – in an urban scenario this would be knowledge about the corresponding or adjacent intersection. Of special interest are:

- Lanes (including their length in case of emerging lanes; think of a tailback on the neighbour lane)
- Signals with association to the lanes
- Allowed driving directions for each lane
- Further traffic restrictions or signs
- Information about neighboured intersections

This information or parts of them might be available from the Urban Road Operators, but often it is non standardized and often maybe only available in paper versions and not detailed enough. For this reason, the effort to create and making available a standardized electronic version for the intersection topology must not be underestimated within a project – and usually, a huge number of intersections has to be taken into account. Furthermore, this process will differ a lot among the different cities and road operators.

As the topology data does not change a lot in time, it is possible to equip the R-ITS-S manually with this data, if an automated data transfer is too extensive.

Usually, modern cars do have their own map service on board, but in order to operate on a common data base for specific applications, it might be useful to broadcast the topology out to the vehicles. Of course this is no high-frequency operation (think about the amount of data). It might be also useful to send it out from the R-ITS-S only on request from a vehicle.

7 Use Case “Road Information”

7.1 Description and Requirements

The second Seamless use case is the seamless dissemination of road information, with a particular focus on **journey times**. This case has been described in Seamless Reports 1 and 2. The whole value chain is of interest. The previous reports identified that local and national authorities collect a range of relevant data that could be used to provide seamless information services to end users through mobile or in-vehicle devices. The reports also identified that there is considerable variation in data collection across nations, due to attitudes and legislation, for example in Germany there is generally no journey time available from urban traffic systems whereas in UK a sample illustrated that journey time is collected by many local authorities.

7.1.1 EasyWay Deployment Guidelines

EasyWay has published the guideline “Traveller Information Services: Traffic Condition and Travel Time Information Service”, TIS-DG03-05 (December 2012), with recommendations and requirements for deployment of traveller information services. EasyWay is a project driven by national roads authorities and operators, and so naturally the focus is on inter-urban roads, not on local/urban roads. However it is interesting to consider how this material could apply to the urban context in order to create seamless services for travellers.

The “vision” specified by the guideline should be common to local roads authorities, but the specific requirements and recommendations require further consideration and potential refinement if they are to apply equally to local services. The guideline presents no conflicts with the Seamless generic architecture, but further consideration of harmonisation of the detailed requirements and recommendations is a candidate work item for SEAMLESS WP4. Further EasyWay guidelines are also relevant to this use case e.g. on “Forecast and real-time event information”.

7.2 Architectural Reference Model

Figure 41 shows how the Seamless architectural reference model may be instantiated for the travel times use case.

