Report on Legal and Organisational Structures for C-ITS Operation

C-Roads Platform
Working Group 1 - C-ITS Organisation

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List of Figures

Acronyms

A	Applications layer
ABT	Arrow Board Trailer
AG	Amsterdam Group
(B1)	Planned roadwork, in accordance with the distinct classification of the SCOOP-Roadwork warning
(B2)	Road operator's intervention, in accordance with the distinct classification of the SCOOP-Roadwork warning
(B3)	Road maintenance, in accordance with the distinct classification of the SCOOP-Roadwork warning
CA	Cooperative Awareness
CAM	Cooperative Awareness Message
CITSC	C-ITS Corridor
C-ITS-S	Central ITS Station (the so-called SCOOP platform)
CRW	Collision Risk Warning
CT	Container
DE	Data Element
DEN	Decentralized Environmental Notification
DENM	Decentralized Environmental Notification Message
DF	Data Frame
F	Facilities Layer
GN	Geo Network Layer
GNSS	Global Navigation Satellite System
HF	Header Field
ITIL	Information Technology Infrastructure Library.
ITS-G5	ITS-G5 is a European standard for ad-hoc short-range communication of vehicles among each other (V2V) and with Road ITS Stations (V2I). ITS-G5 refers to the approved amendment of the IEEE 802.11 (standard IEEE 802.11p). This technology (possibly others) uses the 5.9 GHz frequency band to support safety- and non-safety ITS applications. In this document ITS-G5 stands for IEEE802.11p/ETSI ITS-G5.
ITS	Intelligent Transport Systems
ITS-S	ITS Station
ITSS-VG	ITS-S in a road operator mode
IVI	In-Vehicle Information

IVIM	Infrastructure to Vehicle Information Message
IVI service	Infrastructure to Vehicle Information (IVI) service
IVS	In-Vehicle Signage
km	kilometre
m	metres
MAPEM	MAP (topology) Extended Message
ms	milliseconds
MS	Member State
OBU	On Board Unit
OHLN	Other Hazardous Location Notifications
OSI	Open Systems Interconnection model
P	Parameter
PDU	Protocol Data Unit
R-ITS-S	Roadside ITS Station (the so-called RSU or ITS-S R in the French terminology)
RSP	ITS-G5 Roadside System Profile (abbreviated as Roadside System Profile or Infrastructure Profile)
RVU	Road vehicle unit
RWW	Roadworks Warning
s	seconds
SAP	Service Access Point
SCT	Sub-Container
SDU	Service Data Unit
SP	Service Primitive
SPATEM	Signal Phase And Timing Extended Message
T	Transport
TCC	Traffic Control Centre

N/A	*Not Applicable*
TBC	*To Be Checked, with MS or associated partner*

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Glossary

Use case	Denotes a procedure of executing an application in a particular situation with a specific purpose [ETSI TR 102 638 V1.1.1 (2009-06)] e.g. is RWW, IVS and CRW.
Use case scenario	Denotes a more specific way to execute a use case, e.g. the stand-alone mode of Roadworks Warning in case of safety trailers failing to connect to the centre. As another example, in the CITSC terminology, “TCC-triggered RWW” denotes a use case scenario to implement RWW use case based on TCC data only.

1. Introduction

The present report consolidates the findings and recommendations from ongoing C-ITS pilots with regard to organizational issues in their widest definition. It provides insight on most promising approaches and explores the provisions that need to be put in place to foster harmonized and interoperable C-ITS deployment on a European scale.

The C-Roads Platform brings together road authorities and operators currently covering 16 European Member States. The objective of C-ROADS platform, as a flagship initiative in deployment and harmonisation of C-ITS services on a European level, is to contribute to safe and sustainable travel and transport objectives as expressed in the EU transport policy document with the aim to reduce the number of casualties and reduce congestions and its effect on the environment using Intelligent Transport Systems technologies. The main objective being to create a platform for the deployment of interoperable C-ITS services between various public/private sector stakeholders such as national bodies, automotive industry, telecommunication operators, road authorities etc. The key element underpinning this is a suite of harmonised specifications for cooperative intelligent transport systems (C-ITS).

Member States and infrastructure operators as implementing bodies are represented at the C-Roads Steering Committee (SCOM). The SCOM provides an interface to all internal and external stakeholders, including the European services (European Commission and INEA). They are closely linked to the C-Roads Platform through policy guidance and the legislative framework of C-ITS. Additionally, the Steering committee guides and ensures interaction with external stakeholders through dedicated workshops as well as to the EU-C-ITS-Platform and acts as the ultimate decision body of the C-Roads Platform.
To enable adequate decisions towards interoperable deployment, Working Groups are established as a decision support for the Steering Committee, bringing together member states experts and individual experts participating in the single pilots and nominated by C-Roads Steering Committee. The various Working Groups and Task Forces setup focus on validation and consolidation in light of preparing recommendations.

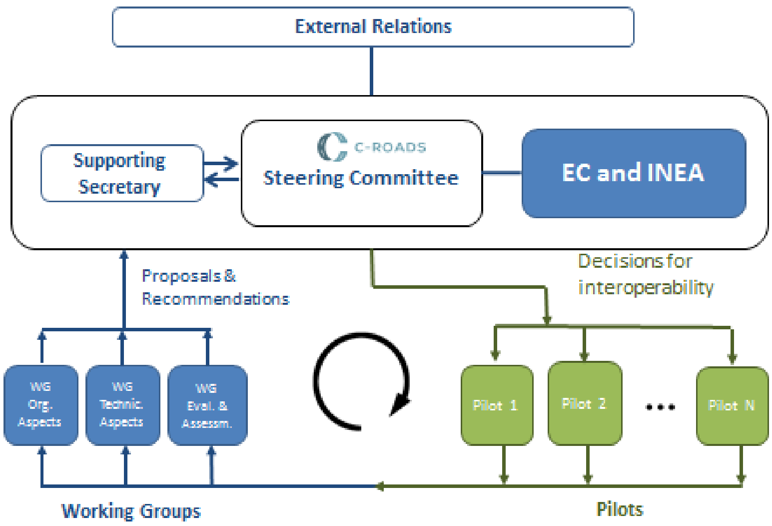

Figure 1: C-Roads Structure

This report has been prepared by Working Group 1 on 'C-ITS Organisational' as the key driver for exploring the potential for a broader roll-out of C-ITS in different organisational environments in Europe. The main role of Working Group 1 is to consolidate the perspective of public actors (Road operators and authorities) and the private sector. The latter has an equal and important role in the deployment C-ITS services. The legal framework is provided via the EU ITS Directive, delegated regulations in various priority areas to deliver some of the crucial services, such as the delegated act on road safety. C-Roads objectives include delivery of suitable suite of standards and specification including guidance documentation to ensure harmonised deployment of all interoperable C-ITS services, taking into consideration varying operating environments. A harmonised approach to the deployment C-ITS services will help improve road safety and better traffic management using real –time traffic information. The resultant effect be better management of congestion on our networks and the effects of congestion on the environment. It is therefore important to ensure the interaction and alignment of the Working Groups on future strategies towards raising awareness, involving end users and promoting solutions to overcome known or potential legal barriers/ obstacles (including privacy issues) related to C-ITS.

Aim of the report

C-Roads Member States are focused at realizing seamless operation of C-ITS services across borders and therefore helping to create a platform for connected and automated driving in the future. This document has been structured in separate parts which have been completed over time according to the activities assigned to participating partners. Emphasis is given to legal and organizational requirements and provisions to foster harmonized and interoperable C-ITS deployment on a European scale. The document has been designed for enabling partners to apply best practices in the operating environments they manage and also to assess potential risks to delivery.

Each member state has provided information regarding their pilots and the respective service chain responsible for the implementation. Detail has been provided on the entire process such as how the final service is generated from the Content side to content processing, service provision and to Service presentation. System costs, benefits are in the process and how to quantify them are also mentioned.

Different organizational schemes in individual pilot applications have been analysed because it is important to learn from suitable organizational models and procedures used for harmonized and sustainable deployment C-ITS services in Europe.

The document comprises basic C-ITS Elements of the deployment framework considering defining (minimum) common elements and of realizing an exchange of best practices in Europe and a mutual learning for C-ITS Implementation. Key activities included analysis of actors involved in these systems´ implementation processes and documentation of their cooperation. Transfer of best practices, experience and knowledge by means of specific documented examples is a way to roll-out in various operation environments at national levels.

Description of procedures and responsibilities, C-Roads members service chain is enclosed as Appendix 1 to this document. The process towards roll-out of C-ITS services are recommended based on main and clearly defined existing business models.

The report content is made up of two elements as suggested by the crescents (see also Figure 2):

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* Elements constituting the deployment framework: These are preconditions considered essential for deploying C-ITS services successfully. However, most of these are out of scope, more precisely: out of direct influence, of this Working Group. The preconditions identified are briefly described in chapter 2 of this report.

* Elements impacting an organisational harmonisation of services (chapters 3 and following) and most relevant considering service harmonisation and service continuity. These elements are being addressed from an end user perspective. This does not necessarily imply – regarding integration into legacy of ITS systems of road operators – that each and everything' needs to be harmonised but points at required (communication) interfaces to be agreed and at a common approach and adherence to essential auxiliary processes such as security, privacy etc.

The report provides insight on organisations that provide C-ITS services, on cooperation models as reflected e.g. by service chains, and handover processes between telecom networks, cross-border and between service providers.

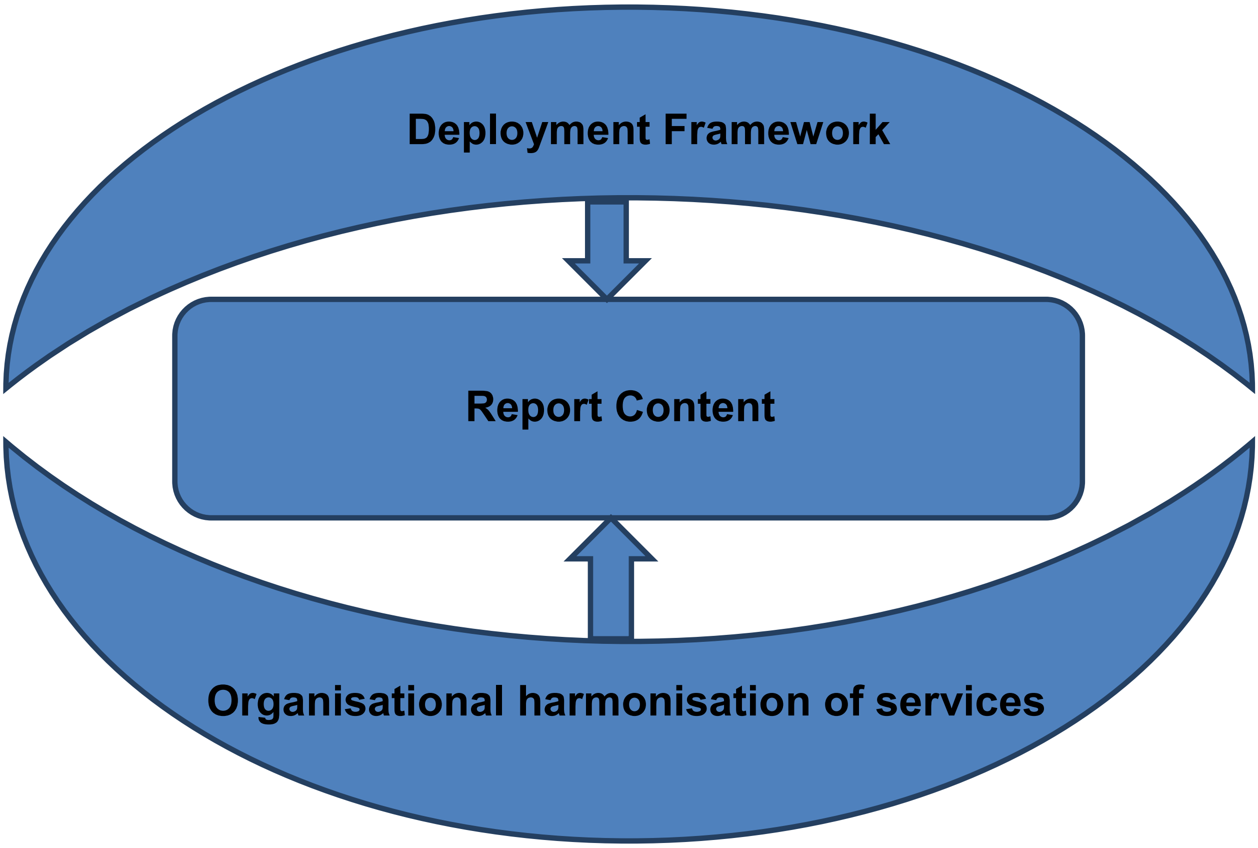

Figure 2: Key perspectives addressed

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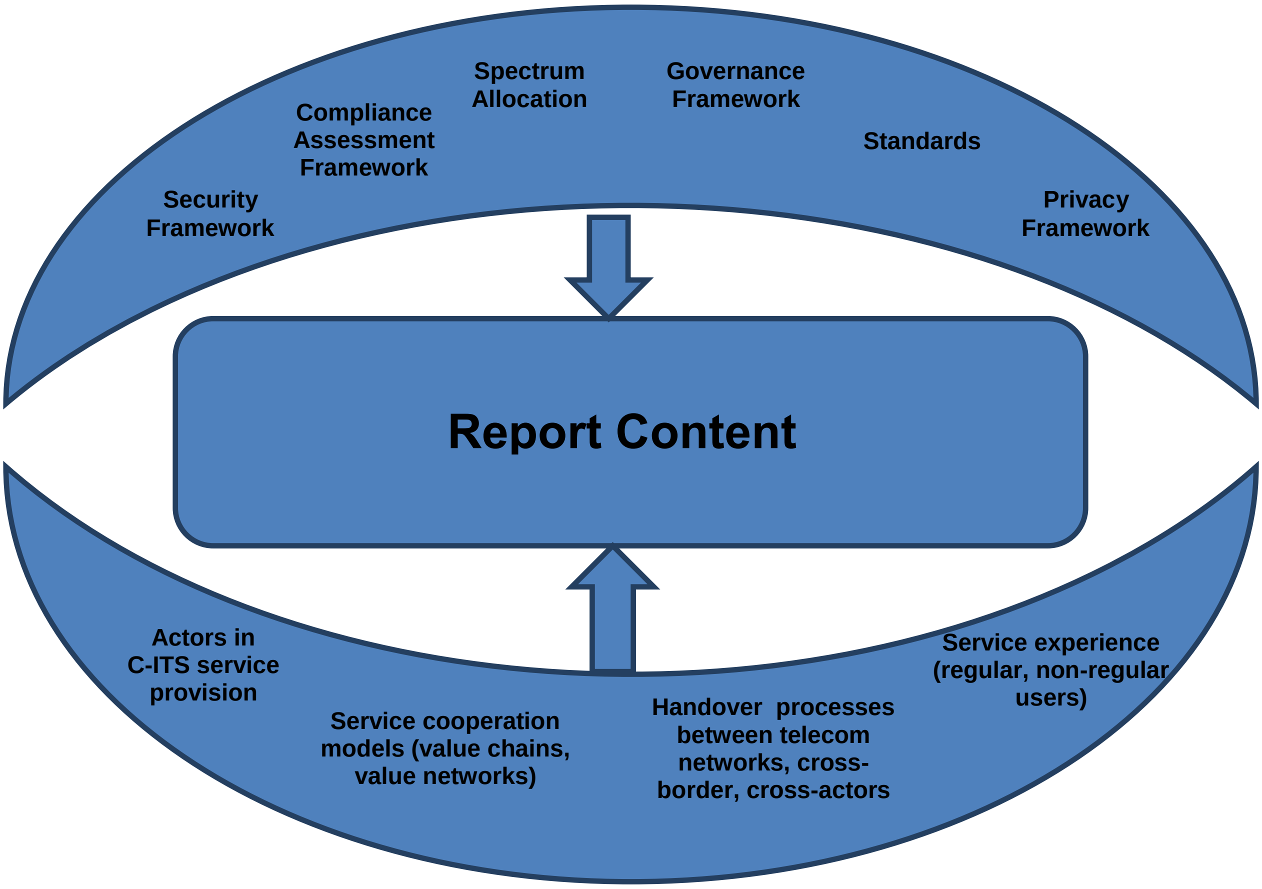
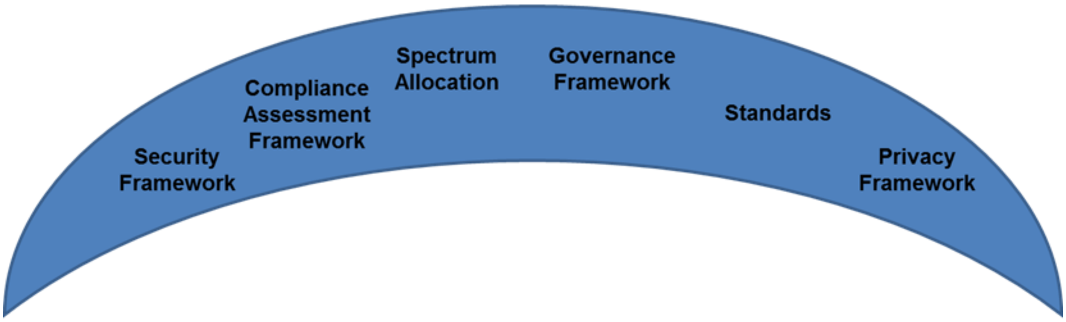


Figure 3: External Factors influencing the Report

2. Elements of the deployment framework

This chapter provides a brief description on the state-of-play of the deployment framework for C-ITS services, i.e. security framework, compliance assessment framework, spectrum allocation, governance framework, standards and privacy framework. It lists per element the institutions in charge, where it is anchored in the C-Roads WG´s and what is the relevance for WG 1 on organisational issues.



Security framework (EU C-ITS Security Credential Management System)	
Relevance of the element	The security framework is key for the management of information security for the deployment and operation of the European Cooperative Intelligent Transport System (C-ITS). It defines the policy requirements for information security management for all organisational entities that process C-ITS data or manufacture equipment that will process C-ITS data. The C-ITS system is a distributed system with many stakeholders and many actors processing parts of the C-ITS data which makes information security not only a responsibility of the individual organizations but also a joined and shared responsibility.
State-of-play	The building blocks of the security framework have been one of the key achievements of the C-ITS Platform. First releases of the certificate policy and the security policy have been published on the European Commission website. The legal certainty is ensured by incorporating these elements in the Delegated Regulation on C-ITS (item/article on security incl. annex links).
Institution(s) in charge	European Commission
C-Roads WG in charge	WG 2 (Technical Issues) – TF 1 (Security). Security framework is defined for the needs of C-ROADS pilot projects only. It will not be defined the whole security framework.
Relevance for WG 1	Migration between evolving versions of the security standards
Useful links	Certificate Policy Release 1 [Link] Security Policy Release 1 [Link] C-Roads (Draft) Report on European Security Mechanism

Compliance assessment Framework	
Relevance of the element	Harmonized deployment of C-ITS services requires an effective compliance assessment framework that allows services to be checked against EU standards and technical specifications. Especially for road-safety-related applications, there is a strong public interest in developing such a framework for key elements of the C-ITS network such as security, privacy and interoperability, to ensure that road users receive consistent warnings in different traffic environments across the EU. Compliance assessment process for all C-ITS key elements will harmonize deployment and continuity of C-ITS services.
State-of-play	Within the C-ITS platform, 2nd phase has been designed the basic organizational scheme of compliance assessment framework, which includes key roles and individual interactions throughout the process. The key actors in the process include the C-ITS Supervision Body, the C-ITS Governing Body and the Compliance Assessment Body.
Institution(s) in charge	European Commission
C-Roads WG in charge	WG 2 (Technical aspects). Within the C-ROADS project will be defined the tests for interoperability. The compliance assessment framework will not be defined. This is beyond the C-ROADS platform scope.
Relevance for WG 1	To monitor and analyse the compliance assessment process across Member States and evaluate it and ensure the migration of good examples within the C-ROADS platform.
Useful links	C-ITS platform – Report, Phase II - [Link]

Spectrum allocation	
Relevance of the element	For the operation of C-ITS, it is necessary to block certain frequencies. Wireless communication is used for a variety of purposes and objectives. Ensuring proper functioning and communication within C-ITS without interference with other frequencies is possible only through exclusive C-ITS frequency allocation. A crucial stakeholder in the determination of the frequency band decisions is the Electronic Communications Committee (ECC) of the European Conference of Postal and Telecommunications Administrations (CEPT). In function of the type of C-ITS application it is possible to use short-range (e.g. ITS-G5) and /or long-range communication (e.g. cellular) technologies. For long range communication with respect to spectrum allocation is situation different compared to short range communication.

