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BSI Standards Publication

Intelligent transport systems — Cooperative ITS

Part 3: Concept of operations (ConOps) for 'core' systems

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National foreword

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TECHNICAL REPORT

ISO/TR 17427-3

First edition
2015-11-01

Intelligent transport systems — Cooperative ITS —

Part 3: Concept of operations (ConOps) for 'core' systems

Systèmes intelligents de transport — Systèmes intelligents de transport coopératifs —

Partie 3: Concept des opérations (ConOps) pour les systèmes 'principaux'

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: Foreword - Supplementary information

The committee responsible for this document is ISO/TC 204, *Intelligent transport systems*.

ISO 17427 consists of the following parts under the general title, *Intelligent transport systems — Cooperative ITS*:

— *Part 2: Framework overview* [Technical Report]

— *Part 3: Concept of operations (ConOps) for 'Core' systems* [Technical Report]

— *Part 4: Minimum system requirements and behaviour for core systems* [Technical Report]

— *Part 6: Core systems risk assessment methodology* [Technical Report]

— *Part 7: Privacy aspects* [Technical Report]

— *Part 8: Liability aspects* [Technical Report]

— *Part 9: Compliance and enforcement aspects* [Technical Report]

— *Part 10: Driver distraction and information display* [Technical Report]

The following parts are under preparation:

— *Part 1: Roles and responsibilities in the context of co-operative ITS architectures(s)*

— *Part 5: Common approaches to security* [Technical Report]

— *Part 11: Compliance and enforcement aspects* [Technical Report]

— *Part 12: Release processes* [Technical Report]

— *Part 13: Use case test cases* [Technical Report]

— *Part 14: Maintenance requirements and processes* [Technical Report]

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This Technical Report provides an informative 'Concept of operations for ore systems' supporting *Cooperative intelligent transport systems* (*C-ITS*). It is intended to be used alongside ISO 17427-1, ISO/TR 17465-1 and other parts of ISO 17465, and ISO 21217. Detailed specifications for the application context will be provided by other ISO, CEN and SAE deliverables, and communications specifications will be provided by ISO, IEEE and ETSI.

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Introduction

Intelligent transport systems (*ITS*) are transport systems in which advanced information, *communication*, sensor and control technologies, including the Internet, are applied to increase safety, sustainability, efficiency, and comfort in the movement of people and goods.

A distinguishing feature of '*ITS*' is its *communication* with outside entities.

Some *ITS*s operate autonomously, for example, 'adaptive cruise control' uses radar/lidar/and/or video to characterize the behaviour of the vehicle in front and adjust its vehicle speed accordingly. Some *ITS*s are informative, for example, 'Variable Message Signs' at the roadside, or transmitted into the vehicle, provide information and advice to the driver. Some *ITS*s are semi-autonomous, in that they are largely autonomous, but rely on 'static' or 'broadcast' data, for example, *GNSS*-based 'SatNav' systems operate autonomously within a vehicle but are dependent on receiving data broadcast from satellites in order to calculate the location of the vehicle.

*Cooperative intelligent transport system*s (*C-ITS*) are a group of *ITS* technologies where service provision is enabled by, or enhanced by, the use of 'live', present situation related, dynamic data/information from other entities of similar functionality [for example, from one vehicle to other vehicle(s)], and/or between different elements of the transport network, including vehicles and infrastructure [for example, from the vehicle to an infrastructure-managed system or from an infrastructure-managed system to vehicle(s)]. Effectively, these technologies enable vehicles to 'talk' to each other and to the infrastructure, and in so doing will have significant potential to improve the safe, sustainable and efficient operation of the transport network.

A distinguishing feature of '*C-ITS*' is that data is used across application/service boundaries. This means that data collected at one point and/or processed by one application becomes available to be re-used by other applications, which may be operating in the same, or different physical entities.

The difference between any '*ITS* implementation' and a '*C-ITS* implementation' is that *C-ITS*s are dependent on the interaction with other vehicles and/or the infrastructure, and the exchange of dynamic data, to receive data to enable their function, or conversely to provide data to other vehicles/infrastructure to enable their *C-ITS*s to function.

C-ITS as an entity, is therefore the *functionality that enables* such 'cooperative' and collaborative exchange of data, and in some cases, collaborative control, or even decision making, that will enable applications to provide their services to one or more *actors* (3.1).

ISO/TR 17465-1 provides a summary definition of *C-ITS* as a "subset paradigm of overall *ITS* that communicates and shares information between *ITS-station*s to give advice or facilitate actions with the objective of improving safety, sustainability, efficiency and comfort beyond the scope of stand-alone systems".

ISO 17427-1 will provide descriptions of the roles and responsibilities of *actors* involved in the provision and use of *C-ITS*.

ISO/TR 17427-2 provides a framework overview which characterize the components of a *Cooperative-ITS* (*C-ITS*), its context and relevance for *ITS service* provision, and provides references to Standards deliverables where specific aspects of *C-ITS* are defined.

This Technical Report concerns the high-level generic requirements for the "Concept of operations" for a 'Core System' (*CorSys)* (3.10) to support *C-ITS* in a connected vehicle-highway system paradigm. It is agnostic in respect of technology and operates with whatever (and probably multiple) *communication*s technologies and hardware technologies that can support its functionalities.

The benefits of *Intelligent Co-operative Systems* (*C-ITS*) stem from the increased information that is available from the vehicle and its environment and from other vehicles. The same set of information can be used to extend the functionality of the in-vehicle safety systems and through vehicle-to-

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infrastructure *communications* for more efficient traffic control and management. The benefits include the following:

— improved safety;

— increased road network capacity;

— reduced congestion and pollution;

— shorter and more predictable journey times;

— improved traffic safety for all road users;

— lower vehicle operating costs;

— more efficient logistics;

— improved management and control of the road network (both urban and inter-urban);

— increased efficiency of the public transport systems;

— better and more efficient response to hazards, incidents and accidents.

(source: EC project CVIS)

It is important to understand that *C-ITS* is not an end in itself, but a combination of techniques, protocols, systems and sub-systems to enable 'cooperative'/collaborative service provision in a connected vehicle-highway system paradigm.

Other parts in this family of *C-ITS* standards will define specific aspects of technology and behaviour, and the roles and responsibilities within the context of *C-ITS*.

This Technical Report is a 'living document' and as our experience with *C-ITS* develops, it is intended that it will be updated from time to time, as and when we see opportunities to improve this Technical Report.