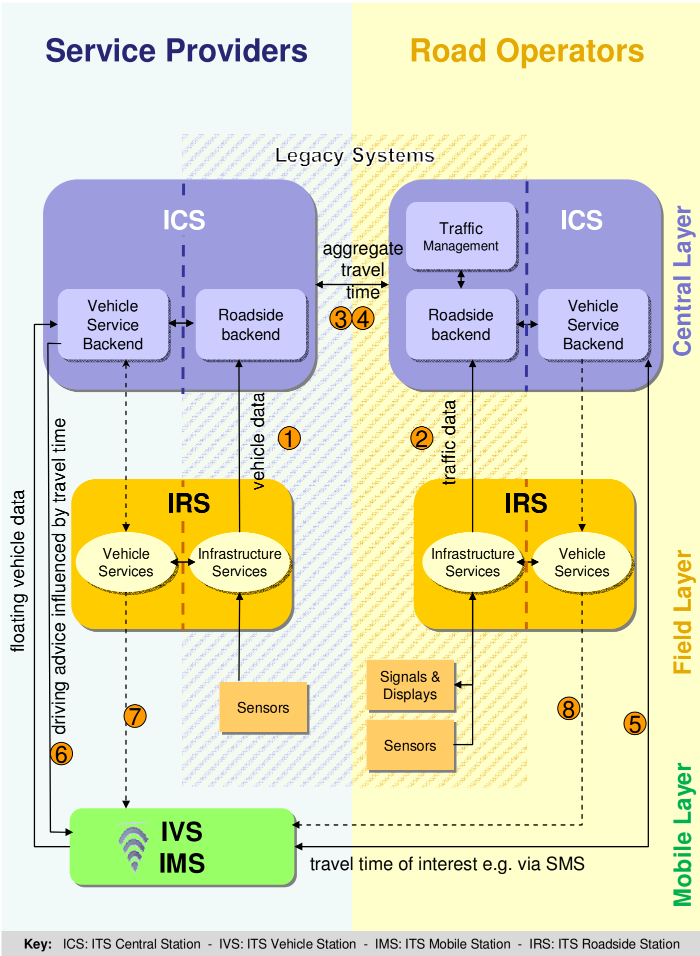

Figure 41 Travel times use case

7.2.1 Communications from R-ITS-S to centre (1,2)

A range of sensor technologies are used for journey time detectors. The foremost is camera-based ANPR but journey times are also derived from SCOOT urban traffic control systems and there is increasing interest in alternative detection technology such as Bluetooth device detection.

In UK there is a defined UTMC ANPR protocol for R-ITS-S-centre communications (based on XML web services). It is not yet used in many systems because it was published as recently in 2010, but it was created by a group of private sector suppliers and therefore should have market support.

In theory the UTMC ANPR protocol could also be used in private sector systems.

It is not expected that the R-ITS-S-to-centre protocol would be used for any R-ITS-S to V-ITS-S/P-ITS-S communications as it contains a level of detail that is suited to the manager of the devices rather than a traveller.

These communications are sufficiently distant from the end user services that differences in their communications protocols do not necessarily have a negative impact on the provision of seamless services to travellers. However, there are aspects which do have an influence – the data elements available, and the quality of service characteristics, as the centre cannot fully compensate for shortcomings of the source data.

Other roads information

Other kinds of traffic data that can be used for information services follow similar architectural patterns. Sensors collect the information, typically for traffic management purposes, and transfer to the centre, in some cases using defined protocols like UTMC, and in some cases with proprietary protocols.

The OCIT-Outstations protocol (current version 2.0) widely used in Germany is very specific for traffic signal and sensor data, which is transferred into a central station. Generating travel times out of this information is currently not (yet?) common practice in Germany.

7.2.2 Cooperation between centres (3,4)

Data available from these services may be aggregated or fused from multiple sources.

In UK there are defined UTMC protocols to exchange journey times for links and routes. There are CORBA and HTTP/XML specifications for this, both derived from the same information model (although with some manual tailoring in the case of HTTP/XML).

There are also DATEX II services offering journey times. This centre-to-centre communication is exactly the purpose for which DATEX II was originally designed. The adoption of DATEX II as a CEN specification, and its continued support by EasyWay, indicate that it is viewed as the leading European specification in this area.

Seamless Report 2 considered the protocols available for public-to-private publication (3) in the UK as well as their practical deployment. There is widespread deployment of UTMC “common database” systems, and substantial deployment of DATEX II publication services from these systems, but there has been limited knowledge and uptake amongst service providers.

Work of the Highways Agency illustrated that DATEX II can adequately represent the UTMC data elements for journey time.[18]

Seamless Report 2 identified potential tactics to encourage uptake of urban data services and thereby increase the seamlessness of services overall: the creation of profiles, with validation, and a directory of services. Further refinement of these proposals is a candidate work item for Seamless WP4.

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[18] See the UTMC and DATEX II mappings to Journey Time Core Components in the HA Metadata Registry at www.itsregistry.org.uk

Private-to-public publication is also limited but does occur. This is believed to use proprietary protocols at present but there is no apparent reason why DATEX II could not be implemented in this direction.