State-of-play	• Short-range communication: In 2008 the European Commission (EC/2008/671) designated a specific frequency band of 30 MHz in the range of 5 875-5 905 MHz (in short 5.9 GHz frequency band) for safety-related ITS applications in Europe. It was followed by the spectrum allocation in 2008 and the release of a complete set of tested ITS-G5 standards by 2013 (ETSI G5). • CEPT has currently a mandate to study an extension of the upper edge of the EC harmonised safety-related ITS band (5 875-5 905 MHz) by 20 MHz up to 5,925 MHz. the telecommunications industry in 3GPP has started standardization on LTE-V2X (also known as 5G Sidelink); • coexistence ITS-G5/DSRC (5,8 GHz) used for tolling, which might cause interference has been described and resolved in C-ROADS WG2 TF3 document; • coexistence ITS-G5/CBTC; under investigation by CEPT; • coexistence ITS-G5/LTE-V2X: under investigation by CEPT.
Institution(s) in charge	European Commission
C-Roads WG in charge	WG 2 (Technical Issues) – TF 3 (Infrastructure communication) and TF 4 (Hybrid communication)
Relevance for WG 1	C-ITS market analyses (LTE-V2X, extension of ITS band)
Useful links	CEPT - [Link] Coexistence Interoperability of ETSI ITS-G5 & DSRC - [Link]

Governance Framework	
Relevance of the element	The overall governance of the European C-ITS system including the components and entities of C-ITS. C-ITS Governance Framework is an organisational model of the whole C-ITS environment. It describes, defines and visualize the Actors, Role, sub-roles, Legal entity and their position in the overall C-ITS. It is using architecture diagrams that show dependencies and interconnections between the roles and how they work together. The tasks, respective categorisation and properties of each specific role and sub-roles must be clearly described and connect to the overall framework. Very important part of Governance framework is a Classification of roles in the EU C-ITS trust system. Another essential part is the management of migration of new technical specifications throughout the C-ITS ecosystem, including the necessary upgrade of existing systems that do not use the new technical specifications. This process still needs to be properly organised.

State-of-play	The Governance framework has been designed by the C-ITS Platform (2017 Phase II) in the report which is mentioned below. Within the C-ROADS platform is under development overall Organisational scheme, definition of Actors, roles and legal entities and it is one of the scope of this Report.
Institution(s) in charge	European Commission
C-Roads WG in charge	WG 1 (Organisational Issues)
Relevance for WG 1	Setting up a Governance framework within the C-ROADS platform. System deployment monitoring within the EU
Useful links	Security Policy & Governance Framework for Deployment and Operation of European Cooperative Intelligent Transport Systems (C-ITS) Release 1 December 2017 [Link]

Standards	
Relevance of the element	Standardisation of C-ITS systems is vitally important in order to ensure that the advantages of the internal market can be achieved. If C-ITS is to fully achieve its potential, it is necessary to obtain a sufficient market penetration so that the technologies can contribute to achieving transport policy objectives. Standardisation for C-ITS systems has already been initiated by CEN, ETSI and ISO as well as within other international standards organisations. Standardisation work is still ongoing. As part of the implementation of the project, the applicable European and world standards and guidelines for the use of C-ITS and transmission protocols must be respected. These standards are listed in ANNEX II of this report.
State-of-play	C-Roads is to create a specification that profiles the large set of C-ITS Standard used in a way that enable application developers to implement in-vehicle applications based on infrastructure-to-vehicle information sent from ITS G5 stations operated by the road operator. Similar development had already been carried out by the Car2Car Communication Consortium to create such a profile as the basis for vehicle-to-vehicle applications (“Basic System Profile”).
Institution(s) in charge	European Commission
C-Roads WG in charge	WG 2 (Technical Issues) – all TF´s within the WG2. Each TF has its own set of standards.
Relevance for WG 1	Migration between evolving versions of the standards and technical specifications for interoperability.
Useful links	European Telecommunications Standards Institute - ETSI - [Link]

	ANNEX II of this report – List of standards [Link]

Privacy framework	
Relevance of the element	'Trust' in the system as well as legal certainty is crucial; cybersecurity, protection of personal data and data privacy goals should be met at the required level, even for 'Day 1 applications' as laid down in COM 2016/766. GDPR entering into force furthermore requires a broad perspective, and engagement from all involved actors.
State-of-play	Working group on data protection and privacy under the C-ITS platform is seeking guidance and points to be taken into account from Article 29 in order to be able to take further steps with sound level of data protection. Beside of the C-ITS platform exists and works with the privacy issues the „Privacy group "within the European Commission.
Institution(s) in charge	European Commission
C-Roads WG in charge	WG 1 (Organisational Issues) WG2 (Technical issues)
Relevance for WG 1	WG 1 has been entrusted to clarify the status and to potentially come up with further proposals at platform level.
Useful links	Processing personal data in the context of C-ITS [Link] Opinion 03/2017 on Processing personal data in the context of Cooperative Intelligent Transport Systems (C-ITS) [Link]

3. Organisations that enable C-ITS services

This chapter describes which organisations enable the provision of C-ITS services in Europe. It starts with brief fundaments on terminology, followed by a concise description of actors and a more detailed explanation of the (pilot) organisations in the different Member States.

3.1 Terminology

C-ITS services provide a valuable contribution in order to make road traffic safer, more efficient and more environmentally friendly. For realising the significant potential in terms of impacts, C-ITS services need the collaboration of many in a distributed system. An ITIL-based fundament for a shared perception and understanding has been laid out in ISO TS 17427-1 on roles and responsibilities in the context of C-ITS. It has introduced the concept of four top-level roles as illustrated in the following figure.

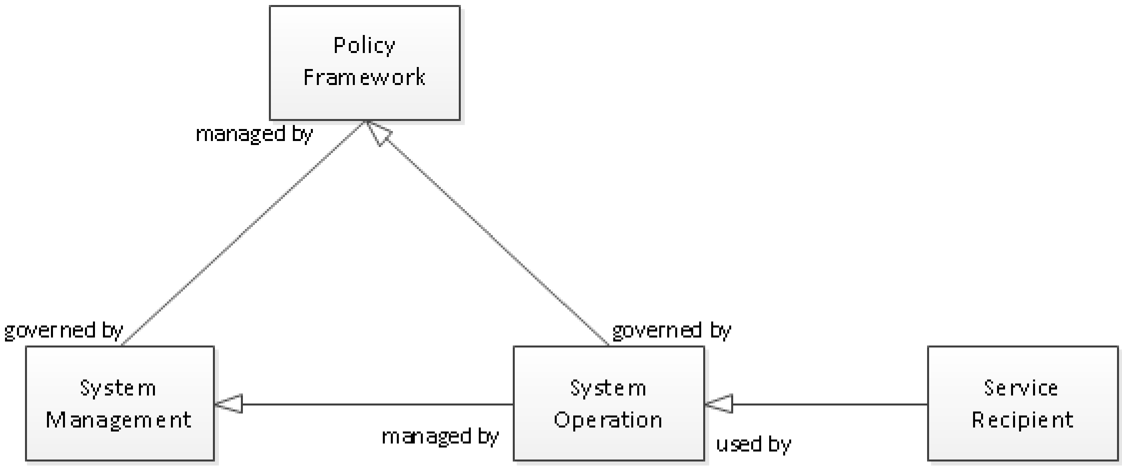


Figure 4: Roles and Responsibilities in the context of C-ITS

3.1 Organisation

For this terminology section, it is appropriate to define relevant terms.

Organisation

An organisation is a social unit of people that is structured and managed to meet a certain need or to pursue collective goals. All organisations have a management structure that determines the relationship between the various activities and members, whereas roles, responsibilities, and the authority to carry out specific tasks may be subdivided and are assigned. Organisations are open systems; they affect and are affected by their environment.

The key terms used in the organisational context – role and actor – are briefly defined below:

Role

A role is a generic description on accountability. It is characterised by the execution of a series of activities that are assigned to operational processes. Roles are assigned to organisational units/persons in the structure of an organisation, e.g. a road authority or a road operator. That way a role can be parted (this means that multiple organisations units/persons can perform the role) and/or combined (this means that a role and different one can be performed together by only one person/organisational unit). The benefit of the usage of a role model is that it can be used for different organisations without giving specifications on the current organisation structure.

Actor
An actor is a generic organisation to which one or more roles can be assigned. Actors can be defined on the level of an entire organisation (e.g. Hessen Mobil as a road operator in Germany) whereas tasks are done by an organisational unit (section, department) or a person within this organisation. On a more high-level view, it is sometimes also appropriate to label a specific industry or sector as an actor (e.g. automotive industry, telecom industry, National Road Authorities).

In the case of C-ITS services, where responsibilities are to some limited extent separate, but to large extent joint responsibilities, it is further appropriate to add a definition on committee.

Committee
A committee is an entity that is assigned for decision-making and voting tasks. It is usually occupied by one or more role(s), which then can be assigned to one or more actor(s).
The tasks of the committees can also be assigned to already existing committees within the organisation or among the participating organisations.
For example, C-Roads is guided by a Steering Committee, the tasks are assigned to various actors within the member states.
This reduced set of definitions may be sufficient for the purpose of this document.
For preparing operational concepts and manuals, an extended set of definitions may be more appropriate, as e.g. provided in ‘C-ITS Corridor Operational Concept’. Also, output from projects like [FRAME NEXT] can be used when the architecture of C-ITS services should be expanded.

3.2 Methods and Procedures

Each ITS system component is governed by responsible authorities. Actors from different areas may jointly contribute to the implementation of application cases, whereas responsibilities of actors can differ, and potentially change/ shift.

Regarding specific investments and specific knowledge, which are required for the networking of intelligent transport systems, the case might occur that there is neither an open market-based solution nor one with only one participant that is efficient. Therefore, it is imperative that a close cooperation between all the participants in ITS networking is achieved. This is especially true for all hybrid-based solutions

From the perspective of a road operator, a question arises prior to any compilation of new ITS variants for an application case, namely which of the future tasks can be transferred to other partners in the private sector. This leads to several possibilities regarding the combination of ITS system components. The content summarized behind detection, evaluation and display is usually provided by both private as well as governmental sources.

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If new actors are to be brought into the picture, a way of formalizing this process has to be found. Regulations and rulesets ensure a quality implementation of use cases on a superordinate level and give detailed requirements for technical details, e.g. which standards are to be used.
In case the road operator chooses to delegate an increasing amount of ITS tasks to partners, it needs to be clarified in which areas the superordinate and final checks need to remain, and how this can be put into practice together with the partners.
Next to the challenges connected with the distribution of tasks and responsibilities, the aspect of financing is also important. There cannot be a universally valid stance on this, as this challenge depends on the application in question. For instance, applications with usage costs can be part of a business model for some partners. Alternative methods to finance services that are free of charge must be developed.

3.3 Actors

In the present report the role of actors must be seen in the context of C-ITS, and – most important – regarding the three core objectives of C-ITS, being safety, efficiency and environmental impact.

3.3.1 Road Operator

The core asset of a road operator is the road network. The operational and traffic management aspects need to ensure safe, efficient and environmentally friendly transport operations.
The main tasks can therefore be defined as:

- traffic management
- security and (road) safety
- road maintenance
- communication

The traffic is principally managed and operated by the traffic authority, irrespective of whether it is operated by the traffic management centre or a third-party service provider. The essential requirement however is that road information is generated that is subsequently disseminated to the end road user. There are of course many dissemination channels for broadcasting this information depending on the content.

3.3.2 Communication Provider

The communication provider is responsible for providing a communication platform for the exchange of messages, this can be either using peer to peer communication such as the ETSI G5, or cellular or a combination of the both.
In general, the communication provider is (also) able to support several services for data providers and service providers, e.g. the collection of floating car data from cooperative cars or distribution/ dissemination of cooperative message (DENM).
It’s a common practice that the road operator is normally responsible for providing the infrastructure for dedicated communication, as is the case for example in Austria, France, Hungary etc.

3.3.3 Service Providers

A service provider is an organisation supplying service(s) to one or more customers. Customers can include both, other organisations or end users.

Since responsibilities may differ significantly, it's common practice to distinguish between two types of providers:

- Service Providers which communicate with smartphone users – via apps, typically telecommunication providers.

  For detailed examples see e.g. the architecture described by NordicWay, chapter 4.6
  The connection between OEMs/ smartphone apps and a national access point currently being investigated. Many architectures may apply, potentially also involving the road operator.

- Service providers, most often car manufacturer (OEM), which communicate via proprietary On-Board Units (OBU) – potentially using ITS-G5 (that also enables cost effective Vehicle-to Vehicle exchange of messages)

  Typically, ITS G5 providers combine tasks related to both "communication provider" and "service provider"; the service(s) which in such cases is delivered is operated making use of RSUs, which they do not necessarily own or manage themselves. The technical RSU-infrastructure indeed might be managed either by the road operator itself or by external companies.

3.3.4 OEMs (Car Manufacturers)

In the given context, OEMs have a role in equipping vehicles with adequate OBUs which are able to communicate with RSUs or with a central unit (making use of cellular communication) (= V2I), and also with other (equipped) vehicles (= V2V). Providing services is not the primary function of OEM's.

3.3.5 Road Users

The road user is an actor driving a (motorized) vehicle that is able to safely receive/ send C-ITS type data or information making use of:

- An (integrated) OBU, or
- A portable device, such as a smartphone or tablet

3.3.6 Public Authority

Public Authorities are in charge of defining and implementing rules on safety, security and environmental provisions and also may facilitate or enable vital elements of the overall C-ITS system. Furthermore, they may assume a role in the provision and potentially maintenance of security infrastructure. As such they significantly (can) impact the generic value chain of C-ITS.

4. Member State pilots - Organisations that enable C-ITS service

Complementary to the core assets described in previous chapter this chapter provides insight on actors and roles involved in real operations.
It however must be clear subtle differences may apply in the 'national' understanding on roles assumed as the historical, institutional (e.g. state level versus underlying entity) or political starting point may differ.

4.1 Austria

The Austrian pilot contributes to interoperable European C-ITS solutions starting from the EU C-ITS Corridor. The implementation is linked to the C-ITS Strategy AUSTRIA of the Ministry for Transport, Innovation and Technology - BMVIT, which defines the C-ITS deployment steps for the years till 2020 in an organisational framework, including the cooperation with public entities and industrial stakeholders.
The Austrian C-Roads-Pilot builds on the core elements of the EU C-ITS Corridor project in Austria (ECo_AT) and extends them to a motorway based network of C-ITS stations in 2020, as defined in the Austrian C-ITS Strategy.
The Austrian C-Roads pilot site stretches from Vienna to Salzburg and includes the Linz area.
In the south the test site will be set up around the city of Graz. In this way C-Roads Austria comprises road network elements of three different TEN-T corridors,
Pilot activities at single test and validation locations are prepared by the Austrian motorway operator ASFINAG. In most cases, the locations will be gantries where C-ITS units are installed and can be accessed without restrictions to passing by traffic flows of vehicles. Furthermore, mobile road side units are planned, e.g. on road works warning trailers.

4.2 Belgium/ Flanders

The C Roads Belgium/ Flanders pilot builds on a cloud based 'virtual infrastructure' making use of cellular 3G-4G/LTE mobile communication networks and enabling direct interaction between users involved and the Traffic Management Centre (TMC) – cfr. Nordic Way PoC. Tests and validation will concentrate on 6 use cases varying from Road Works Warning to Shockwave Damping whereas a trusted fleet of approximately 1000 test drivers is to contribute.

The pilot runs in parallel with projects InterCor (cfr. Intro in UK section) and Citrus:
- as part of InterCor ITS-G5 compliant RSUs will be installed and operated along a significant part of Motorways E313 and E314. A required PKI will be set up (and aligned with partners) to enable performance testing and validation of RWW, IVS and PVD.
- the Citrus project ('C-ITS for TRUckS') focuses on 3G/ 4G based safety and routing information services, and GLOSA. Validation of services and exploration of the Business Case are planned making use of more than 300 HGV intensively frequenting the area around Halle, West of Brussels (fleet belonging to retailer Colruyt). The project builds on the existing Flitsmeister (Be Mobile) information-architecture & smartphone app and incorporates an independent evaluation (by TML).

The overall aim of the 3 projects running in parallel is to gain better insight in the potential of C-ITS Services and to have costs compared under various approaches, scenario's and operating environments.

4.3 Czech Republic

In the Czech Republic will be deployed hybrid communication based on ITS G5 and cellular technologies across motorways, urban nodes and a unique pilot site focussed on railway crossing safety. The deployment of hybrid communication is expected in the following steps:
The first step is the use of existing standardized ITS G5 systems as a base for C-ITS services provision and supplement the coverage by current (existing) technologies in cellular network represented by state of the art – LTE (4G). It will be investigated what cellular technology/ protocols will be the most appropriate for C-ITS messages transfer. Next step is the extension of communication used in the first step for testing/evaluation of performance of new cellular technologies as e.g. LTE-V or / and LTEB.
The Motorway deployment is following an existing C-ITS project called "MIRUD" on the Prague ring road (D0) and small parts of motorways D5 and D1. This deployment is being viewed as a base stone for future deployments as the C-ITS back-office which has been developed for Road and Motorway Directorate (further stated as RMD), the road operator of the Czech national road network. C-ITS equipment and services will be deployed on the D1 motorway between Prague and Brno, D5 motorway between Prague and Rozvadov (German border), on the D11 motorway between Prague and Hradec Králové, and on the D52/I52 connection road between Brno and the Austrian border. Total length amounts to more than 360 km. C-ITS services will be provided via hybrid ITS G5 / LTE technologies. RMD is responsible for ITS G5 technology deployment and for the service operation (Service provider). RMD plays a role of communication provider aswell. LTE-based services will be offered by the mobile phone operators O2 and T-Mobile as with all the pilot actions below (Communication providers). The geographical area for this pilot will cover selected stretches of the D1, D5 and D11 motorways which create major connection links to the Dutch-German-Austrian C-ITS corridor. Within these pilots will be used services Road works warning, In-vehicle information, Probe Vehicle Data, Slow and stationary vehicles, Traffic jam ahead warning, Hazardous location notification, Weather conditions warning and Electronic emergency brake lights.

The Urban deployment will be located in Brno city. Service provider will be Brnenske komunikace (BKOM). BKOM is the road network operator in city of Brno and is responsible for deployment of ITS G5 technology. C-ITS services will be provided via hybrid ITS G5 / LTE system and the pilot will be deployed on urban roads, which will be selected complementarily to the major roads equipped by RMD on motorway D1 deployment. Public transport deployment in cities of Ostrava and Pilsen will be organized by the public transport company of Ostrava and public transport company of Pilsen. Together they are responsible for ITS G5 deployment. C-ITS services will be offered via hybrid ITS G5 / LTE system and the pilots will cover selected streets/sections of cities.

Functional and technical requirements of field tests will be defined by all beneficiaries for each use case and each pilot site (all beneficiaries will be responsible for some selected use cases). The scope of the laboratory testing will set by INTENS and ČVUT (Czech technical university in Prague). Definition of testing of cellular networks will be specified by the mobile operators.

4.4 Germany

Seven so called Day One Services, which shall be supported by the basic system at the time of C-ITS market introduction, are trialled in the German test fields in Hessen[1] and Niedersachsen[2]. In total, the motorway network with pilot deployment of C-ITS services comprises approximately 200 km of which – in terms of km – 90% account to the pilot in Hessen and 10% to the Lower Saxony pilot. In addition, 12 intersections in Heusenstamm, a medium sized city near Frankfurt, are equipped with ITS Stations.

The pilot sites are characterised by a different level of maturity which is to be attributed to their heritage of involvement in C-ITS pre-deployment activities. In Hessen, the pilot builds on and extends the DRIVE Test Field Hessen for Connected and Automated Traffic, which has been pivotal to Field Operational Tests like simTD, DRIVE C2X and the transnational deployment initiative of the European C-ITS Corridor. In Lower Saxony, the R&D test area AIM (Application Platform for Intelligent Mobility) originates from the urban context in the city of Brunswick. The test area will be enlarged and transferred to Federal roads and motorways between Hanover, Brunswick and Wolfsburg. In geographical terms, the Lower Saxony pilot of C-Roads Germany takes place on the motorway A2.