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TECHNICAL REPORT **ISO/TR 17427-3:2015(E)**

Intelligent transport systems — Cooperative ITS —

Part 3:
Concept of operations (ConOps) for 'core' systems

1 Scope

This Technical Report provides the high-level generic requirements for the "Concept of operations" for a 'Core System' (*CorSys)* (3.10) to support *C-ITS service* delivery. It is intended as an input to the planning and development elaboration of core functions that will support the deployment of *cooperative intelligent transport systems* (*C-ITS*) in a connected vehicle-highway paradigm

The objective of this Technical Report is to raise awareness of and consideration of such issues and to give pointers, where appropriate, to standards existing that provide specifications for all or some of these aspects. This Technical Report does not provide specifications for solutions of these issues.

This Technical Report is agnostic in respect of technology and operates with whatever (and probably multiple) *communications* technologies and hardware technologies that can support its functionalities.

2 Normative references

There are no normative references.

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
actor
party participating in a system, within this Technical Report participating in *C-ITS* (3.6) service provision/receipt

3.2
application
'app'
software application to provide functionality to realize *C-ITS* (3.6)

3.3
application service
service provided by a service provider accessing data from the *IVS* vehicle in the case of *C-ITS* (3.6), via a wireless *communications* network, or provided on-board the vehicle as the result of software (and potentially also hardware and firmware) installed by a service provider or to a service provider's instruction

3.4
back office
central system ('*centre*'/*CorSys*) for commercial *applications* (3.2)

Note 1 to entry: The terms '*back office*' and '*Centre*' are used interchangeably throughout this Technical Report. '*Centre*' is a traditionally transport-focused term, evoking management *centres* to support transport needs, while *back office* generally refers to commercial *applications* (3.2). From the perspective of this *ConOps,* their functions are considered to be similar.

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3.5
bounded secure managed domain
BSMD
secure *ITS-station* entity capable to conduct secure peer-to-peer *communications* (3.8) between entities (*ITS-stations*) that are themselves capable of being secured and remotely managed

Note 1 to entry: The bounded nature is derived from the requirement for *ITS-stations* to be able to communicate amongst themselves, i.e. peer-to-peer, as well as with devices that are not secured (referred to as 'other *ITS-stations*'),and realizing that to achieve this in a secure manner often requires distribution and storage of security-related material that needs to be protected within the boundaries of the *ITS-stations*, leads to the secured nature of the entity - as there is great flexibility to achieve desired *communication* goals, there is a requirement that this flexibility be managed; within *C-ITS* (3.6) and ISO 21217 such *ITS-stations* are defined as operating within *bounded secured managed domains* (*BSMD*), or outside of the *BSMD*.

3.6
cooperative ITS
C-ITS
group of *ITS* technologies where service provision is enabled, or enhanced by, cooperating to provide the use of 'live', present situation related, data/information from other entities of similar functionality, for example, from one vehicle to other vehicle(s), and/or between different elements of the transport network, including vehicles and infrastructure, for example, from the vehicle to an infrastructure managed system or from an infrastructure managed system to vehicle(s)

3.7
centre
central system
traditionally transport-focused term, evoking management *centres* (3.7) to support transport needs and/or providing/supporting *application service(s)* (3.3) managed through a central facility; from the perspective of the *CorSys* similar to '*back office*'

3.8
communication
communications
wireless (and in some cases, *wireline*) networks that facilitate data exchange, including roadside *ITS-stations* where appropriate

3.9
Concept of operations
ConOps
document describing the characteristics of a proposed system from the viewpoint of an individual who will use that system

Note 1 to entry: It is used to communicate the quantitative and qualitative system characteristics to all stakeholders.

3.10
core system
CorSys
combination of enabling technologies and services that will provide the foundation for the support of a distributed, diverse set of *applications* (3.2)/*application* transactions which work in conjunction with external *support systems* (3.24) such as certificate authorities

Note 1 to entry: The system boundary for the *CorSys* is not defined in terms of devices or agencies or vendors, but by the open, standardized interface specifications that govern the behaviour of all interactions between *CorSys* users.

3.11
data store
permanent storehouse of data (files, databases, text documents, etc.)

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3.12
end user
citizen or legal entity who exercises or benefits from the services of the transport system

3.13
equipped person(s)
persons with mobile phones, tablets or similar *communications* (3.8) devices that provide data collection and processing capacity to perform in the *C-ITS* (3.6) context

3.14
equipped vehicle(s)
vehicles equipped with the device(s) that provide the role of an *ITS-station* in the *C-ITS* (3.6) context

3.15
global navigation satellite system
GNSS
several networks of satellites that transmit radio signals containing time and distance data that can be picked up by a receiver, allowing the user to identify the location of its receiver anywhere around the globe

3.16
home agent
'IPv6 router' with which mobiles register their current Care-of Address (RFC 3753)

3.17
in-vehicle system
IVS
hardware, firmware and software on board a vehicle that provides a platform to support *C-ITS* (3.6) service provision, including that of the *ITS-station* (ISO 21217), its facilities layer, data pantry and on-board 'apps'

3.18
intelligent transport system
ITS
transport systems in which advanced information, *communication* (3.8), sensor and control technologies, including the Internet, are applied to increase safety, sustainability, efficiency, and comfort

3.19
ITS application
functionality that either completely provides what is required by an *ITS service* (3.21) or works in conjunction with other *ITS applications* (3.2) to provide one or more *ITS services*

3.20
ITS-s border router
ITS-S router with additional functionality that provides connectivity to other ITS *communication* (3.8) nodes over external networks

3.21
ITS service
functionality provided to surface transport system users

3.22
ITS-station
ITS-s
entity in a *communication* (3.8) network [comprised of *application* (3.2), facilities, networking and access layer components] that is capable of executing *ITS-S* application processes (sometimes within a bounded, secured, managed domain), comprised of an *ITS-S* facilities layer, *ITS-S* networking and transport layer, *ITS-S* access layer, *ITS-S* management entity and *ITS-S* security entity, which adheres to a minimum set of security principles and procedures so as to establish a level of trust between itself and other similar ITS stations with which it communicates

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3.23
jurisdiction
government, road or traffic authority which owns the *regulatory applications* (3.2)

EXAMPLE Country, state, city council, road authority, government department (customs, treasury, transport), etc.