The EasyWay guideline "Traveller Information Services: Traffic Condition and Travel Time Information Service", TIS-DG03-05, includes an informal specification of a DATEX II profile, identifying the subset of DATEX II elements that should be used to publish travel condition and travel time information. Review of the adequacy of this profile (and others for other roads information) for the urban context is a candidate work item for WP4.

For seamless interoperability there would be benefit in formalising such a profile and producing an XML Schema that could be used to verify the compliance of implementations of the profile.

Other roads information

Other kinds of roads information follow similar architectural patterns. The set of information available may be more than the simple aggregation of data reported to the centre, because the centre may create its own content – for example creating traffic events from observing CCTV images of the road network, or publishing planned events which have been manually entered.

Planned events information may come to the traffic management central system from one or more external systems, and there are further protocols and specifications in this area e.g. ETON and SDEP in the UK.

7.2.3 Communication from centre to V-ITS-S/P-ITS-S (5,6)

The primary realisations of these links are:

- RDS-TMC broadcast
- TPEG broadcast
- Internet HTTP-based publication

Seamless report 2 discussed current capabilities and future trends in these areas. These categories are not mutually exclusive e.g. a TPEG XML service could be available on the Internet using HTTP.

TISA has recently developed the "TPEG TFP" (Traffic Flow and Prediction) specification which will potentially become CEN/ISO TS 21219-18. It specifies an information model and corresponding XML Schema that includes travel time.

Since DATEX II is the leading specification for communications 3 and 4, and TPEG is the leading future specification for communications 5 and 6, it is important that there is alignment of these specifications. Existing developments have shown that significant effort can be required to resolve DATEX II/TPEG translation issues. New profiles may partly help. Further analysis in this area is a candidate work item for Seamless WP4.

7.2.4 Communication from R-ITS-S to V-ITS-S/P-ITS-S (7,8)

The Journey Time use case is one in which direct communication, between central services and in-vehicle or mobile devices, is appropriate. Nevertheless, there is also work on communication from R-ITS-S to V-ITS-S/P-ITS-S in this area, although not yet significant deployment.

ETSI's basic set of applications for cooperative ITS includes the application "co-operative navigation" with the use case "traffic information and recommended itinerary". In this use case, an R-ITS-S informs the approaching vehicles of traffic conditions and issues recommendations in the case of congestion. The information is seen as an authoritative message from the traffic manager.

Requirements stated for this ETSI application are:

- Capability for a road side unit to broadcast periodically some local traffic information and provide circulation advices to reduce traffic jams.
- Capability for a vehicle to receive and process broadcasted traffic information and establish a P2P unicast session in case of local map download.
- Minimum frequency of the periodic message: 1 Hz to 10 Hz according to used broadcasting technology
- Maximum latency time: 500 ms.

8 Other Use Cases

8.1 In-vehicle signage

The ISO Technical Committee 204, WG 18 is going to publish a data exchange specification for in-vehicle presentation of external road and traffic related data [ISO13], which is described here.

In-vehicle signage applications will supply road users with various type of information, which can be

- Prescriptive, such as special routing information,
- Informative, such as danger warnings
- or additive, such as information about weather or even abduction alerts.

The source of the information chain discussed here is forced to be a road operator (of course the road operator itself has further sources for his information). There are different types of information chains to reach the road user:

- Direct operation of Variable or Dynamic Message Signs (VMS, DMS)
- Supplying Vehicle ITS Stations with information, which spread the information into cars and in consequence to the drivers

In general the allocation of tasks between the different ITS stations can be seen as follows: The C-ITTS will provide the general information about the variable traffic sign information; the R-ITTS will generate appropriate messages and the V-ITTS is responsible for a relevance check and publishing the information to the end-user.

Of course there are different rules, which determine the life cycle of the variable message sign information (duration, validity, time-out, …) and the kind of relevance checks (e.g. authorization, correct driving direction, but also language, prioritisation of more than one sign, …). The messages might be different for different types of vehicles (for example lorries vs. cars) and for different situations, such as for vehicles in a traffic jam, for example.