The deployment activities in C-Roads Germany comprise a bundle of in total seven C-ITS services:

- Road Works Warning (RWW, extension of existing service for stationary roadworks in Hessen),
- Slow or Stationary Vehicle Warning (SSVW, implementation in both pilots),
- In-Vehicle Information/In-Vehicle Signage (IVI/IVS, implementation in Lower Saxony),
- Traffic Jam Ahead Warning (TJW, Implementation in Hessen),
- Shockwave Damping (SWD, Hessen),
- Green Light Optimal Speed Advisory (GLOSA, implementation in Hessen)
- Probe Vehicle Data for improving traffic management (PVD, implementation in Hessen both pilots, while in Hessen the existing version will be extended).

In terms of communication technologies, the pilots involve ITS G5 and cellular communication as well as DAB+ RWW for the pilot in Hessen.

The organisation and deployment plans of both pilots (C-Roads Germany M40 and M47) specify the responsibilities of the different actors in more detail. In a perspective towards regular operation, some assignment is subject to change or has to be confirmed due to different position of the pilot sites in the pilot life cycle.

4.5 Hungary

In Hungary, C-ITS deployment started within CROCODILE project Phase I in 2015, the improvement of road safety –especially in work zones – was the key issue on M1 motorway between Austria and Budapest (pilot deployment). For maintenance vehicles, mobile RSUs were also installed, which can

[1] DRIVE-test field Hessen for connected automated traffic in the Rhine-Main region around Frankfurt, part of Rhine-Alpine and Rhine-Danube corridors around Frankfurt

[2] Test field Lower Saxony near Brunswick, part of North Sea-Baltic and Orient-East Med corridors

operate in stand-alone mode as well. The communication between RSUs and OBUs is thus far based solely on ITS G5. The system itself covers ‘Day-1 services’ comply with ECO-AT specifications (‘Traffic jam ahead warning’, ‘Hazardous location notification’, ‘Road works warning’, ‘Weather conditions’, ‘In-vehicle signage’, ‘In-vehicle speed limits’). The system architecture – the 3 components – follows the ECO-AT specifications, too.

In the framework of C-Roads Hungary pilot extension the Implementing Body intends to extend the C-ITS deployment both in terms of geographical coverage and offered services. The focus will be put on urban deployment, GLOSA/Time-to-green as well as intersection safety (signal violation). The upgrade would also concern the communication technology – deployment of hybrid DSRC / cellular technology is envisaged in near future.

With the extension, major part of motorway M7 (Mediterranean corridor) will be covered, and urban deployment will be carried out in the city of Győr by motorway M1 (Orient-East Med corridor).

In Hungary, the existing pilot – which is planned to be upgraded/extended - is using solely ITS-G5 communication. In this case, the road operator (Hungarian Public Road Non-profit PLC.) is responsible for both content and (primary) service provision. So, this company is the Road Infrastructure & Works Operator, the TCC (TIC) Operator, and also the R-ITS-S and C-ITS-S Operator. In addition, the Road Operator is the Communication and Service Application provider as well. To the end user – or other possible private service providers – the information is provided in DATEX II 2.3 format via the so called ‘DATEX-HUB’ (the single access point of the company) – besides classical means of ITS, of course.

Within C-ROADS project, besides some additional Day 1 services, the cellular communication is planned to be implemented as well, so at the end a hybrid solution shall be in operation. Negotiations are ongoing with public transport operators, telecom companies (mobile network operators) and other possible cloud providers, but this process is still in progress, so the exact roles and actors are not defined, yet.

4.6 Italy

The Italian pilot takes place in a cross-border area (on 350Km) in the North Eastern part of the country, mainly along the Brenner corridor, an important section of the Scandinavian-Mediterranean CEF corridor, with high volume of traffic and with three motorways involved as road operators. It does not include – at this stage - urban and interurban roads and not involves external service providers. Therefore, the organisational and legal structure could change in the future, when moving to a larger national C-Roads system.

In the actual pilot the Road Operators are represented by the motorways Autostrada del Brennero, CAV and Autovie Venete. They are acting both as Traffic Data collector/Provider and as Services/information Provider through their Traffic Management Centres. Furthermore, they are also Communication Provider with the ITS-G5 technology, installing and managing proper RSUs along around 350 km of their road infrastructure.

The Communication Provider Telecom Italia (TIM), assisted by AZCOM, assures the necessary technological facilities for the testing of the 3G/4G cellular communications, by the interaction “cloud” with the road operators TCCs and with the OBUs/cellular on vehicles.

Regarding OEMs, IVECO, a truck manufacturer, together with CRF (Centre of Researches FIAT) for the light vehicles, is participating in the Italian pilot, also to test “Truck Platooning” and “Highway Chauffeur” in addition to the selected Day1 services.

Co-financed by the European Union
Connecting Europe Facility

Moreover, Codognotto, a transport company, will made available some trucks (not equipped with the Platooning technologies) to compare two fleets: one exploiting C-Roads technologies and one with normal equipment.
Polizia Stradale is involved as additional actor in the Italian pilot scenario. The objectives start from safety and legal compliance of pilot tests - passing from the identification of emerging legal requirements of a hypothetical future Road Regulation - ending to the tachograph 4.0 understanding, to carry out a two-fold objective: the anticipation of first, rudimentary, manumissions, and the development of a prototype of device able to perform a wireless exchange of tachograph data with heavy vehicles.

4.7 NordicWay

The NordicWay2 pilot covers a corridor including parts of urban networks and urban-interurban transport interconnections along the northern part of the Scandinavian-Mediterranean Core Network Corridor in Finland, Norway, Sweden and Denmark. The hybrid communication pilot focuses primarily on Cellular communication but will also cover solutions based on ITS G5 in relation to specific locations and use cases.

The cornerstone in the pilot is a common cloud solution architecture that allows all partners and stakeholders to exchange information between each other. The NordicWay2 early working concept architecture is presented in following picture and roles explained after it in more detail.

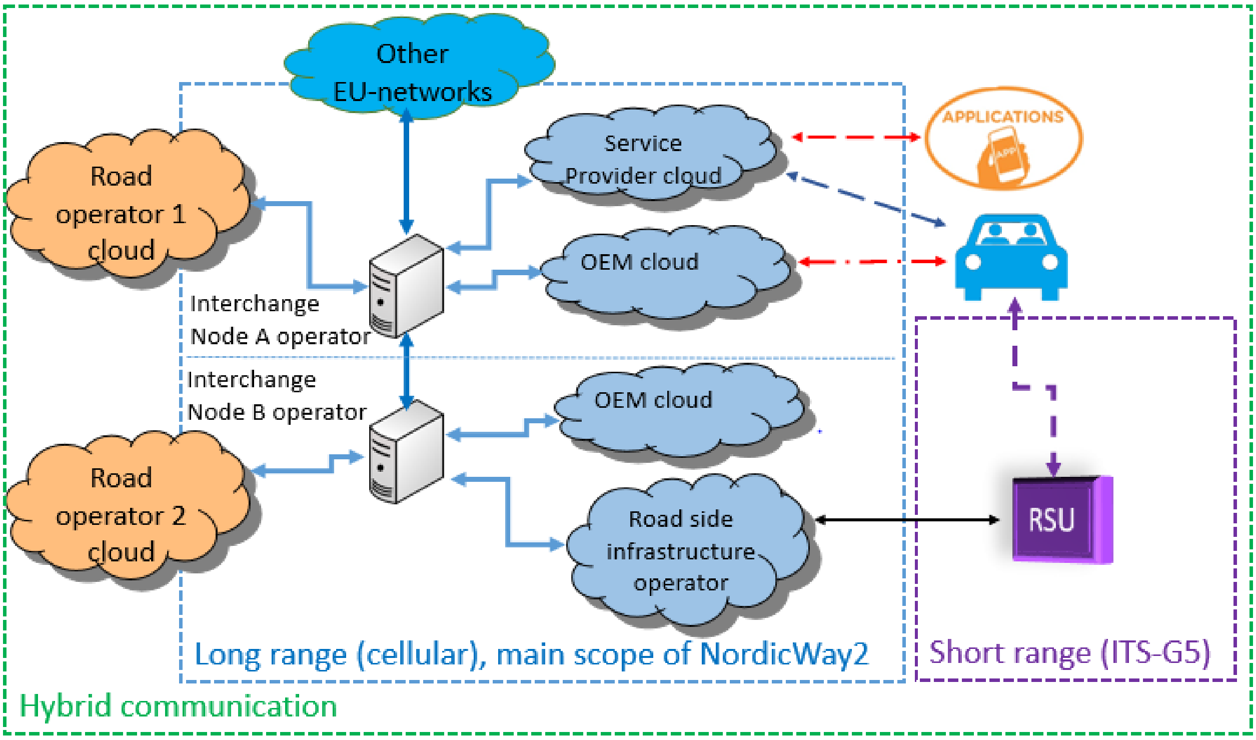

Figure 5: NordicWay2 early working concept architecture and roles (2018)

Interchange Node operator (Interchange Node A and B as well as Other EU-networks in the picture). The NordicWay2 digital infrastructure domain consists of most notably the NordicWay Interchange node, which communicates with the vehicles and devices via the access network and service provider, OEM or road operator clouds. Interchange node is a similar type of implementation than the neutral server concept presented by ACEA (2016), although it should be noted that in 2018 development is still underway and models evolve. Interchange Node routes appropriate traffic information offering a subscription model for the different partner. Interchange node operator manages access rights according to the common agreed model with the service providers and OEMs for the geolocalized information. Several Interchange Nodes operators may agree on data exchange. Group of several Interchange Nodes is referred as interchange network, which may be for example European wide network of different nodes and neutral servers.

As an example, an OEM X continuously measuring road friction through its own sensors, sends this information to the OEM X cloud. Based on this data from numerus vehicles, a slippery road can be detected, and a warning messages can be generated in OEM X cloud (or service provider's Y cloud offering the service to the OEM). This warning can then be sent to all OEM X vehicles in the area, but also to the interchange node where it is distributed to other service providers clouds who can use this information in their own services. In the same way, a national or local TMC can generate warnings based on numerous data sources and distribute this warning through its own service channels, but also distribute it through the interchange node to enable other service providers to distribute this information directly into their vehicles, apps or other solutions.
Therefore, most instances connected to the interchange node can be regarded as both data provider, data consumer and service provider.

Road Operators (road operator clouds in the picture)
Road operators will connect to the interchange node through one or more national traffic clouds, and in most cases a local or national Traffic Management Centre (TMC) will be connected to the national cloud. Through the national traffic cloud, the TMC's can send relevant messages to the interchange node, and receive messages for their territory generated and send to the interchange node by other data providers (such as OEM clouds).

Communication provider (blue communication lines in the picture)
The main communication providers in the NordicWay2 are Mobile Network Operators (MNO) operating the existing cellular access networks. Users, devices and vehicles use their existing mobile subscription acquired from the markets. Hybrid communication is used for particular services (road works and other hazardous locations) and will be linked to the NordicWay Interchange network through fixed and cellular network connections. The NordicWay2 pilot is planned to include use of as well mobile (vehicle mounted) as fixed RSU.

Service provider (similarly named clouds in the picture)
Service provider is an Original Equipment Manufacturer (OEM, i.e. a vehicle manufacturer), company or service developer, which produces C-ITS services and an application providing the services.

The in-vehicle domain is composed of an On-Board Unit (OBU) and Application Units (AUs). The OBU is responsible for communication with the infrastructure via the access network. It also provides communication services to AUs. An AU is a device that executes a single, or a set of applications, and utilizes the OBU's communication capabilities. An AU can be an integrated part of a vehicle and be permanently connected to an OBU. It can also be a portable or nomadic device. Both units can be retrofitted aftermarket devices. For compatibility reasons, the OBU can be equipped both with cellular and 5.9 GHz DSRC communications.

Roadside Infrastructure Operator (similarly named cloud in the picture)
Roadside Infrastructure Operator operates the short-range communication system. Roadside infrastructure Operator may exchange bidirectional information in a commonly agreed way from the Interchange node operator and other clouds connected to it.

4.8 The Netherlands

In the Netherlands C-ITS services will be implemented based on ITS G5 and on cellular communication (hybrid approach). ITS G5 communication is used for the services Roadworks Warning (RWW), In-vehicle Signage (IVS), Probe Vehicle Data (PVD) and Green Light Optimal Speed Advisory (GLOSA). In order to realise these services ***road operators,*** install the Roadside Units (role of ITS G5 **communication provider**). In case of RWW, IVS and PVD this is Rijkswaterstaat, the road operator of the Dutch national road network. In case of GLOSA this is the municipality of Helmond, which installs these RSUs on a number of intersections, connected to the present traffic light systems. The road operators will not only be responsible for the installation of the hardware along the roads, but also for the services delivered through ITS G5 (role of ***service provider***).
The information that will be sent by ITS G5 to the ***vehicles***, will also be made available at the National Data Warehouse (NDW), the Dutch national ***traffic data provider***. This also applies to aggregated anonymous data, collected from vehicles (PVD). The NDW delivers the data to a number of (private) **service providers.** These service providers will deliver RWW, IVS and GLOSA services by cellular communication.

In order to be able to do the evaluation of the pilot, a limited number of vehicles will be equipped with ITS G5. For the pilot this is the responsibility of Rijkswaterstaat. It is expected that in 2019 the first vehicles from the ***OEMs*** will be on the road, which will be able to use the services. These are standard cars equipped with ITS G5, normally sold to the public. For the evaluation of GLOSA in Helmond, vehicles of a local transport company will be used.

In addition to the services already mentioned, there will be also pilots of a number of logistic services. In this stage the organisation of these pilots is not clear yet.

4.9 Slovenia

Within C-Roads two different C-ITS pilot projects will be implemented one with G5 and one with cellular communication technology.

- **G5:**
  Motorway operator (DARS) acts as a communication, data and service provider. The involvement of the contractor is planned with the realisation of the public procurement. Information from RSU and/or vehicle goes also to the TMC and via TMC to the DARS Traffic Information Centre. As soon as it is in the platform of the TIC it is also available for other service providers.

It is planned that Infrastructure PKI Operator is going to be the body within the government and yet to be defined.
The area of implementation is south-western part of motorway network:

Figure 6: Slovenia - The area of implementation is south-western part of motorway network

- **Cellular:**
  Existing 3G/4G/LTE communication is used. Motorway operator (DARS) with a smartphone app and contractor HERE with a cloud solution are in the role of data provider. DARS TIC is a service provider. The information from the app or/and the car is available for other service providers.
  The integration of both, G5 and cellular is planned as an interface in front of TMC and TIC platform.

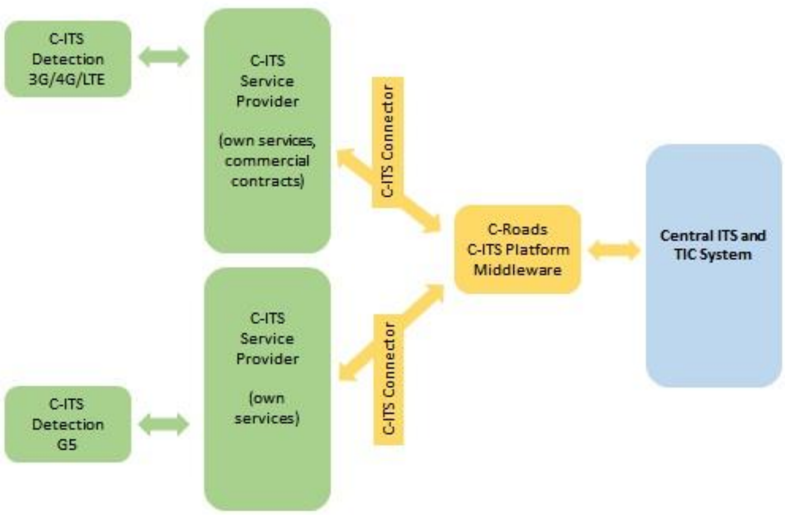

Figure 7: Slovenia – Scheme of C-ITS implementation

4.10 Spain

The Spanish pilot is made out of five different pilots, each of them with their unique set of technologies and C-ITS services, and with the involvement of different actors. This heterogeneity is meant to cover a wide spectrum of use cases, for the sake of assessing the impact of connected mobility in many representative scenarios. From the organizational point of view, 2 of the 5 sub-pilots are coordinated and leaded by public road operators in collaboration with the necessary actors for the proper roll out of the C-ITS services.

One of them, executed by the national public road operator DGT (Ministerio del Interior), is extended throughout the Spanish TEN-T network (12,270 km.) and is based on an IoT platform allowing the interconnection of all the relevant stakeholders and final users involved in the traffic ecosystem: vehicles, drivers, pedestrians, car manufacturers, dealers, rental companies, transport fleets, vehicle technical inspection facilities, or MaaS platforms. These actors are data generators as well as their ultimate consumers. Therefore, the platform works as a cooperative Hub promoting the open data exchange with car manufacturers, service providers, and final users. In particular, the platform provides the National Access Point with events information in DATEX format. The expected C-ITS Services will be delivered exclusively through cellular 3G and 4G / LTE communication technologies.

The second one takes place in the capital city of Spain, focused on the ring motorway circles the central districts of Madrid, with a length of 32 km and operated by mixed economy society belonging to the Madrid City Council. In the sub-pilot also participate RSUs, OBUs and sensor providers and integrators, C-ITS services and V2X communication developers and traffic information providers. Tests are also included in the HOV-BUS Lane on the A-6 motorway at the entrance to Madrid as well as a parking infrastructure in the city centre to carry out tests on real-time emissions measurement and to integrate information on parking spaces in the services offered.
The proposed architecture aims to deploy a central server that will be used by data and C-ITS service providers to deliver their information for processing and by end users, through the centralized system, to access the deployed services and available information. Taking advantage of its modularity, the server will be connected to the proposed data sources in order to collect and process all available information, thus working as a central hub where all information and alerts are made available from one single interface to the mobile users –apps. By means of hybrid communication technologies it will be possible to give coverage to a wide range of users and services.

Among the other sub-pilots stands out SISCOGA Extended, which cover 130 km interurban roads and 20 km urban environments in Vigo. CTAG, the pilot coordinator as well as equipment and service provider, has access from DGT (road operator) to the road equipment and is connected to its Regional Traffic Management Centre for the interurban tests and for urban environments CTAG has access from Vigo City Council (infrastructure operator) to the public Traffic Management Infrastructure and to the city traffic management centre. This Pilot is based on the development of SISCOGA test site, that has been involved in different FOTs and pilots devoted to testing ITS-G5 based cooperative services. The current existing infrastructure is prepared to test ITS-G5 communication technology and covers 120 km of interurban and urban roads, including AP-9, A55, A52, and 10 km of urban road covering some parts of Vigo City. SISCOGA is the most experienced test site for C-ITS Services and communications in Spain with more than 6 years of tests.

The Mediterranean sub-pilot is carried out by two private toll road operators, 20 km in Cataluña by Autopistas (an Abertis company) and in Andalucía in the AP7 of AUSOL. Both test sites are highly ITS equipped, and the technology providers are developing the communication link between the Traffic Management Centres of the operators and the test sites (vehicles and infrastructure equipment) using hybrid communication.

Finally, the Cantabrian pilot will be deployed approximately on 75 km along the following road sections located in Galicia, Asturias and Basque Country, in which national and regional administrations are involved, as infrastructure operators and as transport authorities. In Galicia the services are focused in fog detection and emergency brake alert systems in A-8/AP-8 at Mondoñedo where there is a recurrent visibility problem due to the dense fog in collaboration with DGT, road operator. In Asturias the main objective of this study is to have global information on existing mobility alternatives in the region of Asturias and other advanced services for private vehicle such as parking information. In Basque Country (Bizkaia), the aim of Diputación Foral Bizkaia is to give personalized information about traffic and weather information to the road user based on his/her habits and recurrent routes.

4.11 France

The French pilot deployment project SCOOP has been built from scratch on a cooperation between road operators and car manufacturers, to equip 2000 km of roads and to sell serial ITS G5 equipped cars to real customers. It has therefore faced all the real-life challenges of privacy, security, industrial processes, procurement, compliance assessment and interoperability,

In a second wave of SCOOP; and also, in InterCor and C-Roads France, France is deploying hybrid communication based on ITS G5 and cellular technologies.