3.24
support system(s)
facilities that assist in *C-ITS* (3.6) service provision, including security credentials certificate and registration authorities, that allow devices and systems to establish trust relationships

3.25
wireline
traditional permanent 'wired' connection (although may in reality include microwave and other wireless connections)

4 Abbreviated terms

2G second-generation cellular phone technology, e.g. GSM

3G third-generation mobile phone technology, e.g. UMTS

4G fourth-generation mobile phone technology, e.g. E-UTRAN (sometimes known as LTE)

BSMD bounded secure managed domain

C-ITS cooperative intelligent transport systems, cooperative ITS

CALM Communications Access for Land Mobiles

ConOps concept of operations

CorSys core system

CVIS Cooperative Vehicle Infrastructure Systems

DoT Department of Transport

ESS External System Support

E-UTRAN Evolved UMTS Terrestrial Radio Access Network

GNSS global navigation satellite systems

GSM Global System for Mobile Communication (2G mobile communications)

IPv6 Internet Protocol version 6

ITS intelligent transport systems

ITS-s ITS-station

IVS in-vehicle system

PII personal identification information

RSE roadside equipment

SatNav Satellite Navigation (see 3.15)

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TMC	transport management centres
V2I	vehicle to/from infrastructure
V2V	vehicle to vehicle
VANET	vehicular ad hoc network
VMS	variable message sign
UML	Unified Modelling Language (ISO/IEC 19501)

5 Using this Technical Report

This Technical Report is intended to assist parties instantiating a *CorSys*, becoming involved as an *actor* in a *C-ITS* (3.6) that involves the use of a *CorSys*, or becoming involved with the development or use of such a *CorSys*.

This Technical Report provides guidance on the aspects to be considered in developing a 'Concept of operations' (*ConOps*) for a *CorSys* for *C-ITS* support. As such, the advice in this Technical Report is generic and not instantiation specific to any one *jurisdiction* (3.23) or implementation.

This Technical Report is intended to provide a framework and guidance to enable the development of an instantiation specific *Conops* specification after taking into account the aspects specified herein together with the location specific situation (technical and political) and conditions.

6 Overview of the role of a 'Core System' in C-ITS

6.1 What is a Concept of operations?

A 'Concept of operations' is a user-oriented document that describes system characteristics for a proposed system from the users' viewpoint. This 'Concept of operations' describes *C-ITS* stakeholders, their roles and responsibilities in a connected vehicle-highway system paradigm, an overview of the emerging system design, and provides a high-level description of how such systems may operate.

A concept of operations document describes the systems' objectives, user needs, the functions, the *actors* (3.1) and stakeholders involved, and the enactment of roles and responsibilities. (ISO 17427-1 contains an explanation of roles and responsibilities.) A concept of operations is one of the early phases of the Systems Engineering approach. Systems Engineering is an interdisciplinary approach used to enable the realization of successful systems. It focuses on defining customer needs and required functionality early in the development cycle, and then proceeding with design synthesis and system validation.

In respect of *C-ITS*, additional information can be obtained from one of the "standard" architectures such as the US 'Connected Vehicle Reference Implementation Architecture',[3] or the 'European ITS Framework (FRAME) Architecture',[12] or in the architecture document supporting a specific implementation.

It is important to understand that this 'Concept of operations' is focused on, and relates to the provision of, *CorSys* requirements that are necessary in order to facilitate and enable *C-ITS* assisted service provision. This deliverable does not consider in any depth the whole *C-ITS* perspective in a connected vehicle-highway systems paradigm (ISO/TR 17427-2 and ISO 17427-1 contains more detailed consideration of such aspects). This Technical Report is focused on the 'core' system aspects required to support *C-ITS* in a connected vehicle-highway system paradigm. This '*Core system* Concept of operations' does not provide a concept of operations for any particular *application service(s)* (3.3), but for the background facilitation and infrastructure support required for such service provision.

Much of the source material for this deliverable has been obtained from the US DoT RITA "connected Vehicle" initiative [Connected Vehicle Technology. US DoT; Connected Vehicle Reference Implementation

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Architecture. (CVRIA); Core System- System Architecture Document (service architecture document), US DoT; Core System- System Requirements Specification (SyRS)]; from relevant Australian publications (*Cooperative ITS* (3.6): Concept of operations for *C-ITS* core functions – Draft Report. ARRB; Cooperative ITS Regulatory Policy Issues. National Transport Commission, Australia) and from the European Project CVIS. See Bibliography for further detail. The permission of these bodies to freely use their material is gratefully appreciated and their source acknowledged.

6.2 What are the core functions?

The 'core' functions are functions that enable the trusted and secure data exchange necessary to enable a platform for *C-ITS applications* (3.2) in a connected vehicle-highway system paradigm. These 'core' functions can be seen as a collection of operational and institutional functions, such as the exchange of security certificates, storage and redistribution of *application* data, and exchange of system management information like subscriptions to *C-ITS applications*. These core functions require policies and management structures to be in place as a basis from which to operate. An example of a policy requirement is a policy on whether core functions are required for *all C-ITS applications*, or only for *some*. Also, ensuring correct implementation of system components and correct functioning of the system requires some form of compliance insurance, such as accreditation, certification, type approval or auditing, to be in place.

This Concept of operations aims to identify those core functions that are required to enable connected vehicle highway systems (*cooperative ITS*) to evolve, as well as the institutional changes required, to enable *C-ITS applications* to be deployed and positive transport and societal outcomes to be realized. Based on an assessment of international *C-ITS* developments, and an assessment of the current local situation, it is proposed that the core functions required to support *C-ITS* are the following:

— Secure exchange of data between users and *applications*;

— Facilitate trust between users;

— Maintain integrity of data;

— Assure privacy between users and from third parties;

— Facilitate a platform for sharing of data and efficient use of resources;

— Assure national/regional interoperability and nationally/regionally consistent service access.

In the predicted paradigm, connected vehicle-highway systems (*C-ITS*) will use several wireless media, as available, in order to provide *C-ITS* based *application services* (3.3), and in all probability, in many circumstances, will use multi-media simultaneously. Service provision will, in all probability, in many cases, not depend on a single wireless medium and will also use on-board sensors and other available data in order to effect robust service provision. Media selection will depend on media availability at the location of the vehicle at the time of service provision and suitability of the characteristics of the media for the particular *application service* provision. Vehicular ad hoc networks (VANETS) are likely to use the allocated 5,9 GHz spectrum for vehicle-vehicle *communications* (3.8), particularly for time-critical safety *applications*, and the infrastructure will use 5,9 GHz spectrum for infrastructure-vehicle *communications* at safety-critical locations. Although this Technical Report uses this working hypothesis, it does not require the use of any particular wireless medium for any particular purpose, rather it considers the consequences of such selection and the *CorSys* support requirements that will need to be in place to enable such service provision.