It is intended to use the 802.11p protocol in a 2Hz cycle to communicate from R-ITS-S to V-ITS-S (i.e. to the vehicles). There is also some long range communication in discussion for publishing information directly from C-ITTS to V-ITTS.

9 Recommendations and conclusion

There are well-accepted structures for the emerging C-ITS architectures which become clear in several R&D and FOT projects. The 1st release of standards for Cooperative ITS in response to the European Commission Mandate M/453 tightens these structures. The big challenge is to merge these architectures on existing urban systems with focus on connecting legacy. This document shows, with a generic approach, that the appropriate urban standards like UTMC and OTS can be mapped to the Cooperative ITS architecture. Considering the other way round, C-ITS architectures can be fitted into existing urban architectures and constraints, bringing forward urban seamlessness.

Nevertheless, there are challenges left open. The biggest lack of clarity seems to apply to the role of the R-ITS-S – the number of possible R-ITS-S scenarios is as huge as the number of different tasks for the ITS communication. A key question is where (and in which systems) the intelligence of the R-ITS-S is best allocated. A similar lack of uniformity can be seen in the use case for the Traffic Light Phase Assistant. Because of its overall nature, this use case covers a lot of topics, which are solved very differently in a variety of projects.

The progress as well as the problems are shown in this document by urban context examples, but they exist exactly the same way in inter-urban scenarios. For travel times or in-vehicle signage along motorways other standards apply, but mapping to the generic architecture can be done in a similar manner. Also the question of R-ITTS forming is the same in an inter-urban context.

Road Operators should be aware of having more than one possibility to publish their data. This is opportunity and duty at once. They can reach a wider audience and increase the amount of information and its reliability. But by handling this difficult task the wrong way, they can even reduce the reliability of the data and their own reputation. So careful consideration is needed to ensure the necessary quality for the task.

The ideas and the work of this document will be continued in workpackage 4 with a set of deliverables. The theoretical based approach here will be aligned by concrete examples and recommendations. It is planned to develop and publish DATEX II schemata for Travel Times and the Traffic Light Phase Assistant. The mapping from ETSI standards to UTMC will be elaborated in detail. Furthermore, the DATEX II – TPEG liaison will be enriched by some guide.

10 Appendix

10.1 References

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10.3 Abbreviations

A list of abbreviations and acronyms occurring in this document

API	Application Programming Interface
C2C	Car to Car (communication)
C2I	Car to Infrastructure (communication)
C2X	Car to Car and Car to Infrastructure (communication)
CALM	Continuous Air interface for Long and Medium distance
CAM	Cooperative Awareness Message
CEN	European Committee for Standardization
C-ITS	Cooperative Intelligent Transport Systems
C-ITS-S	Central ITS Station (also: ICS)
CVIS	*A cooperative systems project*
DENM	Decentralized Environmental Notification Message
EC	European Commission
EN	European Norm
ETSI	European Telecommunications Standards Institute
EV	Electric Vehicle(s)
FOT	Field Operational Test
I2I	Infrastructure to Infrastructure (communication)
Ipv6	Internet Protocol version 6.0
ISO	International Organization for Standardization
ITS	Intelligent Transport Systems

M	Mandate
MDM	Mobility Data Market Place (Germany)
NDW	National Data Warehouse (Netherlands)
OCA	Open Traffic City Association
OCIT-O	OCIT-Outstations
OTS	Open Traffic Systems
P-ITS-S	Personal ITS Station (also: IMS for ITS mobile station)
POI	Point(s) of Interest
PT	Public Transport
R&D	Research and Development
R-ITS-S	Roadside ITS Station (also: IRS, RSU)
SPAT	Signal Phase and Timing Message
TC	Technical Committee
TPEG	Transport Protocol Experts Group
TPEG-TEC	TPEG Traffic Event Compact (message)
V2C	Vehicle to Centre (communication)
V2V	Vehicle to Vehicle (communication)
V-ITS-S	Vehicle ITS Station (also: IVS)
VMS	Variable Message Sign(s)
WG	Working Group