All these projects are coordinated to harmonize specifications.

Different areas are covered by these projects, such as motorways, city ring, national roads, urban area …

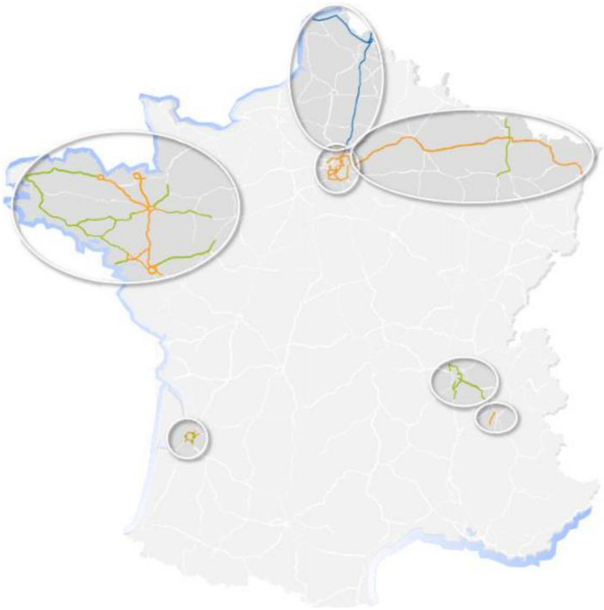

Figure 8: French pilot sites

For ITS-G5:

Each road operator has his own traffic management centre linked to a local associated platform (SCOOP-platform) used to operate the local RSU ITS-G5 stations.

For Cellular communication:

Each road operator using his local SCOOP-platform provides and receives traffic information to/from a National Cellular RSU. A dedicated mobile application will be created and linked to this National Cellular RSU.

The system security already uses PKI ETSI TS 103097 v.1.2.1 for SCOOP and actual deployment. In 2020 all the installed system will migrate to PKI ETSI TS 103097 v.1.3.1 to ensure full European compatibility.

The road operator vehicles are also equipped to act both as mobile RSU and as special vehicles that provide specific services to regular vehicle users (e.g. mobile RWW).

The range of use cases deployed and tested is large due to the several needs of each project. An emphasis has been made on Day 1 services.

4.12 C-ITS activities in the UK

GLOSA- Newcastle

Compass 4D EU funded project

Compass 4D was an EU –funded project which involved deploying C-ITS infrastructure in 7 pilot sites across Europe, including Newcastle. In Newcastle, the project equipped 21 junctions in the east of the city with Road Side Units and 11 North East Ambulance Service non-emergency patient transfer vehicles with OBUs. The technical partners in this project were Siemens & Commsignia. The C-ITS technology deployed included Green Light Optimal Speed Advisory (GLOSA), Green priority and Idling support. The data analysis for the project looked at Fuel consumption/ energy efficiency, Emissions of CO2, Number of stops, duration through a junction and Modelled traffic management (network level).

C-ITS Smart Corridor Gosforth the Department for Transport Funded project

The Department for Transport provided further funding to expand the Compass 4D trials in the north of the city to equip 18 junctions on Great North Road with Road Side Units and 35 ARRIVA express buses with OBUs. The technical partners include Siemens and Zircon, Cycle Alert and Envirowatch. The C-ITS technologies deployed includes Green Light Optimal Speed Advisory (GLOSA), Green priority and Idling support plus, additional air quality monitoring and modelling when compared to the Compass 4D project, along with upgraded RSUs, OBUs, and HMIs. There will be a greater focus on subjective evaluation of drivers' usability/ acceptance, Vulnerable Road Users (VRU) element, feasibility studies of cycle alert, disabled parking support and the implementation and subjective evaluation of Cycle Alert technology (in vehicle alert).

Middlesex C-ITS test bed

The Middlesex testbed was established as part of the Department for Transport funding to study the interaction between urban and motorway traffic, vehicular safety and maintenance issues as well as to develop techniques for wide-scale deployment of C-ITS using the ETSI G5 band, such as the Day 1 and beyond services. The A41 motorway link site was chosen in a busy urban London environment to deploy 3 RSUs and 40 vehicles equipped OBUs with G5 capability. Further aims and objectives of the project was to examine the key strengths and weakness of G5 communication in the light of other technologies such as LTE and G5. This was achieved by using the full capacity of the LTE infrastructure by backhauling via the Mobius Network's LTE network coverage and services.

UK Connected Intelligent Transport Environment (CITE)

UK Connected Intelligent Tran sport Environment (UKCITE) is a project to create the most advanced environment for testing connected and autonomous vehicles. It involves equipping over 40 miles of dual-carriageways and motorways with combination of three 'connected technologies and testing for a fourth, known as LTE-V. The project will establish how these technologies can improve journeys, reduce traffic congestion, provide entertainment and safety services through better connectivity.

The project is expected to take a total of 30 months and is made up of the following consortium members: Visteon Engineering Services Limited, Jaguar Land Rover Ltd, Coventry City Council, Coventry University, Highways England Company Ltd, HORIBA MIRA, Huawei Technologies (UK) Co Ltd, Siemens PLC, Vodafone Group Services Ltd and WMG at University of Warwick.

UK InterCor

InterCor (Interoperable Corridors) is a European project which aims to connect C-ITS initiatives of four participating member states: the C-ITS Corridor in the Netherlands (connecting the Netherlands with Germany and Austria); the French Corridor of the SCOOP@F project; the UK A2/M2 Corridor and the Belgium C-ITS initiatives corridor.

Figure 9: InterCor Corridor Roads

The InterCor project will deliver seven interoperable C-ITS services across the European corridors with four common use cases to demonstrate interoperability using hybrid communication, these are: GLOSA, RWW, PVD and IVS. The platforms will provide a living lab test facility for OEMs and SMEs to test immerging technologies for current and future deployment activities in Europe, creating a seamless continuity of services across borders.

The InterCor project will provide vehicles to vehicle, vehicle to infrastructure and infrastructure to back-office connectivity using a combination of technologies, such as cellular and/or ITS- G5. The main goal of the project will be to gain better understanding through monitoring and evaluation contribution connectivity might make towards safer and more efficient operation of the road network in each partner member state.

<u>InterCor- A2/M2 UK Connected Corridor partnership approach</u>

The UK connected corridor will connect the Blackwall tunnel on the A102 to the port of Dover via the A2 and M2. The A229 in London and Kent will also be part of the project. The UK corridor will be a joint collaboration between the Department for Transport (DfT), Highways England (HE), Transport for London (TfL), and Kent County Council (KCC).

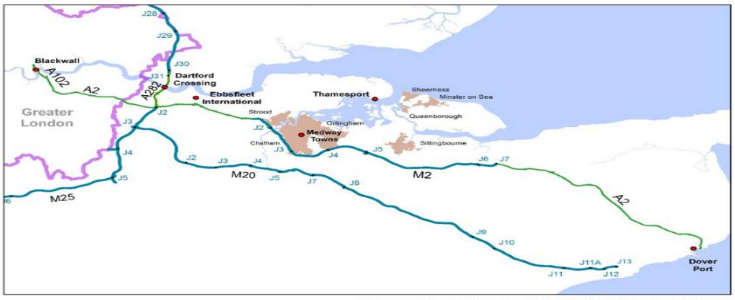

Figure 10: InterCor UK - A2/M2 Connected Corridor

The project will deliver real-world capabilities from research to deployment, creating opportunities for testing and evaluating emerging technologies. £15 million have been ear marked to create a

London to Dover 'connected corridor' as part of the UK roads Investment Strategy to enable vehicles to communicate wirelessly with infrastructure and potentially other vehicles

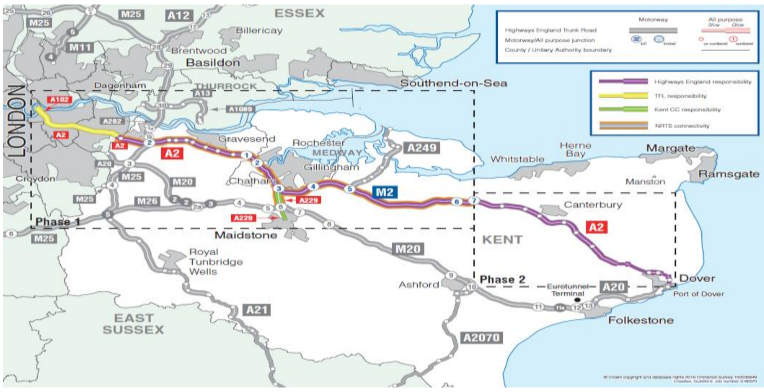

Figure 11: UK Connected Corridor

The UK segment of the project will be done in three separate phases:

- Phase 1: 4km of continuous ITS G5 wireless access infrastructure
  Deliver early Day 1 services in partnership with HE, TfL and Kent CC;
- Phase 2: 17 km of continuous ITS G5, wireless access infrastructure using LTE;
- Phase 3: 54 km of continuous ITS G5 wireless access infrastructure using LTE.

Common use cases using hybrid communication

Service	Use Case: Communications Implementation
Floating Car Data	Hybrid and separate cellular services
Green Light Optimisation, speed assistance	ITSG5 and separate cellular services
In Vehicle Signage	Hybrid and separate cellular services
Road Works Warning	Hybrid and separate cellular services

Figure 12: Common UK Use Cases

5. Co-operation Models based on their contribution to the services

5.1 Service Chains

A generic service chain underpinning detailed process chains related to cooperative services and clarifying ‘handover’ of operational status messages, is shown in the figure below. This framework is largely universal so that, with its help, new cooperative services can be presented at a later stage and compared, if necessary, with other services in a simple form. Subsequently, the process chain of IT-security relevant process steps is also discussed.
The basic process blocks described are shown at the top of the horizontal line in Figure 11:

- Content collection
- Content processing
- Service provision
- Service presentation

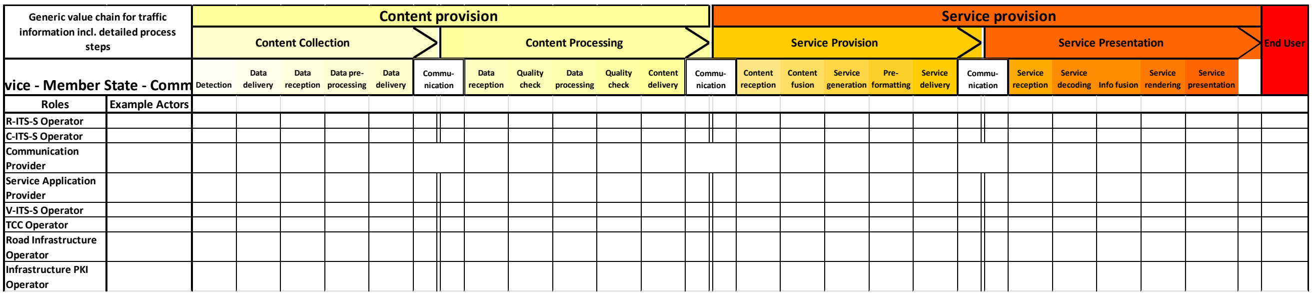

Figure 13: C-ITS Service Chain

Examples of detailed de-composing of typical C-ITS Services are illustrated in Section 5.3.

Security credentials: C-Roads partners consider the registration, provision and delisting of security credentials for C-ITS stations a necessary part of the mentioned service steps that needs to be performed/guaranteed by C-ITS station operators for each station under control and during its entire life cycle.

Further details on this are provided under chapter 6.

5.2 Conclusions of the different service chains

Based on the detailed description of reported pilots a <generic> ‘organizational lay-out’ was proposed. This general architecture captures the basic principles required for sound functioning and logical data flows. The purpose is not to detail and accurately propose a mandatory scheme, but to illustrate the links and relationships between composing subsystems, and as such the actors and roles identified, and the interfaces required. The entire service chain is clearly visualized.

Setting a unified architecture for all Member States within the C-ROADS platform would be impossible and also is not the objective – as differences between Member States need to be considered (organizational structure and starting point, particular objectives and policy

options taken, country size, number of transport operators, etc.). Also differences in the level of implementation of the C-ITS system need to be considered.
The C-Roads initiative indeed faces consolidated and extended pilots in some member states, e.g. in France or Austria, that provide a sound basis for broad deployment, compared to initial pilots, sometimes on a limited road network in other MS (e.g. Austria, Germany), where first tests need to underpin a national strategy and options for adjusting the chosen C-ITS system architecture are open. In addition, there are also different road management structures, e.g. centralized in The Netherlands or Czech Republic, partially distributed in Italy (26 motorways concessionaires).

It is therefore appropriate to perceive the following scheme as a possible but not obligatory lay-out of a C-ITS system within a single country. The Scheme below complemented by a textual description and explanation of key elements, links and basic recommendations.

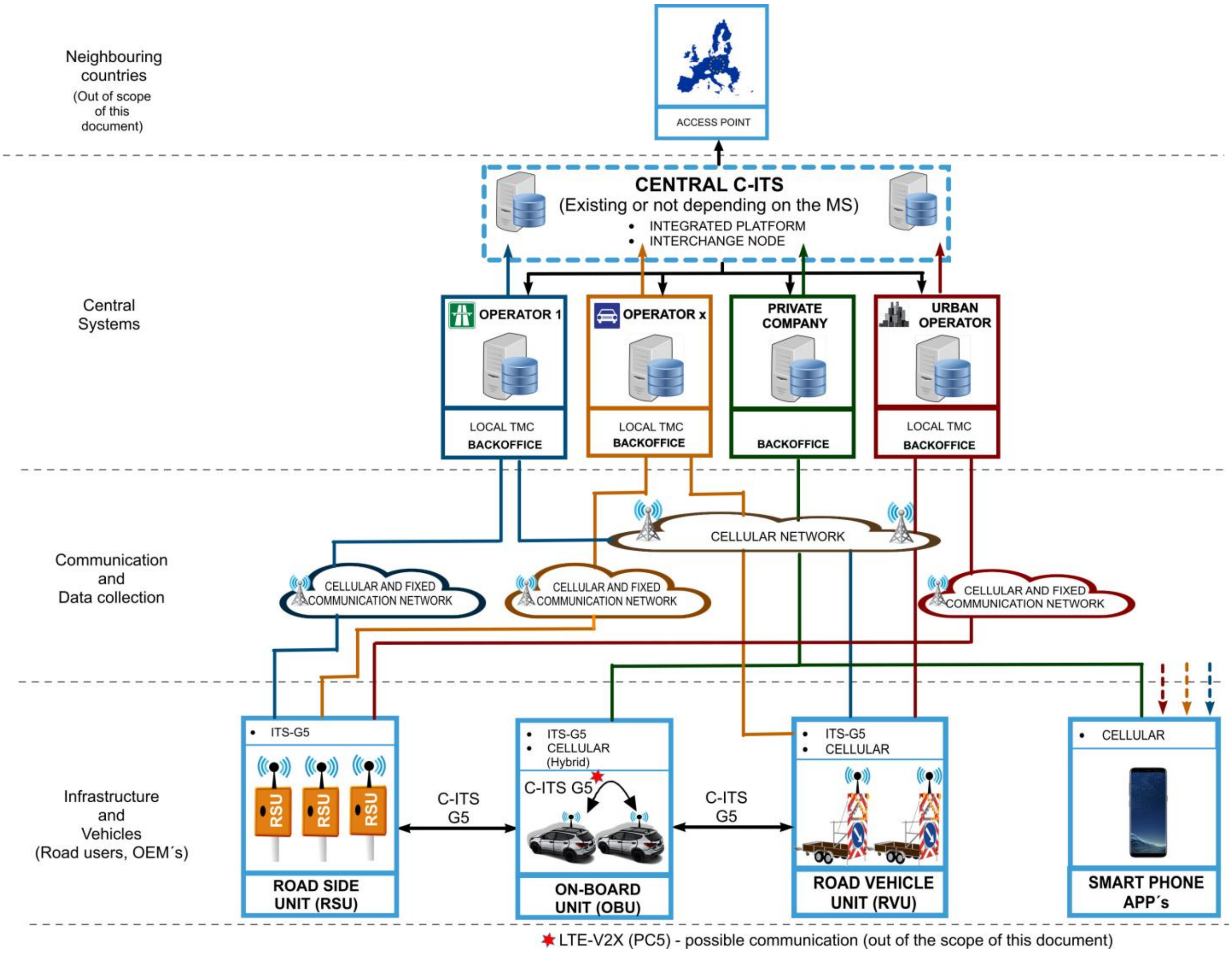

Figure 14: Simplified organisation scheme

5.2.1 Central systems

In the layer of Central systems, we identify two main important elements:

- C-ITS Back-office
- Central C-ITS

C-ITS back-office (BO)

Back-office is the central element of the C-ITS system, it concentrates most of important system data which is distributed to the lower-level elements of the C-ITS system (RSU/RVU/OBU/Mobile applications) and possibly to the Traffic Control Centre's (TMC) based on clearly specified rules. Communication among C-ITS BO and the entire C-ITS system elements is bi-directional. BO´s is the part of C-ITS related to content collection and processing and act as data "distributors" for individual software modules within the whole system.

Content processing is one of the crucial parts of the C-ITS BO. All the traffic information from both higher-level systems and lower-level elements (from units under service responsibility) are processed and sorted here, corresponding C-ITS messages are then composed on its basis. These messages then migrate between the RSU/RVU/OBU and the higher-level systems (Central C-ITS, Neutral Servers, Traffic Management Centres, neighbouring countries access point). BO´s could be operated by road operators themselves or service providers (OEM´s, private companies etc.).

It is important to ensure that in the BO´s security and privacy requirements are considered.

Central C-ITS

Implementation of the Central C-ITS aims to unify connections of vertical C-ITS BO partners participating in the C-ITS system to ensure fast and reliable data exchange among individual C-ITS BO´s and the TMC. Within the C-ROADS platform we identify different possible ways. In NordicWay, Czech Republic etc. it is an element which fulfils the role of mediating communication between BO´s. On the other hand, in France or in Germany BO is directly linked to the National Access Point without Center C-ITS node between. In France a National cellular node is used (in architecture is "below" the road operators BO´s between cars and BO´ s and it is designed as a Cellular RSU).

This solution involving infrastructural element of the Central C-ITS offers connection / mutual interconnection of C-ITS BO systems and at the same time, it transforms data formats and application logic towards Traffic centres, it also enables, by means of these Traffic centres, use of cooperative infrastructures by other traffic information systems of third parties. The main advantages of these solutions comprise unification of existing central systems connections and simplified connection of new systems.

The concept of central ITS is still under investigation work.

5.2.2 Neighbouring countries

This part is out of scope of this document.

The Neighbouring countries access points are collecting confirmed C-ITS events and distribute them to service providers or other road operators. The Access Point could play a role of Central C-ITS within one country without any middle element between C-ITS back-office and the Access Point

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5.2.3 Infrastructure and vehicles

Road side units (RSU)
The Roadside Unit (RSU) is an element located between C-ITS BOs and mobile devices on the road (RVUs/OBUs in safety trailers and in vehicles). The RSU receives and transmits data from/to C-ITS BO as well as from/to vehicles (collecting DENM/CAM events, can translate to DATEX II and send DATEX II messages to central systems but, in some C-ROADS member states the translation can be done in back office). The unit communicates with passing vehicles by means of the ITS-G5 standard which is defined in the ETSI EN 302 663 directive. Data transmission between RSU and C-ITS back-office will be executed by means of existing fixed/cellular communication infrastructure and with a coordination of communication provider.

Road vehicle units (RVU; in maintenance vehicles/trailers)
Road Vehicle Units (RVU) are installed directly into maintenance vehicles or into mobile safety trailers (warning or advance warning safety trailers). These units represent “hybrid” between RSU and OBU units as they can provide communication with roadside equipment and possibly, with other near-by RVUs/OBUs in the same way as OBUs (but with additional services, specific to the road operator, e.g. mobile RWW), but at the same time, they can also become roadside equipment and partially function as RSU units. These units thus handle provision of traffic information to other vehicles (e.g. warning safety trailer with RVU unit provides road works information to other vehicles).

On-Board Units (OBU; in passenger vehicles)
The On-Board Units (OBU) are located directly in individual, motorized vehicles. They provide communication with roadside equipment, possibly also with OBUs in other equipped vehicles. Depending on a device type and provided service, they also interpret relevant information to drivers (service presentation). It combines multiple trigger conditions. The OBU is connected to vehicle control systems. It receives data from them (detecting sensor status etc.) and sends it to higher-level C-ITS system element. This data then presents key input for the services and applications provided within this system.