6.3 Functional subsystems

Within this Concept of operations, the *C-ITS* core functions are clustered in seven functional subsystems, performing

— data distribution,

— misbehaviour management,

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— network services,

— service monitoring,

— time synchronisation,

— user permissions management, and

— user trust management.

These core subsystems interact with other *C-ITS* components, such as the *applications*, the networking and transport algorithms and the *communication* infrastructures.

6.4 Institutional context

The *C-ITS* core functions will need an institutional context to operate. This is essential because the functions are executed on different physical *C-ITS* components, being

— vehicles,

— *ITS* roadside equipment,

— mobile devices and

— back office (3.4)/control centres (3.7).

These components are management managed by different stakeholders.

Roles that need to be performed are

— governance roles,

— management roles,

— installation roles,

— certification roles,

— operational roles and

— user roles.

Examples of activities that may require new institutional entities or structures to enable *C-ITS* in a connected vehicle-highway paradigm, include a device certification and possibly registration, security credential distribution, application certification, and compliance insurance. These roles could be assigned to existing organizations or new organizations can be created.

ISO 17427-1 contains further detail regarding the roles and responsibilities of *actors* involved in *C-ITS service* provision and ISO/TR 17427-2 for a framework overview.

Additionally, a policy framework, including the following policies, needs to be put in place:

— a policy setting National, regional or international compliance requirements;

— a policy authorising the issuing of security certificates;

— a policy authorising road users to use certain *C-ITS applications* and send certain *C-ITS* messages;

— a policy defining interpretation of the privacy rules and regulations and ‘privacy by design’ aspects.

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6.5 Specific service features characterizing C-ITS service provision

A nation's road transport system is critical not only to its economy, but also to its social and environmental well-being. It includes numerous different modes of transport, including passenger vehicles (cars and vans), buses, trucks and motorcycles, and needs to be considerate and inclusive of vulnerable road users such as pedestrians and bicycle riders. It also is increasingly integrated and interfacing with other non-road transport modes, such as trains.

ISO 14813-1 describes the ITS service groups and services that are generally considered to comprise the realm of ITS. From ISO 14813-1, we can establish that ITS services can operate in different paradigms, and some application services (3.3) operate autonomously (see examples given in the introduction).

Some *ITS*s are semi-autonomous, in that they are largely autonomous, but rely on 'static' or 'broadcast' data (see examples given in the introduction).

Cooperative ITS (*C-ITS*) is a subset of the broader suite of *ITS*, within a paradigm of connected vehicle-highway systems. *C-ITS* refers to the use of wireless *communication*s to share information from vehicle-to-vehicle (V2V), vehicle-to-infrastructure (V2I) and infrastructure-to-vehicle (I2V). This will enable a paradigm that allows vehicle and transport *applications* to cooperatively work together to deliver outcomes that are beyond what is achievable with standalone *ITS* and vehicle *applications*.

The *cooperative intelligent transport system*s that are evolving will involve wireless connections between the *actors* involved in road transport, and its deployment will be multimodal, as shown in Figure 1.

Figure 1 — Multimodal cooperative intelligent transport domain [Source: ARRB/Andersen and McKeever (2011)]

The emerging cooperative intelligent transport domain will involve connections between the following:

— Vehicles – equipped with built-in, aftermarket, or nomadic, *C-ITS* devices

— Infrastructure – *ITS* roadside infrastructure connected through *C-ITS*

— Centres – traffic management centres and service providers' *back office/ centre*s.

The cooperative intelligent transport domain will also include mobile devices (e.g. cellular smart-phones), and also other nomadic devices, focused on assisting vulnerable road users (e.g. bicycle riders, pedestrians, physically and mentally challenged).

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In addition, many *C-ITS applications* and services will also require a connection with 'Global Navigation Satellite Systems' (*GNSS*) for positioning, navigation and timing data. The connections between the various *actors* in the cooperative intelligent transport domain are illustrated in Figure 2.

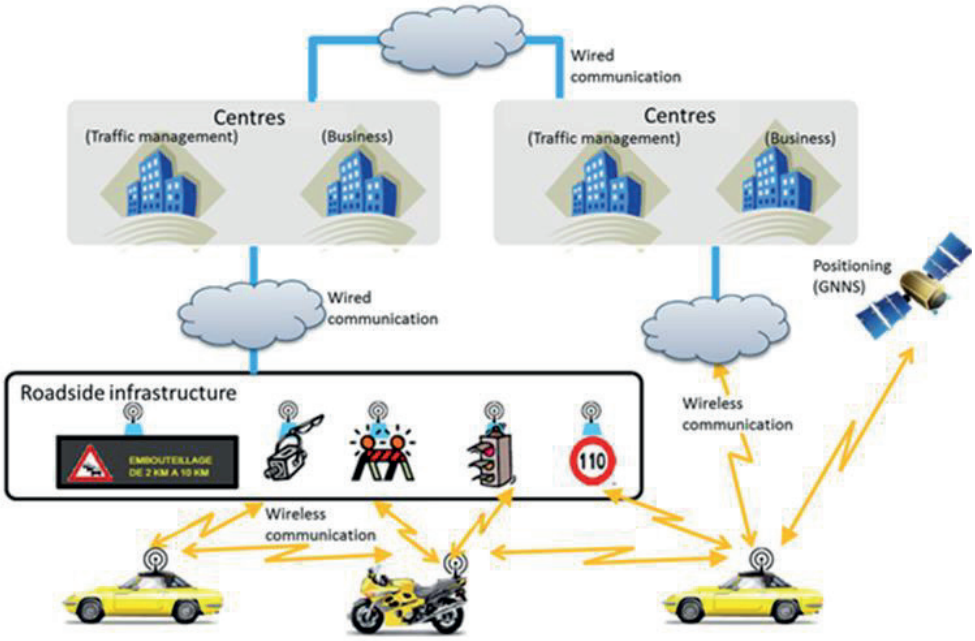

Figure 2 — Cooperative intelligent transport domain
[Source: ARRB/Modified from Lan (2013)]

Cooperative intelligent transport systems (*C-ITS*) are a group of *ITS* technologies where service provision is enabled, or enhanced by, the use of 'live', dynamic, present situation related, data/information from other entities.