The first stage of C-ITS development mostly relies on the “aftermarket” solution (however in France there are OBU integrated in PSA, Renault vehicles), i.e. manufactured units retrofitted into vehicles. Next C-ITS stages assume vehicles to be equipped with the OBU units directly by car manufacturers (i.e. embedded solution). Individual OBU unit elements will be integrated into vehicles in such a way so they do not interfere with their common use.

Different unit types will be/are implemented within the C-ROADS platform:

- Standard ITS-G5 OBU units communicate only with near-by RSU/RVU/OBU units;
- Hybrid ITS G5/cellular units communicate with near-by RSU/RVU/OBU and at the same time with back-office by means of mobile networks;
- Cellular units.

Mobile applications
Mobile applications can provide C-ITS services to end users without the need for OBUs. This way, limited amount of services with no demands for availability of vehicle information or possibly for certain transfer speed or reliability can be provided. It is specific communication arranged by a

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service provider while its openness is not required. Mobile application can be provided by private companies by their own BO´s, by the Road operators BO´s and the other Service providers.

5.2.4 Data collection and transmission

There are interfaces with specific requirements among individual C-ITS system elements. Some of them are clearly defined by international standards, other interfaces have not been standardized at the international level due to specific conditions in individual countries.
Short-range microwave technology (ITS-G5) is used for communication among OBUs and RSUs and between equipped vehicles. This type of technology has been selected because of its high speed and reliability which present prerequisites for use in high traffic speeds and flow rates on roads. This type of communication also employs the internationally recognized ITS-G5 standard which defines clear rules for information exchange among the units.
Other interfaces within the C-ITS system are mostly of two types – interfaces utilizing fixed communication networks and interfaces using cellular networks (mobile operators). These most important interfaces were defined in the C-ITS system:

- Interface1: OBU/RVU x OBU/RVU/RSU;
- Interface3: Back-office x on-board units (Communication providers);
- Interface4: C-ITS back-office x cellular OBU´s;
- Interface5: C-ITS back-office service providers mobile applications x C-ITS back-office;
- Interface6: C-ITS back-office x C-ITS Neighbouring countries Access Point or possibly Central C-ITS x Traffic control centres.

5.3 Service Chain examples

5.3.1 Austria

The Austrian service chain is relatively simple, due to the broad involvement of the Austrian motorway operator ASFINAG, being - in the area of motorways network – the only operator of both, R-ITS and C-ITS as well as the dominant communication and service application provider. This might be different for specific services in local and/or urban networks, such as GLOSA.
Also, services provided through means of cellular communication might see different ITS-Operators, such as telecom companies or even communities.
For a simplified version, see graphic 13.

		Content provision				Service provision		
Roles	**Actors**	**Content Collection**		**Content Processing**		**Service Provision**		**Service Presentation**
R-ITS-S Operator	ASFINAG	**X**						
C-ITS-S Operator	ASFINAG			**X**		**X**		
Comm. Provider	ASFINAG		**X**		**X**		**X**	
Service App. Provider	ASFINAG							**X**
V-ITS-S Operator	tbd						**X**	**X**

Figure 15: Generic Service Chain Austria

5.3.2 NordicWay

The NordicWay concept builds on the following elements:

- cloud-to-cloud communication for the communication between the different service providers and Traffic Data providers;
- the NordicWay Interchange Node which is the key element to assure interoperability, allowing different service providers and traffic data providers to communicate with each other.;
- cellular technologies for the transmission of traffic information with sufficiently low latency and complemented with Infrastructure-to-Vehicle communication based on ITS-G5 for specific use cases.

The NordicWay ecosystem includes public and private actors that exchange both safety and non-safety related traffic information. The market actors create new ecosystems including both cooperation and competition yet enabling them to maintain and develop their own businesses and business models. Below is shown an example of public and private actors involved in the ecosystem.

	Finland	Sweden	Norway	Denmark
Service Provider/OEM	MAP provider	OEMs Equipment supplier	OEM	
Traffic Data Provider	Equipment supplier	Communication systems supplier Road Authority	Road Authority	Road Authority
TMC/Road Authority	Road Authority	Road Authority	Road Authority	Road Authority

Figure 16: Actors in the NordicWay pilots

The NordicWay2 concept architecture and its actors and roles are presented in the previous Member States pilots' chapter. The following picture illustrates the NordicWay2 service chain. Although the picture below does not describe differences between the national pilots, it gives a general overview of the NordicWay2 service chain where driver, TMC, vehicle and/or application have content provision roles and OEM and/or service provider as well as TMC have content processing roles. Service provision is on the OEM and/or service provider and service presentation in the vehicle or application.

Nordic Way cellular	Generic value chain for traffic information incl. detailed process steps		Content provision												Service provision												End User
			Content Collection						Content Processing						Service Provision						Service Presentation						
			Detection	Data delivery	Data reception	pre-processing	Data delivery	Commu-nication	Data reception	Quality check	Data processing	Quality check	Content delivery	Commu-nication	Content reception	Content fusion	Service generation	Pre-formatting	Service delivery	Commu-nication	Service reception	Service decoding	Info fusion	Service rendering	Service presentation		
	Roles	Example Actors																									
	Driver	Private and profession	X	X	X	X	X																				
	Vehicle or application	Any OEM vehicle or service provider smart phone applications	X	X	X	X	X		X												X	X	X	X	X		
Hazardous location	Communication Provider	Any telecom operator						X						X						X							
	OEM or service Provider C-ITS cloud operator	Any OEM or service provider C-ITS cloud							X	X	X	X	X		X	X	X	X	X								
	NordicWay Interchange Node / Neutral server cloud operator	Any neutral server cloud provider							X	X	X	X	X														
	TCC Operator	Road traffic management centre	X	X	X	X	X																				
	National access point	Road Authority							X	X	X	X	X														

Figure 17: Nordic Way Service Chain

5.3.3 Czech Republic

The C-ITS system for the needs of the C-ROADS CZ project is divided into the following basic layers, where the physical and communication elements are located:

1) Central systems are a key part of the system based on the elements that allow the data reception, data processing, generation and distribution of information. The elements of the central systems include:

- C-ITS Back-office – (C-ITS BO)
  - Motorways and Roads - responsible partner RMD

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- Urban system - BKOM responsible partner and Public transport organizers in Ostrava and Pilsen
- Private Service providers - responsible partner O2, T-Mobile, INTENS and associated partner Škoda Auto
  - Integration platform (IP) - O2 responsible partner. The purpose of the IP is the connections of the vertical C-ITS BO partners involved in the C-ROADS CZ system to ensure fast and reliable data exchange between C-ITS BO and NDIC/JSDI (National Transport Information Centre/ Integrated Traffic Information System of the Czech Republic – National TMC).
  - NDIC/JSDI – RMD responsible partner - is the subsystem for control, authorization and authentication traffic information from various sources. In accordance with the Government Resolution. NDIC is operated by the RMD

2) Data collection and transmission of information. These are the transmission layers that provide communication between the central systems and the RSU, vehicles and mobile app.

3) Infrastructure. In this layer there are RSU units installed on the roads. Infrastructure is further divided into:

- Motorways and roads
- Urban Infrastructure incl. tram lines

4) Vehicle. This layer contains C-ITS units installed in vehicles (individual/trucks) or mobile warning trailers.

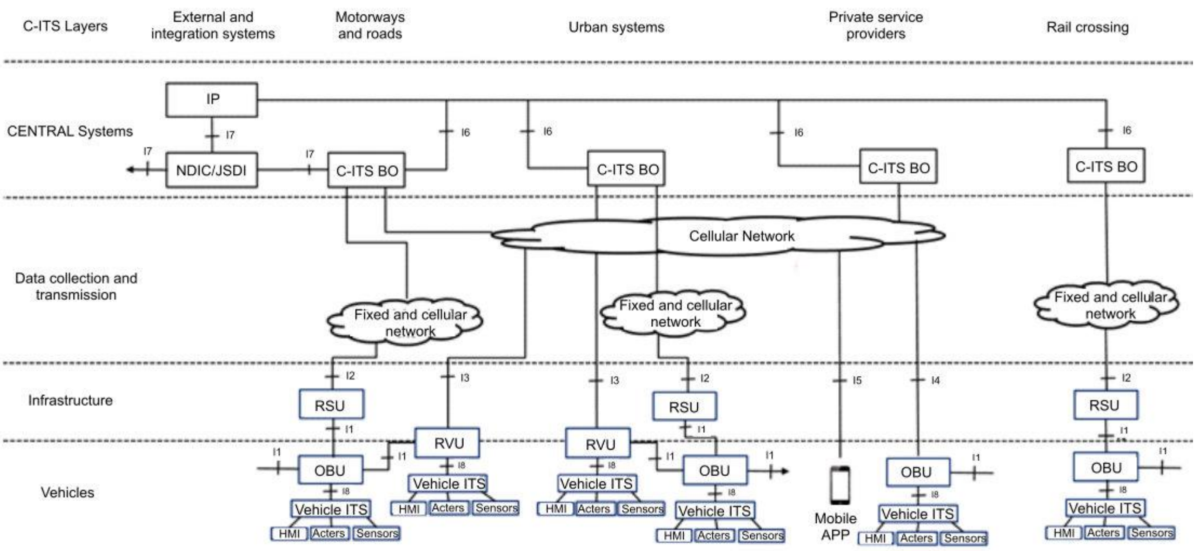

Figure 18: CZ Basic Layers

5.3.4 Italy

The C-Roads Italy technical approach is for a hybrid solution, based on both ITS-G5, IEEE 802.11p connection, and 4G/5G, cellular connection. Consequently, the planned Day 1 services will be provided in accordance with this solution. IoT (Internet of Things) services in ITS have also to be considered (IoT sensors for supporting assisted and autonomous driving).

The objective then is to move toward a unified open and standard approach to the hybrid communication, which is the only way to have the possibility to cover with the C-Roads services all the planned 350 km ca. of the Italian pilot network, even where RSUs are not yet available.
With reference to the messages chain, the envisaged general architecture can be outlined as follows, where Road (Event), Traffic Centre and Vehicle are the same in the two interrelated chains:

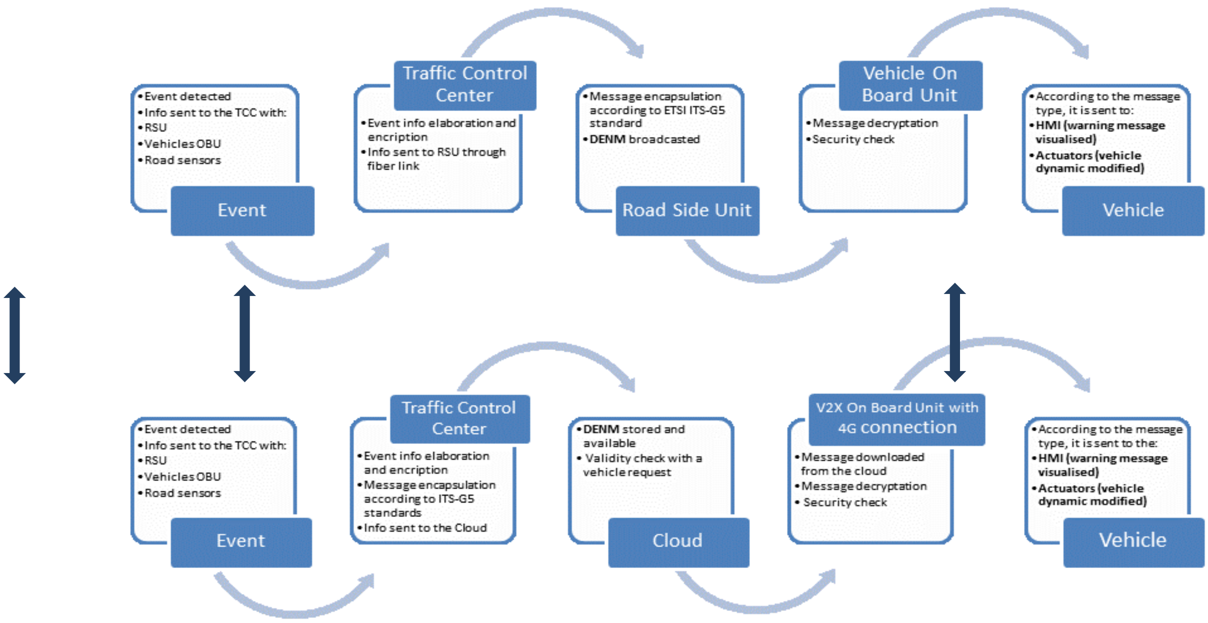

Figure 19: Italy - Message Flow

We highlight however that C-Roads Italy started its activities just a few months ago (GA signed on November 2017) and therefore many technical aspects are still in the definition process.

5.3.5 France

The French technical approach is based on a hybrid solution, based on both ITS-G5 IEEE 802.11p connection, and cellular connection.

- Content collection and Content processing is done by the local Traffic Management System (TMS)
- Service provision is done
  - For ITS-G5 by the road operator on his own local network
  - For Cellular on national level by consolidation of each local TMS information in a national cellular node that works as a national cellular RSU
- Service presentation is done
  - For ITS-G5 in the vehicle by the OBU
  - For Cellular
    - in the vehicle by the OBU
    - or by using an dedicated mobile app on a smartphone

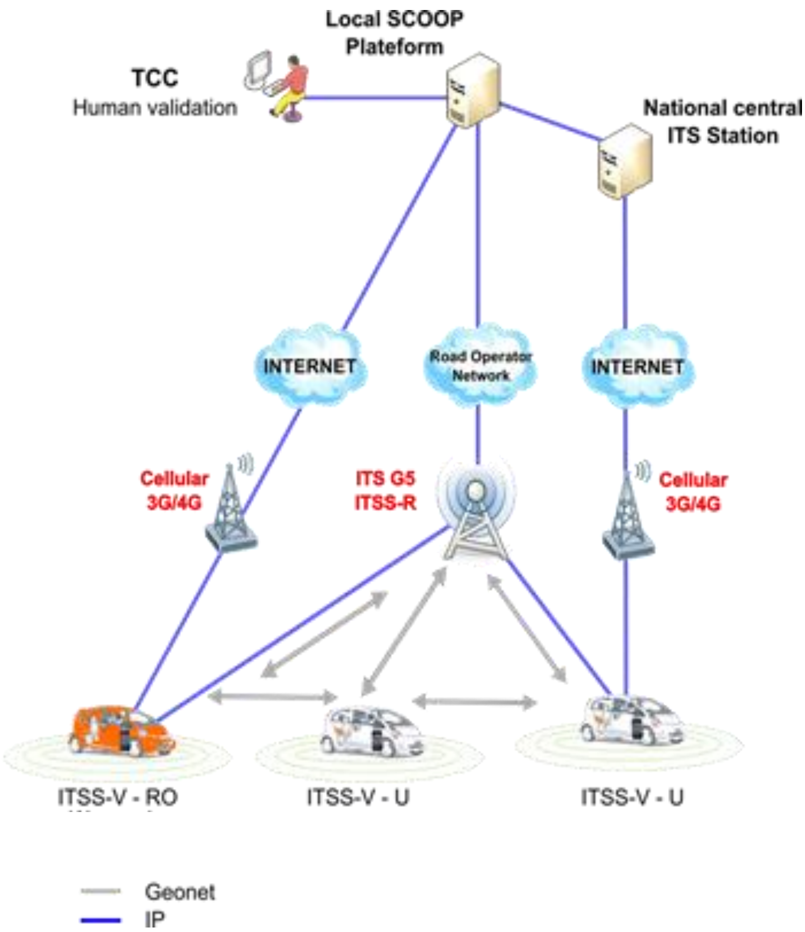

Figure 20: France - Message Flow

On figure 20, the right side of the scheme is dedicated to the C-ITS between the road operator and the drivers using ITS G5 or cellular. The left side illustrate the use of road operator vehicle as mobile ITS G5 ITSS-R.

TMS´s are, in turn, linked to the National Access Points of Action B and C where consolidated information is available for service providers.
The role of each part of the system is best summarized in the scheme below:

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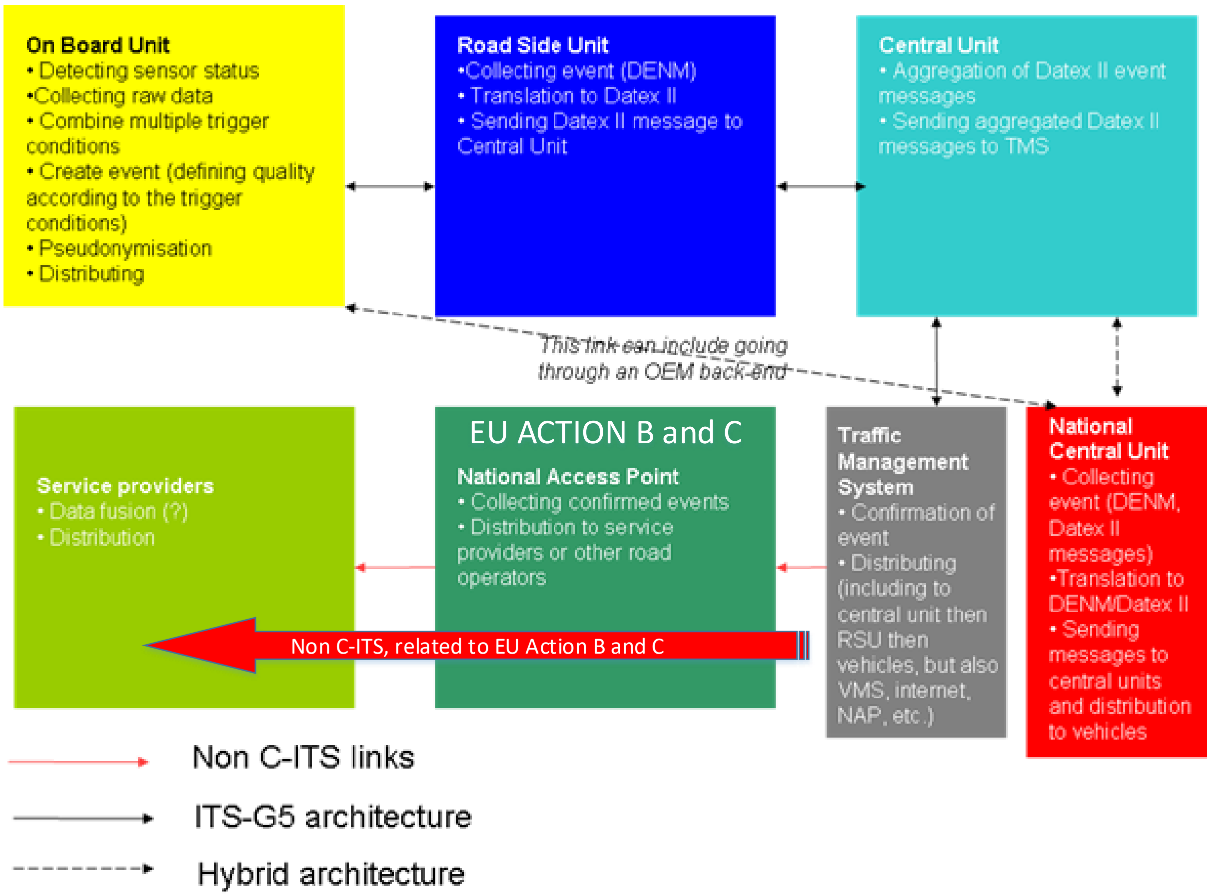


Figure 21: France - The role of each part of the system

5.4 Overview of existing and emerging Business Models

This report is not intended to set new business models. Specific business models will also be based on the real-life deployment phase. In close future the C-ROADS platform WG1 will focus on this crucial issue. The Working Group furthermore proposes to investigate in detail the data and corresponding 'monetary' flows as part of a follow-up exercise - as it becomes clear that the real value creation of C-ITS, therefore: the business model, is heavily connected and impacted to data generation and data sharing – for which sound, transparent and fair agreements need to be agreed - among all actors involved (Conclusions of the C-ITS platform / 'Business Models' WGp). In this context reference is made to the 'Data Task Force' operating under the High-Level Dialogue on CAD. The whole ecosystem is made up of many actors and each of them has a significant impact on the speed of implementation. Different actors have different business models. E.g. car manufacturers and telecommunication providers are basically looking at the company profit, depending strongly also on technological competition. While public authorities and consequently road operators are more focused on all-society benefits which is of course also possible to monetarize. The most important expected impacts are:

Economic impacts:

- The economic impacts are mainly driven by the equipment costs for the technologies required to support the deployment of C-ITS services. These devices such as hardware/devices and associated software and services used to facilitate those C-ITS services

- Several C-ITS services (e.g. traffic signal priority, parking information, smart routing, etc.) lead to significant increases in average speed/reduced congestion by targeting some of the most important areas where delays occur.
- Direct economic impacts - productive working time, etc.
- Secondary impacts such as changes in competitiveness, reliability and distributional impacts
- Impacts on GDP.