Example: from one vehicle to other vehicle(s) and/or between different elements of the transport network, including vehicles and infrastructure.

Example: from the vehicle to an infrastructure managed system or from an infrastructure managed system to vehicle(s).

Effectively, these systems allow vehicles to 'talk' to each other and to the infrastructure. These systems thus have significant potential to improve the transport network. See also ISO/TR 17465-1, ISO 17427-1 and ISO/TR 17427-2.

For specifications regarding *C-ITS* terms, definitions and guidance for standards documents, see ISO 17465-1.

For specifications regarding the structure of specific *C-ITS* Standards deliverables and general *C-ITS* definitions, see ISO/TR 17465-2.

For specifications regarding 'Release' procedures for consistent groups of *C-ITS* Standards, see ISO 17465-3.

It is important to understand that *C-ITS* is not an end in itself, but a combination of techniques, protocols, systems and functions to enable 'cooperative'/collaborative service provision. What separates *C-ITS* from any other *ITS communication* is the sharing and exchange of data to provide information, and in some cases control, cooperatively between *actors* in the road network.

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6.6 C-ITS and communication technologies

6.6.1 General

The functionality of *C-ITS* is based on wireless *communications* (vehicle-infrastructure, inter-vehicle), between *communications* facilities called *"ITS-stations"* (3.22), potentially over several different wireless media, and in some cases supported by wired infrastructure-infrastructure *communications*, and also by intra-vehicle exchange of data and, in some cases, control. The *C-ITS* 'Internal Enterprise Objects', are therefore closely aligned with ISO 21217 (*ITS-station* architecture) and its associated family of Standards (See ISO 21217).

Within Figure 5 (6.7), the 'Internal' enterprise objects are surrounded by the wireless and wired media used to communicate between *actors* in most *C-ITS* situations.

While Figure 5 highlights *ITS-station* wireless *communications* as a boundary *actor* (3.1) between the internal and external objects, it should be noted that, in the infrastructure-infrastructure *C-ITS* context, *communications* may be wired, and that so called 'wired' *communications* now commonly also use microwave and other wireless techniques.

In *communications* terms, "*ITS-station communications*" are peer-to-peer *communications*. But in *application service* (3.3) terms, they are *communications* between *actors* involved in *C-ITS service* provision, in which one *actor* will be the service requestor, and the other party will be the service provider. There may of course also be intermediaries in the provision of service chain, and some transactions will require the service of intermediaries for certification, data collation, anonymisation etc., who are not directly involved in a role either as the service requestor or the service provider.

NOTE The party requesting the service is usually the party receiving the service, but this is not always the case. In some circumstances, there are more than two parties to the transaction.

While *C-ITS* involves both infrastructure and vehicles/travellers, and while the infrastructure may (but not always) be in a fixed location, the nature of the *communications* are most frequently 'ad hoc' networks, formed for the duration that *ITS-stations* are communicating with each other, whether they be other vehicles or are in *communication* with the infrastructure that they are currently driving past, or are in their vicinity.

The range of the *communication* zone where such *communication* can take place will depend on the *communication* technology used and the local topography. Typically, a 5 MHz 802.11p *communication* will have a range of 0,25 km to 0,5 km, while a WiFi connection will have a range of 100 m or less and a GSM/UMTS cell range is measured in kilometres. 4G/LTE *communication* will have a shorter range than GSM/3G, but the cellular networked paradigm of GSM/UMTS means that there can be effectively seamless network access over great distances. However, the latency involved in these systems has significantly poorer performance than that of 802.11p 5,9 GHz.

The advent of E-UTRAN (4G/LTE) cellular networks will provide far more capable *communications*, capable of carrying significantly greater amounts of data, and enabling much more rapid transactions, and provide a generally more suitable commercial operating environment for non-time-critical *C-ITS service* provision. It has the strength of the cellular network architecture, meaning that there is continuous session maintenance over the whole covered network, but with a higher latency than 5,9GHz *communications*.

6.6.2 VANETs, MANETs and 'latency'

Vehicle ad hoc networks, so called 'VANETs' or mobile ad hoc networks (MANETs) form the basis of most *C-ITS communications*; and though transient, indeed often because they are transient, and are frequently time critical/safety critical, they frequently need a high level of user trust and low latency.

Data 'latency' can be taken to mean the time duration between issuing a message from its sender until it is received by receiver vehicles. An important parameter to be considered in sending and receiving a data packet is transmission time delay. Examples where latency is of great significance are collision

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avoidance and dynamic ramp access control systems. Examples where latency requirements are comparatively low significance would involve ice alerts, and even post incident systems such as eCall.

However, the current *ITS* environment does not adequately support time-critical safety *C-ITS applications*. These will require VANETs with a secure and trusted low-latency data exchange that current cellular (GSM/UMTS) and broadcast technologies cannot provide, although the packet switched E-UTRAN (4G/LTE) has faster data rate and lower latency than GSM/UMTS. For the I2V applications, this function is already provided by commercial *C-ITS service* providers and tele*communication*s carriers in the case of the existing cellular-based *applications*.

C-ITS fits into the broader view of what an *ITS* architecture may look like, as shown in Figure 3. With the emergence of *C-ITS* and the subsequent wider use of wireless *communication*s, there is the potential to broaden the interaction between vehicles and the field through the use of V2V and V2I/I2V *communication*s.

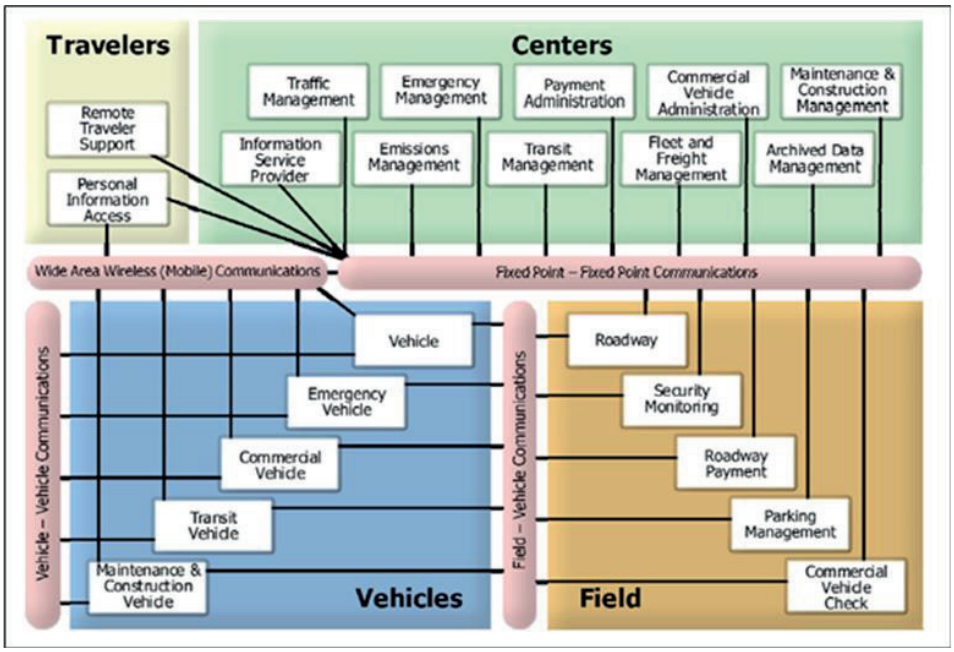

Figure 3 — ITS physical architecture
[Source: Research and Innovative Technology Administration (2012)]

The sharing of data within these situations enables more efficient, safer and efficient service performance and delivery.

There are four important aspects that are significant to understanding the roles of, and therefore the concept of operations for, a *core system*.

a) Some processes relate to the provision of a specific *application service* (external processes, objects and data).

b) Some processes are required to enable a) but are not specifically part of that service provision (internal processes, objects and data).

c) Different transactions require different levels of security.

d) Different transactions require or can tolerate different levels of latency.

Some transactions may be required to operate within what ISO 21217 describes as a 'bounded, secured, managed domain', comprised of an *ITS-s* facilities layer, *ITS-s* networking and transport layer, *ITS-s* access layer, *ITS-s* management entity and *ITS-s* security entity, which adheres to a minimum set of security principles and procedures so as to establish a level of trust between itself and other similar

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*ITS-station*s with which it communicates (see ISO 21217, ISO 21210, ISO 29281 (all parts), ETSI EN 302 636, and associated standards). Other *C-ITS communication*s, and especially broadcast *communication*s, may not have need of such high levels of security.

Some transactions require very low latency, while others are relatively insensitive to latency.

Systems that require a high level of trust, and in many cases, systems that require low latency, have to be managed during, or preferably before, the event. This can only be achieved by measures such as certification verification, and prioritization, and this requires support from 'central' 'core' services, such as user permissions management, user trust management, data distribution, misbehaviour management, network services, service monitoring, time synchronisation.

For a high level overview of how *ITS-station*s communicate within the context of *C-ITS service* provision, see ISO/TR 17465-1, and for a more detailed specification, see ISO 21217.

Ideally, an *ITS application service*, particularly in the *C-ITS* context, needs a *communication* sub system that

— is available wherever and whenever a vehicle is present in a traffic situation,

— can communicate vehicle-vehicle and vehicle-roadside in a transparent way (see ISO 21217:2014, 8.3.3),

— relieves the applications from the need to know about *communication*s setup and management,

— uses modern Internet techniques and standards for global usability (e.g. IPv6), and

— provides a range of different possibilities related to data speeds, *communication* distance, cost, and many other parameters.

However, in terms of security, all systems are not equal. Some *ITS*s can utilize security from the *communication*s network over which their wireless *communication* is made, which provides adequate security for the provision of their service, and others can control their data so it is only provided to a legitimate destination, indeed some data may not be sensitive to misuse. But most data in the *C-ITS* context has some sensitivity, and therefore will have to be effected within layers of security, and some *C-ITS communication*s will have to be effected within the high levels of security that ISO 21217 calls a 'Bounded Secure Management Domain'. (See ISO 21217 and 6.7.)

For detail of aspects of *communication*s aspects of *C-ITS service* provision, see the following:

ISO 21217 Intelligent transport systems — Communications access for land mobiles (CALM) — Architecture

ISO 21210 Intelligent transport systems — Communications access for land mobiles — IPv6 Networking

ISO 21212 Intelligent transport systems — Communications, air-interface, long and medium range (CALM) — 2G Cellular systems

ISO 21213 Intelligent transport systems — Communications access for land mobiles (CALM) — 3G Cellular systems

ISO 21214 Intelligent transport systems — Communications access for land mobiles (CALM) — Infra-red systems

ISO 21215 Intelligent Transport Systems — Communications access for land mobiles (CALM) — M5

ISO 21216 Intelligent Transport Systems — Communications access for land mobiles (CALM) — Millimetre communications

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ISO 21218	Intelligent Transport Systems — Continuous Air Interface, Long and Medium Range — Medium Service Access Points
ISO 24102	Intelligent transport systems — Communications access for land mobiles (CALM) — Management
ISO 24103	Intelligent Transport Systems — Communication access for land mobiles (CALM) — Media adapted interface layer (MAIL)
ISO 25111	Intelligent transport systems — Continuous air-interface, long and medium range (CALM) — ITS using mobile wireless broadband- General requirements
ISO 25112	Intelligent transport systems — Communications access for land mobiles (CALM) — Mobile wireless broadband using IEEE 802.16e/IEEE 802.16g
ISO 25113	Intelligent transport systems — Communications access for land mobiles (CALM) — Mobile wireless broadband using HC-SDMA
ISO 29281 (all parts)	Intelligent transport systems — Communications access for land mobiles (CALM) — Non-IP networking
ISO 29282	Intelligent transport systems — Communications access for land mobiles (CALM) — Using satellite communications
ISO 29283	Intelligent Transport Systems — Communications access for land mobiles (CALM) — Mobile wireless broadband using IEEE 802.20
ISO 17515-1	Intelligent Transport Systems — Communications access for land mobiles (CALM) — E-UTRAN (LTE)

Other *ITS*/*C-ITS communication*s standards will be developed according to need.

The standard networking protocol for most *C-ITS*s will be IPv6 (Internet protocol version 6), although provision for rapid safety critical *communication*s are provided in ISO 29281 (all parts).