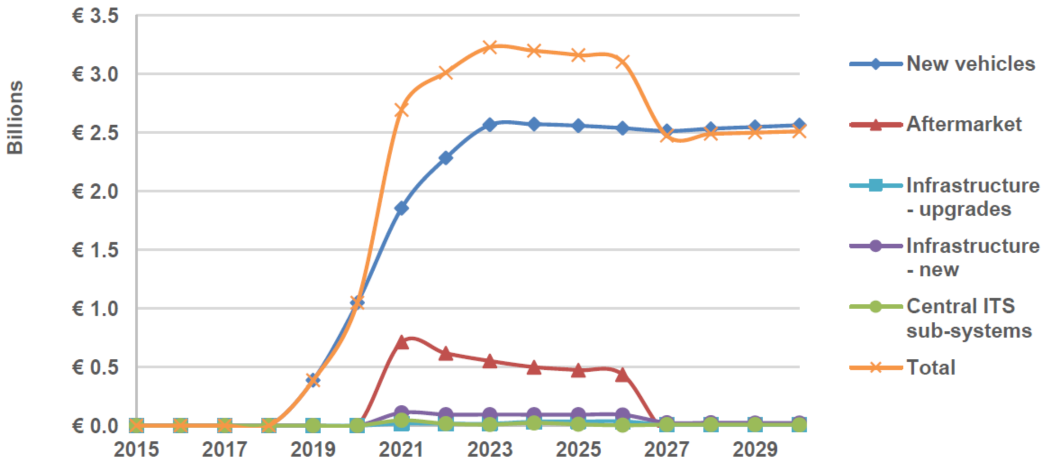


Figure 22: Total additional annual equipment costs relative to baseline

Safety impacts:

- Several C-ITS services (such as hazardous location warning, in-vehicle speed limits, intersection safety, etc.) specifically aim to improve road safety and to decrease both the number and the severity of accidents.

Environmental impacts:

- Fuel consumption and CO2 emissions - The C-ITS services are aimed at improving the smoothness of traffic flow, or at reducing congestion and time spent travelling (e.g. smart routing, parking information, etc.).
- Air quality - The emissions impacts of individual C-ITS services are limited in percentage terms, with some services contributing an improvement and other services (e.g. those focused on achieving other impacts such as efficiency or safety impacts) even contributing to an increase in emissions.

Social impacts:

- Health and safety
- Jobs and employment market
- Privacy and personal data

5.4.1 NordicWay

EU CEF funded NordicWay project in 2015-2017 included public and private funding to create a new model to share Safety Related Traffic Information between different stakeholders. The NordicWay architecture was successfully demonstrated in May 2017 live demonstration. NordicWay evaluation report concluded that financial performance, market potential and business models would require large-scale demonstrations in longer period, i.e. closer to a production system, and therefore financial performance was not able to be evaluated. In the interview road authorities were expected the market to develop and deliver services. A stepwise approach on integrating new functionalities was proposed as it would support adaptive business models, i.e. data and functionalities with costs and responsibilities build one piece at the time.

NordicWay evaluation outcome report included a socio-economic assessment of the Finnish one-year pilot (2017)3. Safety impact included decrease in injury and non-injury accidents and in fatal accidents. Benefit-cost ratio between 2019-2030 with the smallest impact and highest price was evaluated of being 2.3. First years of the service would have negative benefit-cost ratio and therefore public sector funding could play an important role. Expected linear scale up of services would then again increase benefit-cost ratio over longer period (picture below)4.

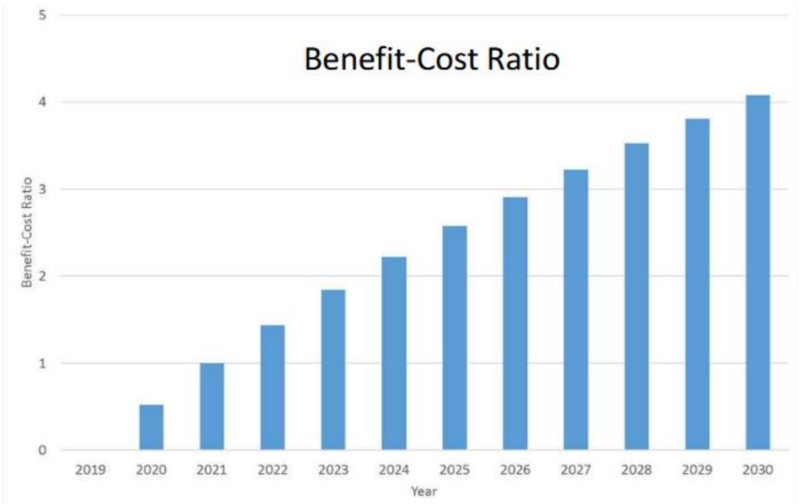


Figure 23: NordicWay evaluation Benefit-cost ration (final event presentation)²

5.4.2 France

Synthesis: SCOOP proposal for a description of a principle business modelITS could be a protected market concern. However, C-ITS will need a progressive investment over several years:

[3] http://vejdirektoratet.dk/EN/roadsector/Nordicway/Documents/NordicWay%20Evaluation%20Outcome%20Report%20M_13%20(secured).pdf

[4] http://vejdirektoratet.dk/EN/roadsector/Nordicway/Documents/C2.%20NordicWay%20-%20Final%20Event%20-%20Impacts_Socio-Economy_v04.pdf

- The number of vehicles equipped with ITS technologies won't come from 0% to 100% in one year. The "new vehicles" roadmap planned by car makers over next years will define in the same time line the investment plan in ITS technologies for vehicles,
- It will be the same in the case of ITS road side units: they won't be invested in one year,
- As a consequence, there will be no « revenue » (no safety improvement effect) before reaching some penetration rate of ITS technology (both vehicles and road side units)
- And Profitability will then increase very gradually

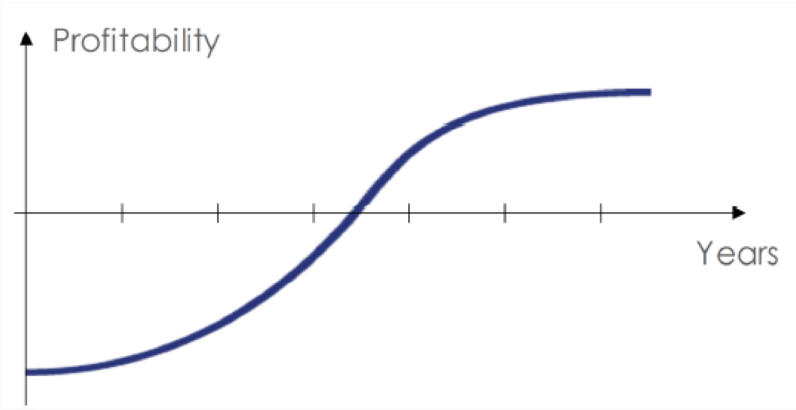
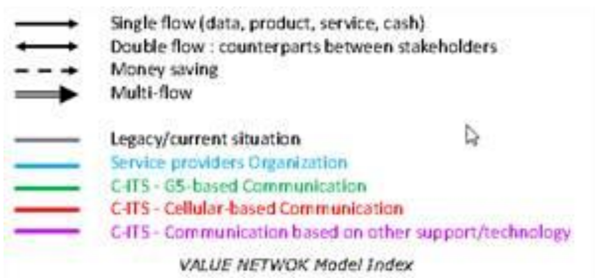


Figure 24: Profitability timeline (SCOOP)

According to what was explained before, it is recommended to limit the business model design to a qualitative description.
The following representations came from SCOOP Business Model and focus on the organization between stakeholders and flows between all of them.
In order to simplify the representation, the following simplifications are made :

- They don't present flows between two units/entities/assets owned by a single stakeholder.
- They don't describe all activities and resources supporting these activities.



Organization of the ecosystem based on ITS G5 technology:

- The service is directly provided on ITS G5 by the road operator using his own RSU network.

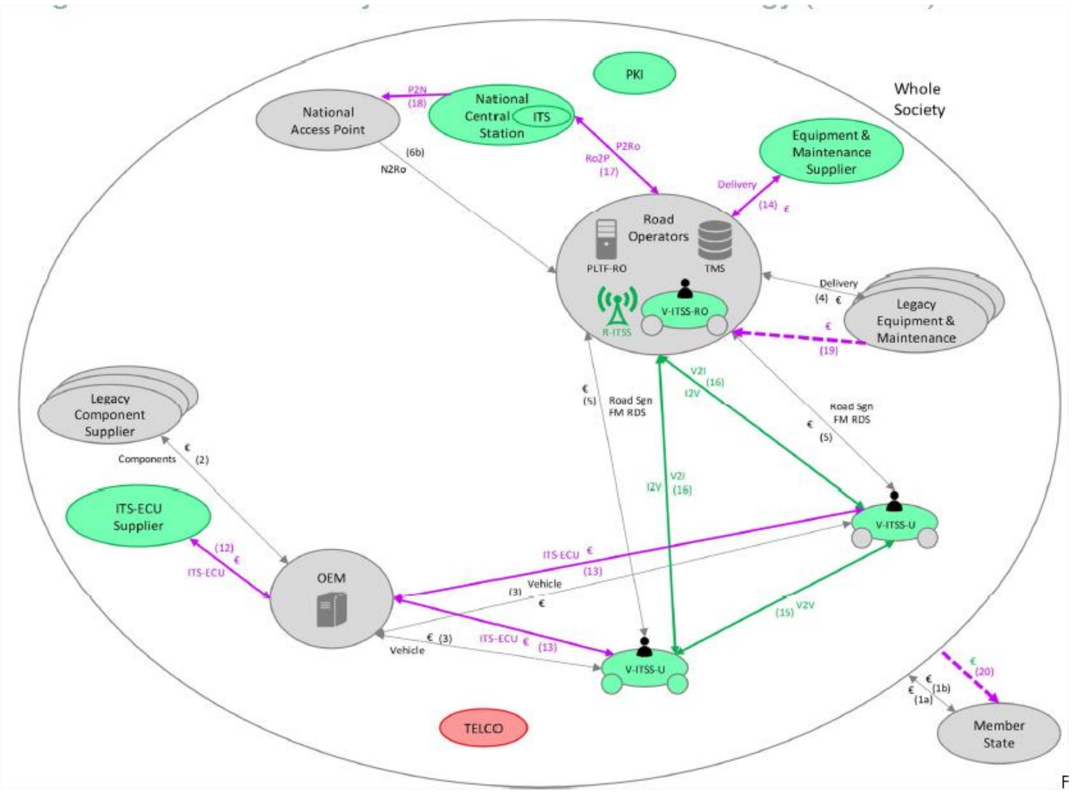


Figure 255: SCOOP - Organization of the ecosystem based on ITS G5 technology

13	Price of the ITS ECU bought by the OEM to the supplier. It won't be exposed since only "14" is important.
14	Price the customer will pay for ITS functionality. It includes "13" but also its integration into the vehicle (screws, electric cables). At this step of the project, no one knows if the vehicle price could be adjusted due to C-ITS services, whether in correlation with OEM costs or not. But, safety being considered by customers as a condition when using the vehicle, he may not accept to pay more than today.
15	Road side units and maintenance services bought by the road operators to suppliers.
16	Messages exchanged between user vehicles (CAM, DENM, according to use cases and ETSI standards).
17	Messages exchanged between road operators (RSU, OBU-RO) and user vehicles (CAM, DENM, according to use cases and ETSI standards).
18	Reduction of equipment cost compared to the actual situation. For instance: • In the short/mid-term: o Sensor under the road to detect vehicles speed and traffic conditions, o Video camera along the road side. • In the long term: o Since Road signage will become vehicle in-signage, thanks to ITS technology.
19	Reduction of "1b" costs, thanks to C-ITS.

LTE/G5" Hybrid based Organization:

- In the following scheme, the cellular services are given by a national central station (also named cellular node or cellular RSU).

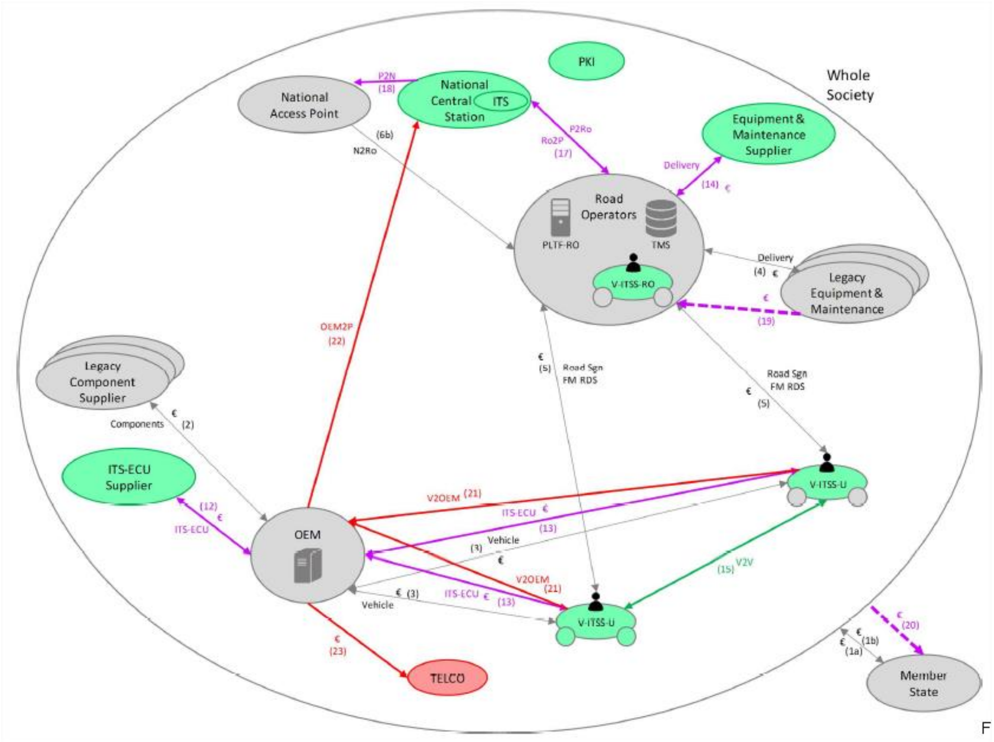


Figure 266: SCOOP - LTE/G5" Hybrid based Organization

13	Price of the ITS ECU bought by the OEM to the supplier. It won't be exposed since only "14" is important.
14	Price the customer will pay for ITS functionality. It includes "13" but also its integration into the vehicle (screws, electric cables). At this step of the project, no one knows if the vehicle price could be adjusted due to C-ITS services, whether in correlation with OEM costs or not. But, safety being considered by customers as a condition when using the vehicle, he may not accept to pay more than today.
15	Road side units and maintenance services bought by the road operators to suppliers.
16	Messages exchanged between user vehicles (CAM, DENM, according to use cases and ETSI standards).
18	Reduction of equipment cost compared to the actual situation. For instance: • In the short/mid-term: o Sensor under the road to detect vehicles speed and traffic conditions, o Video camera along the road side. • In the long term: Since Road signage will become vehicle in-signage, thanks to ITS technology.
19	Reduction of "1b" costs, thanks to C-ITS.
20	DENM messages and aggregated information from CAM sent to the National Central Station.
21	Information sent to the national access point, in compliance with [b] and [c] delegated acts of ITS European directive.
22	V2OEM (Vehicle-to-OEM): the vehicle sends information to the OEM back-end server, using the SIM card included in the TCU.
23	OEM2P (OEM-to-Platform): the OEM sends aggregated data to the National Central Station since the road operator can't do it.
24	It corresponds to LTE/3G fees payed by OEM to TELCO to send vehicle data to the OEM server (22).

6. Procedures and Responsibilities

6.1 Process between different regions (cross-border)

6.1.1 C-ITS based on cellular networks (e.g. Nordic Way)

NordicWay

- NordicWay had a demonstration on the border between Norway and Sweden on the 10th of May 2017. The demonstration showed that the system was agnostic to borders. Messages both received from and sent to the system will work regardless of where the message originated geographically.
- While the system developed in NordicWay works fine while crossing any border, the mobile networks used to communicate with vehicles and equipment requires some time to perform a handover when switching networks (roaming). The time required for the handover process to complete varies between operators and even the geography of the area. The demonstration included live video streaming over the mobile networks from within two vehicles while crossing the border. As such it was critical that the video link was re-established after the border crossing as quickly as possible. The live video feed had a downtime of between 30 and 60 seconds before the handover was completed.
- From the viewpoint of the users in the vehicle however, this was less of a problem as any messages in the surrounding area of the vehicles was locally cached in the vehicles. A system to cache nearby events would be required regardless of whether the vehicle was crossing a border or not as even within one country a vehicle should expect to encounter bigger or smaller areas of no or very low coverage.
- Similar, any events encountered by the vehicle in such areas should be cached so they can be transmitted when the vehicle regains connectivity.
- Road authorities should encourage mobile operators to ensure good coverage in critical areas.

6.1.2 C-ITS based on ITS-G5

EU C-ITS Corridor NL-DE-AT

The handover between participants in the corridor and external parties (ITS Providers, but also vehicle manufacturers and suppliers) is easy to achieve and has been proven in the European C-ITS Corridor.

The single steps are as follows:

- Define the C-ITS day one list of applications and make the specifications publicly available (current version 1.1 of the Communication profile)
- Develop the individual C-ITS stations (roadside, central and vehicle stations) according to these specs and the additional functional needs, e.g. security layer, CCMS etc.
- Test and validate the full implementation of the C-ITS stations according to specifications for the confirmation of full functionalities.

- From this point on handover between different C-ITS stakeholders and message interpretation including security check is operationally achieved.

Additional service introduction and rollout of new e.g. day 1.5 or day 2 services need to follow the same procedural steps and additionally check interoperability with the already deployed C-ITS services.

6.1.3 Hybrid Communication Systems Architecture

InterCor hybrid communication systems architecture

InterCor has elaborated on a high-level system description to support interoperability among hybrid communication solutions that exist or are under development in participating countries. This system description includes two interfaces that need to be specified to realize cross-border interoperability. A first interface (called “IF1”) addresses the ITS-G5 interaction between vehicles and road side systems A second interface (called “IF2”) is a proposed interface between back-office systems, to enable continuity (and interoperability) of service (also) building on cellular communication.
IF2 enables cross-border interoperability in a hybrid communication environment for minimum three of the services actually deployed under InterCor: Road Works Warning (RWW), In Vehicle Signage (IVS), and Green Light Optimal Advisory (GLOSA). The Interface specification includes a minimum set of requirements to be respected and both functional and technical elements. The specification will be tested and validated during a planned’ Hybrid TESTFEST, scheduled for 3rd Quarter 2018.
Following finalisation of all InterCor TESTFESTs planned IF2 is to be implemented and evaluated (pilot operations) whereas resulting suggestions/improvements will be added in the final ‘guidance for implementation’ resulting from the project.

Interoperability for hybrid communication

The main subsystems in the diagram are:

- Network: for hybrid communication, at least two independent networks are required. In InterCor, these will be an ITS-G5 based network, and a cellular network. These networks connect at least the service provider and traffic manager with the end user but can also link different end users with each other.
- Traffic management: to enable data exchange between traffic management systems and road side display systems (VMS, panels, traffic signs, etc.) a traffic management system is included in the diagram.
- Service provisioning: to enable data exchange for specific services between end-users and service provider a service provisioning system is included.
- Data provisioning: to enable data exchange between the traffic management systems and the service provider systems, a data provisioning system is included. In practical implementations, the data provisioning could really be an entity on its own (e.g. the NDW in The Netherlands), but could also be integrated e.g. in the traffic management and/or service provider back-end. Furthermore, it could be a rich function including data aggregation, data conversion, etc., or it could only implement a direct forwarding algorithm from e.g. a traffic management system via a cellular network to the relevant end-users.