6.6.3 Hybrid communications

As described above, *C-ITS* uses wireless *communication*s to share information between V2V and V2I/I2V. *C-ITS* will involve a range of *communication*s technologies, and many *C-ITS* applications will likely use a hybrid *communication*s approach. That is, an application may use several *communication* mediums, and not necessarily rely on just one type.

For reasons of both effectiveness and control and mitigation of liability issues (see ISO/TR 17427-8), applications are also likely to use a combination of *communication*s and on-board sensors, equipment and available on-board data, in order to provide robust *application service* provision (and are unlikely to rely on one *communication* media based solution for provision of any safety-critical *application service*).

Many emerging *C-ITS* applications will likely use a hybrid *communication*s approach, dynamically selecting different *communication* technologies for different types of content, or in different locations. Different *communication* technologies have different characteristics and attributes and are suited to different *communication* requirements. This section explains the hybrid *communication* approach and then explains the categories of *communication* technologies and some of their attributes, and how this affects the nature and type of 'core' systems support required to enable *C-ITS application service* provision in a connected vehicle-highway paradigm.

None of the available *communication* technologies can facilitate the full range of *communication* requirements. For example, time-critical safety warnings would usually require low-latency *communication*. Currently, the only *communication* technology that meets this latency requirement is 5,9 GHz [in some countries called 'Dedicated Short Range *Communication*' (DSRC)]. But it has very limited bandwidth. As E-UTRAN (4G/LTE) rolls out, where supported, it will provide an alternative for

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all but very low-latency service requirements (such as collision avoidance and ramp access control). Many traveller information services require a long range *communication* connection and more bandwidth, and are better offered by cellular *communication* technologies, or broadcast. DSRC is less suitable for this type of application. Some messages, for example, a road works warning message, could be better sent via different *communication* technologies, where available. This also spreads the loading on any one wireless medium, which is particularly important in respect of the limited bandwidth at 5,9 GHz most suited for time-critical safety applications.

Another aspect of the need for hybrid *communication*s and the availability of bandwidth is the desirability for the *ITS-station* to be able to retain data it has downloaded. This reduces the frequency that downloads need to be repeated, and enables some data to be downloaded in less busy periods.

Even a single application, for example, an intersection collision avoidance application, is likely to have different *communication* flows with different *communication* requirements. Warning messages that involve vehicular control (collision avoidance, ramp access control, etc.) will need very low latency. The *communication* of detailed mapping data on the layout of the intersection may have less demanding latency requirements. The same application might also have other requirements for the download of new security certificates for the following week. This type of *communication* flow does not have any low-latency requirement, but it does require bandwidth. These *communication* flows, and probably others, might all be needed for this application to function optimally. A hybrid *communication* approach allows for a more efficient and more robust *C-ITS* because vehicles can choose the best available *communication* channel dynamically.

Which *communication* technology is selected by an application is obviously also subject to the local availability of the *communication* technologies and the minimal *communication* requirements. The ISO standard for *communication*s access for land mobiles (ISO 21217), provides the mechanism for this hybrid *communication* approach. The future availability and coverage of *communication* technologies throughout the network is currently hard to predict and will depend on the local conditions, the demand for *communication*, and allocation of frequencies.

The hybrid approach is also of significant importance because the optimum medium available may vary from one location to another.

VANETs, ad hoc networks (between vehicles), are most likely to use 5,9 GHz for the foreseeable future as a prime source of V2V *communication*. The role of E-UTRAN for V2V *communication*s is as yet unknown and unproven, but will in all probability also have an important role in the future for non-time-critical networking.

Table 1 shows the categories of *communication* technologies and their attributes.

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Table 1 — Wireless communication technologies and attributes

Category	Communication technologies	Attributes
Short range *communications*	Examples include: — 5,9 GHz DSRC — Wireless LAN (e.g. WiFi) — Bluetooth — Infra-Red	— Short range — Low to very low latency — Two-way *communications* — Small data packets

Long range *communications*	Examples include:
	— Cellular networks, including
	  — UMTS (3G)
	  — LTE (4G)
	  — Satellite
		— Long range
		— Medium to low latency
		— Two-way *communications*
		— larger data packets

Wide area broadcast	Examples include: — Digital radio (e.g. DAB+) — Analogue radio	— Long range — Medium to high latency — One-way — Medium-size data packets

6.6.4 Short and medium range communication

Examples of short range *communication* technologies include 5,9 GHz (so called DSRC), Bluetooth and wireless LAN. 5,9 GHz *communication* technologies will generally communicate over distances of 250 m to less than 1 000 m, dependant on topology and atmospheric conditions. Bluetooth offers a range of up to 30 m to 100 m depending on the variant [40 m for Bluetooth 4 (Bluetooth LE)].

So called (and misnamed) Dedicated Short Range *Communications* (DSRC) is short-to-medium range wireless *communication* technology specifically designed for automotive use. It can be used for one-way and two-way *communication*. Currently, a version of DSRC is used for electronic toll collection in the 5,8 GHz band. Globally DSRC based *C-ITS* have been developed and tested extensively in pilots and early deployments, mainly in the 5,9 GHz band. It is technically quite different and more capable than the 5,8 GHz version of DSRC. It has the benefits of having low latency, high mobility and, currently, no *communication* connection charges. Limitations are the narrow bandwidth and limited coverage. Because DSRC is the only technology that can provide ad hoc short or mid-range low latency *communication*, it is required for service announcements and time-critical safety services in ad hoc networks, especially VANETs. However, 5,9 GHz DSRC *communication* is less suitable for *C-ITS services* needing wide area coverage and/or high bandwidth because the 5,9 GHz band is limited in capacity, easily saturated and expensive to deploy. Though it should be noted that, at the time of writing, there is international lobbying in the USA and Europe to open up the whole 5,9 GHz band, including those frequencies currently reserved for automotive safety applications, for general wireless broadband use. At the same time, US DoT NHTSA has announced a decision in principle to take next steps to require light vehicles to be equipped to be able to communicate using 5,9 GHz technology.

Bluetooth technology is a global wireless standard for the exchange of data over short distances using radio transmissions in the unlicensed 2,4 GHz to 2,485 GHz band. Bluetooth is available in many of the current mobile devices such as smartphones or car-kits. The *communication* range varies by Bluetooth specification, but typically effective ranges varies from a few metres to about 30 m (Bluetooth marketing 2011). Bluetooth is sometimes used for traffic monitoring.