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The box surrounding the traffic management, data provisioning, and service provider backend and the lines connecting from the different networks to this box, are used to indicate that any of the back-office systems could have access to both networks. This does not imply that every back-office system will always have access to both networks.

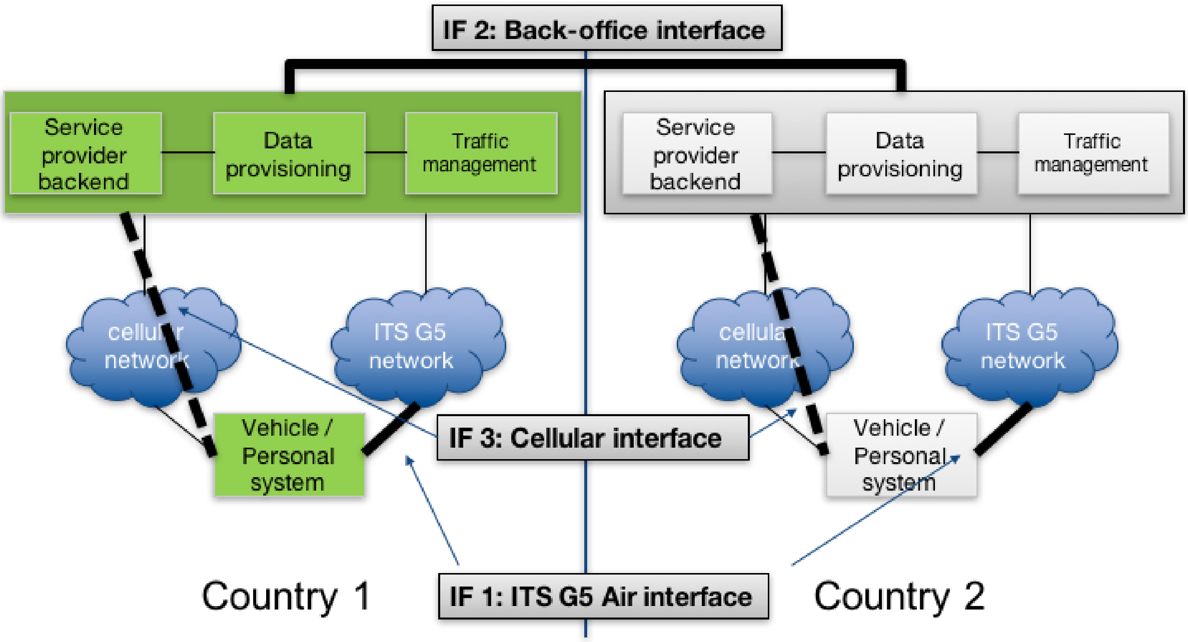

Figure 27: Interoperability diagram for hybrid communication (InterCor)

PKI Trust Model

InterCor will implement a PKI trust for G5 but the use of it for the cellular component of the pilot is still under discussion.
This will enable InterCor partners to learn, develop and enhance understanding in area related to C-ITS.
The Pilot architecture provides flexibility for refining or amending particular aspects of the security solution in the future. The use of PKI over cellular networks is analyzed in InterCor in close relationship with TF4.

6.2 Process between different service providers/organisations

In order to provide an end-to-end connectivity of the C-ITS service chain it is essential that the message standards commonly used by road authorities and operators (DATEX II) and service providers (TMC, TPEG, DENM [admitted that there is an in-vehicle service provision to end users]) are mutually understood. Figure x illustrates the relevant message types. Translatability requires a sort of dictionary or a set of mapping tables between those message types.

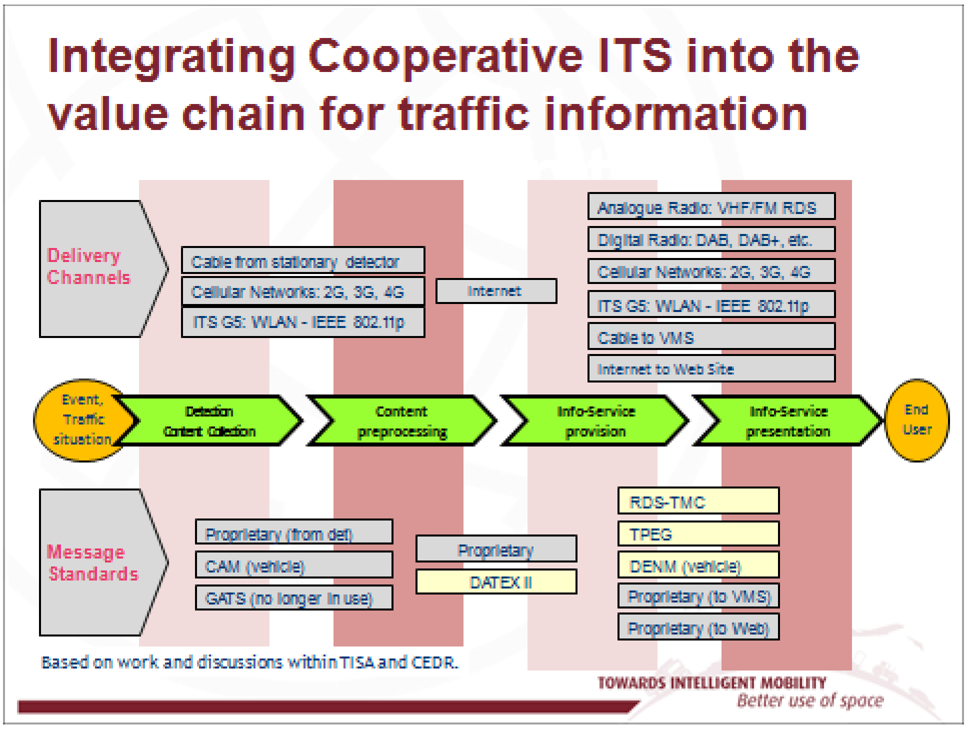

Figure 28: Integrating C-ITS into the Value Chain

Under the framework of the ITS Directive [Directive2010/40/EU] – extended with [Decision2017/2380] a first mapping has been carried out between DATEX II and TMC as well as TPEG2–TEC. The Delegated Act on the provision of safety-related traffic events supports the directive focusing on the data and the procedures for the provision of road-safety-related information free of charge to users [DelReg886/2013]. Main categories are:

- Temporary slippery road
- Animal, people, obstacles, debris on the road
- Unprotected accident area
- Short-term road works
- Reduced visibility
- Wrong-way driver
- Unmanaged blockage of a road
- Exceptional weather conditions

Those event types are handled in different domains. E.g. TISA (Traveller Information Services Association) is home of TMC and TPEG (Transport Protocol Expert Group; synonym for the data protocol which they established). TPEG2-TEC is the successor of TMC messages received by radio receivers in vehicles. It has to cover at least the same categories as mandated by the Delegated Regulation 886/2013 [DelReg886/2013]. Besides that there is the DATEX II community while DATEX II is the format being used in European traffic control centres.

In order to come to a consistent use of the safety-related events of the different message sets in these two domains, the Joint Working Group was formed to enable a mapping of TMC Events and TPEG2-TEC with DATEX II Classes which is in effect profiling of those messages for safety-related events. In Version 2, the events were additionally mapped to DENM in order to include the C-ITS domain additionally represented by the Amsterdam Group [AG/DATEX/TISA2017]. An excerpt of this paper, illustrating mapping table for weather related events, is included below.

DATEX II (CEN/TS 16157)			TMC Events (EN ISO 14819-2)			TPEG-TEC (ISO/TS 21219-15)				DENM (ETSI EN 302 637-3)		
DATEX Class	TYPE	Supplementary Position Description	Line	Text (CEN-English)	Code	Cause Code	Sub Cause Code	Warning Level	Text *SubCauseCode trumps Cause Code*	Cause Code	Sub Cause Code	Text *SubCauseCode trumps CauseCode*
EnvironmentalObstruction	flooding		880	flooding. Danger	908	5	1	3	flooding	9	0	hazardous location - surface condition
WeatherRelatedRoadConditions	surfaceWater		980	danger of aquaplaning	1002	7		3	aquaplaning	6	0	adverse weather condition -adhesion
WeatherRelatedRoadConditions	surfaceWater		977	surface water hazard	1041	7		3	aquaplaning	6	0	adverse weather condition -adhesion
WeatherRelatedRoadConditions	slipperyRoad		979	slippery road (above Q hundred metres)	1003	6		3	slippery road	6	0	adverse weather condition -adhesion
NonWeatherRelatedRoad Conditions	mudOnRoad		981	mud on road. Danger	1055	6	3	3	mud on road	6	3	mud on road
NonWeatherRelatedRoad Conditions	looseChippings		985	loose chippings. Danger	1056	6	8	3	loose chippings	6	8	loose chippings
NonWeatherRelatedRoad Conditions	oilOnRoad		987	oil on road. Danger	1057	6	7	3	oil on road	6	7	oil on road
NonWeatherRelatedRoad Conditions	petrolOnRoad		989	petrol on road. Danger	1058	6	2	3	fuel on road	6	2	fuel on road
WeatherRelatedRoadConditions	ice		992	ice (above Q hundred metres)	1006	6	5	3	ice on road	6	5	ice on road
WeatherRelatedRoadConditions	blackIce		996	black ice (above Q hundred metres)	1008	6	6	3	black ice on road	6	6	black ice on road
WeatherRelatedRoadConditions	snowDrifts		1006	snow drifts (above Q hundred metres)	1016	9	5	3	snow drifts	9	5	snow drifts
WeatherRelatedRoadConditions	icyPatches		996	icy patches (above Q hundred metres)	1047	6	5	3	ice on road	6	5	ice on road

Figure 29: Use of different Message Sets

From different initiatives we have different standards and cross mapping

The evolution of this document (towards version 3) is managed by a cross-sector working group involving experts of the DATEX II, TISA and Amsterdam Group community. It aims at a continuous process for the maintenance of the document. Based on the experience, it should extend the mapping in terms of content and technologies and be tested. In the working group, an approach has been drafted for version 3:

- An inventory on functional level of common best practises is drafted. This does not mean to be a legal framework.
- Deviations from the version 2 document are analysed, especially the impact of functional deviations on technical representations.
- Required adaptations of specific paragraphs are agreed on. This can also include extensions of the functional description of the categories. If this is done in separate sections is still to be defined.
- The mapping is defined in a consistent way.
- The profiling is assessed if it is sufficient as a basis for minimum or core profiles in order to fulfil the requirements from the EU EIP quality framework.

- It is specified how to deal with different versions of the standards. Agreements and timing of migration phases are needed to handle changed semantics and to prevent logical breaks.

The decision of the DATEX II Steering Group in November 2017 to work on hybrid profiles for Day 1.0 services was the starting point for the Joint Working Group. The first step of collecting current functional profiles with a template should be finalised end of March. Via Amsterdam Group (with support of CODECS), C-Roads and C2C-CC, the whole C-ITS community is involved.

6.3 Handover-process between different telecom networks

NordicWay[5]

The NordicWay Interchange Node architecture was live demonstrated in 2017. According to the final report and evaluation outcome report[6], the architecture was seen scalable, allowing for growth. Scalability of C-ITS services means that already existing services, devices and users can be connected to the C-ITS cloud, which makes it possible to scale up C-ITS services faster. The architecture has been designed to accommodate hybrid C-ITS communication, and to be border and relation agnostic. Maturity of existing standards and technologies and low latencies in cellular communication (0.3-2 seconds). Users were willing to continue use of the service and found the service as a first source of information. Results indicate safety benefits and positive benefit-cost ratio between 2019-2030.

The NordicWay project identified and implemented a solution that supports the basic requirements on an ecosystem for C-ITS interoperability:

- It allows for very different organizations (authorities, service providers, vehicle OEM´s, communication providers) to participate within the same ecosystem
- It accounts for very different driving forces behind these organizations (road safety, profit from services, profit from vehicles, …)
- The solution allows for all kinds of relations (also bi-lateral) between organisations involved, each relation with its own business agreement
- The ecosystem is designed to be inclusive – easy to join and select your preferences – and stimulate business and service development
- The ecosystem must support short time to deployment (open for aftermarket solutions, easy to join …) in order to prevent disaggregation. C-ITS is under rapid development and need solutions for interoperability that works now.
- The ecosystem should support further innovation (beyond Day 1,5 services)

[5] http://vejdirektoratet.dk/EN/roadsector/Nordicway/Documents/NordicWay_Final%20Report.pdf

[6] http://vejdirektoratet.dk/EN/roadsector/Nordicway/Documents/NordicWay%20Evaluation%20Outcome%20Report%20M_13%20(secured).pdf

France

France has also tested the seamless switch between G5 and 3G/4G. The G5 link is provided by local RSU. The cellular mode is used on areas not covered by the G5. A national RSU provide information to vehicle using 3G/4G to reach them.

7. Way forward to roll-out of C-ITS services

For many years, core European ITS services have represented a major implementation objective of the road operators. The technological progress in ICT has technically matured into Cooperative ITS (C-ITS) as the next generation of ITS. This process has been stimulated by research and development projects, followed by large scale Field Operational Tests on national and European level.

The development of Cooperative Intelligent Transport Systems (C-ITS) has the potential to play a significant role in achieving the Commission's goals to tackle the increasing problems of congestion, transport energy consumption and emissions in Europe. The benefits span a range of areas, including improving road safety, reducing congestion, optimising transport efficiency, enhancing mobility, increasing service reliability, reducing energy use and environmental impacts, and supporting economic development.

Despite these facts, we still must realize that together we do not have enough experience and knowledge with the operation of these systems. **Thanks to C-ROADS platform, we are only now entering the deployment phase, which is another gradual step in the introduction of cooperative systems of common practice. We can expect that even at this stage we will encounter technical, organizational, operational and economic problems. Without practical implementation, however, we are not able to identify these pitfalls sufficiently and prepare for them. So, we are still in the process "Learning by doing". One of the main objectives is to learn from the experiences among individual member countries and the problems that occur during the implementation.**

In the first step, we need to define key factors that are essential before deployment. The open issues and uncertainties for the initial phase of deployment have a different nature. Some of them are technical, others are related to organisational and business issues. Consequently, they need to be solved on different levels, depending on their hierarchical position between design, planning and execution of the deployment. Some issues, such as a common security and certificate policy, call for a European framework. In this context, the C-ROADS, initiated by the European Commission, has turned out to be a platform for deployment and in parallel to be a hub for scoping the problems and possible solutions between all stakeholders. Other issues, such as testing and cross-testing, are in the responsibility of the deployment initiatives when agreed specifications are in place. road authorities and operators become increasingly engaged in a number of pilot deployment initiatives. It provides the basis for a broader wave of C-ITS uptake. Financial incentives such as the provision of co-funding opportunities via the Connecting Europe Facility clearly play a stimulating and essential role here.

7.1 Organisational planning for demonstration phase

The Detailed pilot overview report[7], which includes C-Roads milestones #6, "Detailed pilot description and demonstration plan available (platform)" and milestone #7, "Detailed pilot partner and structures description available (platform)" was published in Q4/2017 and gives the main facts about the steps during the demonstration phase, including the locations, the involved

[7] https://www.c-roads.eu/fileadmin/user_upload/media/Dokumente/Detailed_pilot_overview_report_v1.0.pdf

partners, the services to be tested and especially the schedule and demonstration plan of each of the C-Roads member-states.

To achieve deployment, the members of the national pilots defined their test procedures and steps but also the single outcomes of the tested applications in the mobile and fixed C-ITS units, resulting in a set of common parameters for all pilot sites. The test procedures are verified, and cross checked with remote laboratory tests between the different pilots in the EU in order to display differences of C-ITS parameters early in the process. The respective locations are selected according to their suitability to distribute C-ITS test messages for validation purposes, but also for a later link with live data streams from the TMC to enhanced Day-1-C-ITS-services. The additional technical C-ITS element that will be specified and implemented is a first version of a C-ITS security solution in cooperation with the public and private stakeholders involved in the management of the C-ITS Network.
While all different European C-Roads-pilots finally will be operated in their specific Member States and regions, they all have committed to regard the European dimension of the whole action and hence to deploy their C-ITS pilot infrastructure in a way to enable harmonised services to end-users.

Summarizing this, it can be stated that the demonstration phase has started with its initial planning already in 2016, together with the first input for other tasks associated with the C-Roads platform.
However, the core phase for demonstrations is the years 2018 till 2020, with a clear focus on planning in 2018, so that first pilot sites are operational and ready for testing by the end of this year.
From 2019 should then see extensive test drives throughout all member states, including demonstrations held in pilots. 2020 will then have all pilots ready for driving, altogether with the whole set of Day-1-services, including access to vehicle data and enhanced message distribution to all travellers

7.2 Service experience

The main purpose of this chapter is to provide examples of the C-ITS pilot installations that have been evaluated from various points of view. The experience with the deployment of C-ITS is necessary for its further development and subsequent expansion in a harmonized way. Within the C-ROADS platform, individual pilot installations will be subject to evaluation, and examples from past solutions will be considered.

7.2.1 The European C- ITS Corridor

- The Eco-AT test sessions with
    - the security headers conducted and
    - recorded under real-user conditions (user-centered ECoAT Living Lab)

  were successful for all participating test teams, which proved multi-PKI interoperability (cross-certification test).

- The C-ITS messages in secured mode with the new Data Frames Secure Header and Secure Trailer have been properly recorded und decoded into plain text using Wireshark

Version 2.2.3 with the latest ETSI's plugins. The message payload content following the ECoAT specification could be verified for having included correct data. Likewise, the receiving and decoding of all types of messages in an unsecured mode, were successful.

- Also, the new formats such as IVIM, SPATEM / MAPEM, were implemented by many participating partners and companies and were transmitted in the unsecured mode and in the secure mode with success.

- The path information for the tested events of DENMs located correctly on the motorway lanes instead of previous deviations e.g. to the hard shoulder or the median strip.

- Most of the C-ITS equipment providers for the RSU were able to send messages in a secured mode and confirmed the maturity of the C-ITS implementations under regular traffic operating environments.

C-Roads partner consider the registration provision and delisting of security credentials for C-ITS stations as one necessary part of the mentioned service steps that needs to be performed by any C-ITS station operator for his station during the complete life cycle.

In order to fulfil the required activities for all C-ITS stations for secure and trusted data transfer within the network, the C-ITS station operator needs to contribute the following process steps in the area of the common trust model.

- Content collection:

  Define:
  - The C-ITS station you want to operate
  - The (backboned) network
  - And other elements requested by the European CP for your type of station, e.g. road side C-ITS station

- Content processing

  - Register your station by an EA (Enrolment Authority)
  - Collect credentials from the AA (Authorisation Authority) and provide them your station(s)
  - Initiate your C-ITS stations with key ceremony and provide valid ECTL (European Certificate trust list)

- Service provision

  Update all provided data and credentials according to the operating rules of the C-ITS network

- Service presentation

  All distributes C-ITS message are recognized by the receiver as valid and your stations are considering as trusted (by the members of the C-ITS network).

7.2.2 InterCor

Evaluation under InterCor encompasses 'technical', 'impact' and 'user acceptance' – the latter being led by BE/ Flanders

To successfully operate C-ITS Services, both a satisfactorily 'technical implementation' (it works! and it works as planned!) and a certain 'understanding and willingness to use' need to be ensured. Of course, there are other elements at stake related to e.g. Service quality and continuity, relevancy - accuracy and trust (cybersecurity, data privacy…) which we assume incorporated in 'sound technical realisation.
To ensure users effectively making use of services provided, and to make sure these services deliver the 'right' (expected) benefits, elements related to awareness, understanding (when and what ?) and confidence need to be addressed – most often referred to 'user acceptance'.

To enhance common understanding of terms and vocabulary used, and to clarify potential strategies and actions to be considered by public authorities, BE/ Flanders has launched a dedicated study for which results are being expected by Summer 2018

7.2.3 Other reference projects

Quantifying the Impact of some of the C-ITS use cases on energy, efficiency and traffic congestion.

An overview of Compass4D and its services

Compass4D collaborated with European cities to facilitate the sustainable deployment of C-ITS. Engaging directly with road operators, vehicle fleet operators and other local road transport stakeholders, it focused on road safety, energy efficiency and traffic congestion, and the significant potential of C-ITS to address these challenges.

FOTs took place in seven European cities based around real-world deployment of C-ITS technology: Bordeaux, Copenhagen, Helmond, Newcastle upon Tyne, Thessaloniki, Verona and Vigo (Mitsakis et al, 2014). The FOTs combined both pre-market and established technologies to demonstrate three services reliant on real-time, two-way communication between vehicles equipped with on board units (OBU) and roadside units (RSU) connected to network infrastructure, enabling both V2I and I2V communications:

1. Red Light Violation Warning (RLVW), to increase driver awareness near signalised intersections, and to warn the driver of the possibility of an unsafe situation involving a signal violation. Such situations include violation of a red signal by the driver's own vehicle, probable violation of a red light by another vehicle on approach to the intersection, or emergency vehicle presence at or near the intersection. Further extensions of the RLVW service include turning warnings, for example the presence of oncoming traffic acting on a green light, or the presence of vulnerable road users;

2. Road Hazard Warning (RHW), to raise driver awareness of potential incidents, and to inform drivers of appropriate behaviour in relation to any hazards faced. Hazards

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themselves may be static, with fixed spatial and temporal properties (e.g. planned road works) or dynamic (e.g. traffic incidents and collisions, evolving traffic queues, weather-based restrictions, etc.);

3. Energy Efficient Intersection (EEIS), to reduce fuel consumption and energy use at intersections, implementing three sub-services through the provision of ‘signal phase and timing’ (SPaT) information to a vehicle:
    i. ‘Green Light Optimal Speed Advisory’ (GLOSA) information provided to the driver, allowing a fuel-optimal trajectory to the signals (either deceleration to a stop, or progression through the lights).
    ii. ‘Time-to-green’ information provided to vehicles to allow engine idling stop support and to limit start-up delay losses.
    iii. ‘Green priority’ extending an existing green signal phase or hurrying a future phase for the vehicle. With multiple intersections equipped with RSUs in an urban area, the potential exists for the system to allow the ‘natural’ formation of ‘green waves’ for equipped vehicles.

The OBUs consisted of a processing unit, a radio system, a GNSS (Global Navigation Satellite System) receiver and a display. Off-the-shelf smartphone or tablet technologies running Compass4D applications delivered the required functionality for service provision to drivers. Additional logging capabilities came via a separate unit for evaluation. The RSUs consisted of a processor unit, a radio system, a GNSS receiver and a mobile or wired network connection. RSUs connected directly to traffic signalling or other sensor infrastructure, with the network connection enabling operational management and ‘back-office’ data collection (Hill and Edwards, 2016).

Communications between RSU and OBUs utilised both short-range wireless communication (ETSI 5G, derived from the wireless 802.11p protocol) and cellular communications (3G/LTE), following ETSI TC ITS (European Telecommunications Standards Institute) standards (ETSI, 2016).

Standardisation, interoperability and certification of C-ITS systems was promoted through cooperation with bodies such as ETSI and CEN.

The trials provided scope for the development of business models, cost benefit analysis and exploitation plan to provide decision- and policy-makers clear and realistic insights into the real-world viability of C-ITS.

The data analysis mainly focused on Energy Efficient Intersection Service (EEIS), in particular GLOSA and green priority. The EEIS was the only service deployed in FOTs in all seven cities, whilst full analysis of the road safety services (RHW/ RLVW) was constrained because accident data analysis requires a longer timeframe for observation and data collection than the twelve months available.

The key findings were:

- Heavy vehicles showed a sustained improvement in emissions/efficiencies with savings in the region of 2-5% based on the modelled emissions. The real-world fuel consumption saving was higher;

- Light vehicles showed a similar relative improvement in emissions/efficiencies but a lower absolute reduction in emissions;
- The effect on buses is highly situational with one site exhibiting a strong saving of over 200gCO2 per bus route per trip. Other sites showed no improvement or a reduction in efficiency;
- Similarly, intersection crossing times and average stop numbers showed an improvement in most cases but with some variation due to conditions at specific pilot sites.

The results indicate that there is potential for significant contributions to environmental policy objectives given certain road configurations and for certain beneficiaries. The caveat to this is that we require a better understanding of configurations where the EEIS can be most effective, and how to optimally deploy the technology. For instance, we must balance the needs of individual users of the system against the possible impacts on the network, whilst in some locations or on some road configurations the effectiveness of the system can be quite limited. For example, network impacts would be minimal in the case of priority in the night-time economy whilst bus priority could act as a public transport incentive.

Furthermore, there is a need to investigate many other potential services (use cases) to tailor deployments to a specific set of objectives and local requirements. To date the services demonstrated for C-ITS have been quite limited and the consideration of 'what else can be done' with V2I communications integrated with traffic management needs to be explored. Even within the frame of the EEIS it may be that analysis of other pollutants, such as NOX, would deliver enhanced impact.

Despite the cautionary note implied by these results, it is clear that the demonstration and evaluation activities in C-ITS performed in the Compass4D project, along with cost benefit analysis, will play a major role in informing early adopters of C-ITS of the benefits and challenges of introducing the technology. What is not clear yet, and is subject to further investigation, is at what penetration levels of equipped vehicles, and what access levels of various services, will the technology be most effective, or will the demands on the services by vehicles become greater than the optimal capacity of the system.

It is crucial that this knowledge gap is addressed as there are some major implementations of C-ITS planned across Europe, including the M2/A2 corridor in the South East of England, UK, the C-ITS Corridor (initially for roadwork warnings and traffic management) from Vienna-Frankfurt-Rotterdam, and an upscaling of deployments in the Helmond-Eindhoven-Tilburg region. Upscaling is also planned in all the Compass4D deployment cities. In Newcastle upon Tyne, UK, expansion of the Compass4D network is progressing on a key arterial route between the suburb of Gosforth and the city centre. The Urban Traffic Management and Control Centre (UTMC) for Tyne and Wear region, in association with regional partners and Newcastle University, have committed to develop and roll out cooperative traffic systems as part of a regional smart traffic management initiative. To part-facilitate this the UK DfT has invested in this extension in terms of the scale and location of future deployment as well as the development of new case studies, which include vulnerable road user detection (cyclists and pedestrians), bus fleet management, support for freight management and the night-time economy through late night taxi movements.

One further area where C-ITS will be considered in future is in the support for automation of vehicle functions. Here one could envisage the C-ITS system providing information to a vehicle with some automated capabilities, to set the optimum speed of the vehicle for traffic management, safety or vehicle emissions purposes, providing information on headway and possibly initiating some automated functions to assist (for example) older drivers to drive safely in the urban environment. This offers a whole array of automated services in cooperation with the infrastructure which potentially have significant benefits to urban traffic management and will be available long before fully autonomous vehicles.

DRIVE C2x – User Acceptance

DRIVE C2X project aimed at delivering a comprehensive assessment of cooperative systems functions. The assessment used log data resulting from Field Operational Tests (FOTs) carried out on several test sites located in different EU countries during the project. In the controlled tests, the drivers were called into the test and followed the driving instructions provided by the Test-Site Instructor, allowing the driver to encounter specific test situations, such as a traffic jam. In the naturalistic approach, the test drivers' behaviour was monitored in their daily driving, and the routes and driving times are based on drivers' needs. The tested scenarios comprise both vehicle-to-vehicle (V2V) and infrastructure-to-vehicle (I2V) communication. Below are some interesting results from research which are focus on user acceptance of C-ITS systems.

The results from user acceptance measurements indicated clearly that DRIVE C2X is perceived as a highly appreciated and long anticipated driving assistance technology. As 91% of the test users stated that they are willing to use the system if it was available in their cars, it can be assumed that basic acceptance of the system will not be a severe barrier to overcome the penetration dilemma if it was offered as standard equipment. In this scenario, it can be expected that users appreciate the additional services and see them as an essential support for future driving.

At the same time the result of only 42% of the drivers that indicated to purchase the system as special equipment, support the theory mentioned in many stakeholder interviews that the critical threshold to solve the penetration dilemma can't be overcome if C2X packages are only offered as special equipment against an additional charge. Especially in the first phase of market introduction, while the actual experience especially in terms of C2X related functions is still limited due to the low penetration rate, OEMs should not consider a model with cost for the end user. The preference of functions seems to be closely connected to the innovation level of the technology. According to the user feedback, functions like GLOSA or AEVW are especially attractive as they offer differentiation potential to existing solutions sometimes even available on smartphones as WAZE or Coyote which mentioned more frequently.

7.3 Recommendations for an operative roll-out

Recommendations for an operative roll-out can be summarised in the following main items:

- Evaluation – clear plan and defined rules are key for successful deployment of C-ITS services.
- Specifications – deployment requirements and installation guidance are pivotal to improve compliance and performance,
- Operational concepts and manuals – they are essential for the transition of C-ITS services into regular operation.

Setting a clear evaluation plan and rules is a key factor in the successful deployment of C-ITS systems. As has been mentioned above, more and more real applications will gain experience. Every

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real deployment of the system must be accompanied by evaluation and verification of functionality and for user acceptance from several points of view.

- Interoperability:
- Service efficiency
- Service interoperability
- Cross-border interoperability

During the field tests it will be possible to measure or calculate different parameters that can reveal a different behaviour of the driver after the receipt of information via C-ITS. Basically, just User Behaviour of single driver/vehicle will be measured, as it can be assumed that the impact on the whole traffic flow during a field test would be negligible.
The measurement of changes in User Behaviour, thanks to the use of Day 1 C-ITS, provides a first indication of the impacts, at a field test scale, of C-Roads implementation. This is a first definition of measured KPI. These are the areas of investigation:

- Safety
- Traffic efficiency
- Environment
- User Acceptance

An additional step is to use the data measured or calculated during the field test for an estimation of impacts when the penetration rate of C-ITS vehicle will be higher.
Such estimation could be based on algorithms and traffic modelling, but even through qualitative assessment. This provides estimated KPI on traffic when C-ITS will be fully implemented.

In addition, evaluation of the performance, compatibility, efficiency, etc., it is also necessary to set and continually improve the minimum technical requirements for the system, but also for the individual system elements. These requirements will always be part of public procurement, which is a necessary part of the implementation of C-ITS. The better the requirements are set, the better it is possible to require their compliance from the suppliers. Below is an example of these requirements from France.

French RSU specifications: deployment requirements and installation guide

Deployment requirements

This paragraph aims at providing methodological elements concerning the deployment of roadside units (RSU).

The objectives taken into account in this paragraph are:

- receive vehicle information (V2I)
- inform drivers (I2V)

General criteria:

The following general criteria are taken into account for an RSU implementation:

- network and level of service;
- type of road;

- traffic;
- quality and coverage of the computer network (cellular, Ethernet, optic fiber, copper cable ...)
- sensitive area: dangerous descent, accident accumulation zone, animal presence area, tunnel, bridge, structures, others;
- penetration rate of on-board equipment;
- operation of the cooperative system;
- network topography.

Here are some examples of using these criteria:

- type of road:

RSUs work optimally in open area. In urban areas, building masking phenomena and the effects of reflection, refraction and scattering cause significant attenuation of signals and longer reception times. The density of RSU must therefore be higher in urban areas. The effects of precision loss of GNSS localisation are also sensitive.

Tunnels are both special points for traffic management and RSU equipment:

- GNSS geolocation of vehicles does not work in the tunnel
- For short tunnels, it is recommended to favour a positioning of the RSU outside of the tunnel
- For long tunnels, the positioning of an RSU in the tunnel involves configuring it to a fixed position outside GNSS

Are considered as sensitive area:

- sensitive or risk areas already known to the manager;
- dangerous turns
- areas with adverse weather conditions: regular fog, high snow risk ...;
- zones of recurrent presence of animals (forest, farm exit, stud farm, etc.);
- areas of recurrent congestion presence;
- zones of danger specific to the city (school, zone 30, ...)

A RSU should be positioned upstream of each sensitive area. Depending on the speed of the vehicles, the position should be sufficient to allow the onboard unit to display the information to the driver, with time to takes knowledge and act with confidence. The relevant area for positioning a RSU is upstream of this sensitive area at the last intersection.

Recurring congestion zones also have the particularity of having a high coverage time that offers a greater potential for data exchange. However, if the penetration rate of equipped vehicles is high, then the saturation effect of communications is even more troublesome for the real-time management of incidents.

Operation of the cooperative system:

- a vehicle must remain at least 2 seconds in range of the RSU to be able to catch the message: for example, for a DENM issued every 1 s, on a 110 km / h road, this means at least 30 m.
- the vehicle must have time to decode the received message: According to the tests carried out in the SCOOP project, this can range from a few ms to 1 second, that is 30 m to 110 km / h.

DENM Relay

The relays are made up to a limit fixed by the messages: in order to avoid any overload of the communication networks, a message will not make more than 10 rebounds before reaching its expiration, If the RSUs are 300m apart, this is about 3km range as the maximum relay, to be taken into account by the road operator.

Other criteria:

More specific criteria can be taken into account:

Traffic data measurements:

These are mainly used to know the speed in the reception area of a RSU. There is the possibility of having several zones of speed in the RSU’s antenna capitation.

Incident detection:

The goal is to optimize the time of detection of incidents with cooperative systems, compared to a situation without them.

It will be relevant for the road manager to position RSUs downstream of areas where such events are regularly detected.

Fixed road works signage:

Here we consider road works planned well in advance (the information is entered into the system before the first user who crosses the work has entered the network ...)

In order to maximize the number of informed users, the RSUs should be positioned at all entrances to his network, and then ensure that there is at least one RSU positioned every 10 km (using the coverage offered by the dissemination of DENMs).

Frequent danger signalisation, animal and person:

For all this information, it is relevant to position the RSU upstream of the areas where the event is regularly detected.

RSU installation guide

Introduction:

This chapter specifies how to deploy RSU. 4 main topics are covered:

- Determining the precise location of RSUs
- Detailed installation of equipment
- Protection and prevention
- System maintenance

Choice of site:

The different antennas for RSUs have maximum ranges of between 300 and 1000 m. In order to have maximum efficiency, the installation of an RSU must take place in an open area over a radius of at least 500 m.

The choice of positioning must also include access constraints for maintenance operations.

In the case of installation on an existing structure, a new calculation note will have to be made to ensure that the support is resistant to the new load.

Power supply:
Depending on the place of installation, attention should be paid to the choice of power supply: main power, battery, wind or solar ... A battery can be integrated to mitigate risk of power cut or support a solar power supply.

Communication network:
In order for the RSU to communicate with the computer centre and other facilities, the RSU must be located in areas covered by at least one of the following networks:

- road operator network
- wired operated network,
- cellular network
  - Wi-Fi network
  - satellite network,
  - Radio, ...

Prevention of breakdowns:
Remote supervision of the RSUs is required for the management of the installed park. This supervision must regularly interrogate the RSUs to know their state.
An annual preventive maintenance is necessary.

C-ITS Corridor operational concepts and manuals

In the context of the transition of C-ITS pilots to regular operation, the crucial aspect of defining roles and responsibilities has to be addressed adequately. It is hence essential to set up operational concept and manuals. An example, illustrating the set-up of operational processes in Germany, can be found in [10].

8. References

1) Edwards S, Hill G, Goodman P, Blythe P, Mitchell P, Huebner Y. Quantifying the Impact of a Real-World Cooperative-ITS Deployment across Multiple Cities. Transportation Research Part A: Policy and Practice (2017) DOI: https://doi.org/10.1016/j.tra.2017.10.001
2) C-ITS Platform, Final report Phase II, September 2017
3) C-ITS Platform Phase II, Certificate Policy for Deployment and Operation of European Cooperative Intelligent Transport Systems (C-ITS), Release I, June 2017
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6) C-ITS Platform, Final report Phase I, January 2016
7) http://www.scoop.developpement-durable.gouv.fr/
8) www.codecs-project.eu
9) www.drive-C2x.eu
10) C-ITS Corridor, Framework to construct operational concepts/manuals for cooperative systems, May 2017
11) ISO 17427-1:2018, Intelligent transport systems -- Cooperative ITS -- Part 1: Roles and responsibilities in the context of co-operative ITS architecture(s) (https://www.iso.org/standard/66924.html)

9. ANNEX I – C-Roads Members Service Chain

C-ROADS_WG1_Analysis_C-ITS_Services-

10. ANNEX II - List of standards

ETSI TS 102 637-1 Intelligent Transport Systems (ITS); Vehicular Communications; Basic Set of Applications; Part 1: Functional Requirements - [Link]

ETSI TS 102 687 Intelligent Transport Systems (ITS); Decentralized Congestion Control Mechanisms for Intelligent Transport Systems operating in the 5 GHz range; Access layer part [Link]

ETSI TS 102 724 Intelligent Transport Systems (ITS); Harmonized Channel Specifications for Intelligent Transport Systems operating in the 5 GHz frequency band [Link]

ETSI TS 102 731 Intelligent Transport Systems (ITS); Security; Security Services and Architecture [Link]

ETSI TS 102 894-1 Intelligent Transport Systems (ITS); Users and applications requirements; Part 1: Facility layer structure, functional requirements and specifications [Link]

ETSI TS 102 894-2 Intelligent Transport Systems (ITS); Users and applications requirements; Part 2: Applications and facilities layer common data dictionary [Link]

ETSI TS 103 097 Intelligent Transport Systems (ITS); Security; Security header and certificate formats [Link]

ETSI TS 102 792 - Mitigation techniques to avoid interference between European CEN Dedicated Short Range Communication (CEN DSRC) equipment and Intelligent Transport Systems (ITS) operating in the 5 GHz frequency range - [Link]

ETSI TS 102 940 Intelligent Transport Systems (ITS); Security; ITS communications security architecture and security management [Link]

ETSI TS 102 941 Intelligent Transport Systems (ITS); Security; Trust and Privacy Management [Link]

ETSI TS 102 942 Intelligent Transport Systems (ITS); Security; Access Control [Link]

ETSI EN 302 636-4-1 Intelligent Transport Systems (ITS); Vehicular Communications; GeoNetworking; Part 4: Geographical addressing and forwarding for point-to-point and point-to-multipoint communications; Sub-part 1: Media-Independent Functionality [Link]

ETSI TS 102 637-1 Intelligent Transport Systems (ITS); Vehicular Communications; Basic Set of Applications; Part 1: Functional Requirements[Link]

ETSI TS 103 097 v1.2.1. Intelligent Transport Systems (ITS); Security; Security header and certificate formats [Link]

ETSI EN 302 637-2 Intelligent Transport Systems (ITS); Vehicular Communications; Basic Set of Applications; Part 2: Specification of Cooperative Awareness Basic Service [Link]

ETSI EN 302 637-3 Intelligent Transport Systems (ITS); Vehicular Communications; Basic Set of Applications; Part 3: Specifications of Decentralized Environmental Notification Basic Service [Link]

ETSI EN 302 663 Intelligent Transport Systems (ITS); Access layer specification for Intelligent Transport Systems operating in the 5 GHz frequency band [Link]

ETSI EN 302 665 Intelligent Transport Systems (ITS); Communications Architecture [Link]

ETSI EN 302 571 Intelligent Transport Systems (ITS); Radio communications equipment operating in the 5 855 MHz to 5 925 MHz frequency band; Harmonized EN covering the essential requirements of article 3.2 of the R&TTE Directive [Link]

ETSI EN 302 931 Intelligent Transport Systems (ITS); Vehicular Communications; Geographical Area Definition [Link]

ETSI ES 202 663 Intelligent Transport Systems (ITS); European profile standard for the physical and medium access control layer of Intelligent Transport Systems operating in the 5 GHz frequency band [Link]

IETF RFC 2460 Internet Protocol, Version 6 (IPv6) Specification [Link]

RFC 6275 Mobility Support in IPv6 [Link]

IEEE Std 802.11p IEEE Standard for Information technology — Telecommunications and information exchange between systems — Local and metropolitan area networks — Specific requirements; Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications; Amendment 6: Wireless Access in Vehicular Environments [Link]

ISO 29281 Intelligent transport systems - Communication access for land mobiles (CALM) - Non-IP networking [Link]

ISO 21215 Intelligent transport systems - Communications access for land mobiles (CALM) - M5 [Link]

PKCS#1 RSA Cryptography Specification [Link]

PKCS#8 Private-Key Information Syntax Specification [Link]

PKCS#10 Certification Request Syntax Specification [Link]

PKCS#11 Cryptographic Token Interface Standard [Link]

FIPS 180-4 Secure Hash Standard Definition SHA-2 [Link]

FIPS 180-4 Secure Hash Standard Definition SHA-3 [Link]

FIPS 186-3 Digital Signature Standard (DSS) [Link]

FIPS 140-2 U.S. government computer security standard used to approve cryptographic modules [Link]