A wireless local area network (LAN) links two or more devices using some wireless distribution method, and generally provides a connection to the Internet. This allows users to move around within a local coverage area and still be connected to the network and Internet. Many modern WLANs are based on IEEE 802.11a) to n) standards, marketed under the Wi-Fi brand name. (The basis of 5,9 GHz DSRC is actually another variant, 801.11p).

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The range of a WLAN [802.11 a) to n)] network depends on the number of routers but is generally linked to a building and its direct surroundings. Wireless (802.11 a)-n) LANs are not suitable for 'fast' moving *C-ITS* devices, but it could be used for exchange of data in stationary situations; for example, the download of security certificates or for application data services at service stations.

6.6.5 Long range communication

For the purpose of this Technical Report, long range *communication*s are considered to include those media that enable 2-way, unique *communication* connections over many kilometres. Current long range *communication* technologies include cellular network and satellite *communication*. Cellular *communication*s networks offer apparent 'seamless' *communication* sessions across the cells of the network.

Cellular *communication* technologies such as UMTS/3G, LTE/4G and WiMAX/4G have the advantage of providing high bandwidth, wide coverage and high mobility. Disadvantages of UMTS/3G are the relatively high latency, and the required *communication* costs. LTE/4G has a much lower latency, and is comparable to that of DSRC.[13] It is as yet unclear to what extent time critical safety applications can use LTE. From a deployment point of view, it is an advantage that cellular *communication* infrastructure already has significant coverage, and offers cell-cell transfer of ongoing *communication* sessions.

Satellite *communication*s provide *communication* via an orbiting tele*communication*s satellite. Satellite *communication*s could be used in remote areas, for example, using digital radio technology. Satellite *communication*s can be used to broadcast data to *equipped vehicles* (3.14), and some systems can be used for bidirectional *communication*s, although the data latency is comparatively high. As with cellular *communication*, using satellite *communication* requires a subscription with a provider. An example of the current use of satellite *communication*s is an Australian implementation of its 'Intelligent Access Programme' application using satellite *communication* to cover areas where no cellular coverage is available.

NOTE Not all satellite *communication*s telephony options offer 24/7 coverage, and depend on the number and orbit of available satellites. Geostationary orbit based systems offer 24/7 coverage.

6.6.6 Wide area broadcast

For the purpose of this Technical Report, wide-area broadcast is considered to include one-way *communication* that involves messages to be broadcast over areas of many kilometres.

RDS-TMC is widely used to broadcast traffic information messages on conventional FM radio broadcasts. Traffic Message Channel (TMC) is a technology for delivering traffic and travel information to motor vehicle drivers. It is digitally coded, using the Radio Data System (RDS).

6.6.7 Positioning services

Global Navigation Satellite Systems (*GNSS*) refers to constellations of satellites that broadcast positioning, navigation and timing data that receivers on earth can receive and use for various applications. *GNSS* is offered by satellite navigation systems of USA (GPS), Russia (GLONASS), China (COMPASS), and Europe is in the process of rolling out its high precision GALILEO system (expected fully operational circa 2020).

A standalone *GNSS* receiver typically achieves a spatial accuracy of 10 m to 20 m. Increasingly, there is a trend towards using a multi-*GNSS* approach where other *GNSS* constellations (e.g. the Russian GLONASS) are used to supplement GPS. This approach can improve spatial accuracy and integrity, and has been demonstrated to achieve a spatial accuracy in the range 5 m to 10 m.

However, many safety-critical *C-ITS* applications emerging internationally require a spatial accuracy of less than 1 m, and also require high integrity, availability and timeliness. Standalone *GNSS* and multi-*GNSS* receivers cannot repeatedly achieve this, although multi-*GNSS* including GALILEO will come close to these accuracies.

International *C-ITS* developments are now often using wide-area augmented *GNSS*, where the positioning signals from a satellite constellation are augmented with correction signals, which are transmitted from satellites and/or ground stations. This is further supplemented by relative positioning

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measurements from on-board vehicle sensors to achieve the stringent positioning requirements. As stated above, safety-critical systems are most likely to use multiple technologies in order to improve system robustness and reliability.

6.6.8 Digital road map data

There are a number of emerging *C-ITS applications* that will require highly accurate digital road map data, which will work together with *GNSS* positioning services and a vehicle's on board sensors to determine the position of a vehicle's position relative to attributes in the road environment. Examples of such emerging applications include intersection assistance, and some collision avoidance applications. (However, as such systems largely require a high percentage of *equipped vehicle*s, there is time-in-hand to address these issues)

The accuracy requirement for *C-ITS* safety applications can be classified into three levels:

— road: on which road the vehicle is placed (metre level)

— lane: which lane of a road the vehicle is in (sub-metre level)

— where-in-lane: where within the lane is the vehicle positioned. (decimetre level)

Emerging safety critical *C-ITS application*s will require high-accuracy digital map data down to lane level (sub-metre) or where-in-lane level (decimetre). The enhanced maps required to achieve this level of accuracy are often referred to as the fourth generation of digital mapping, or eMaps. These eMaps are still emerging internationally, and much development is still required both in terms of standards and with the data supply chain to support them.

Commercial map data companies currently capture and supply digital road map data for use in automotive applications, primarily for navigation and other location services. These companies are progressively improving their coverage, spatial accuracy and timeliness of the road data they supply.

Further to this, government land and transport agencies are the authoritative source for a number of road safety attributes (e.g. speed zone data). This data are not always made accessible to the commercial map data companies that provide data to the end-user applications, and does not always meet the requirements for *C-ITS*. Thus, there are a number of changes that will need to be made locally if the map data requirements of emerging *C-ITS* are to be met.

It is always essential to remember that *C-ITS* is not an end objective in itself, but is a means of achieving *application service* delivery.

In order to understand the role, and therefore the concept of operations of a *C-ITS core system*, it is also necessary to consider the architecture of its *actors* and its *communication*s.

6.7 Actors involved in C-ITS service provision

ISO 17427-1 contains a more detailed characterization of the 'roles and responsibilities' of the *'actors'* engaged in *C-ITS service* provision and receipt/use.

We can visualize the *C-ITS* paradigm as it is shown in Figure 4, which is an update and enhancement of a figure used in the CVIS project, and the authors acknowledge that work in the development of this Technical Report, and advise that the same figure is now also used in ISO 21217, (2013).

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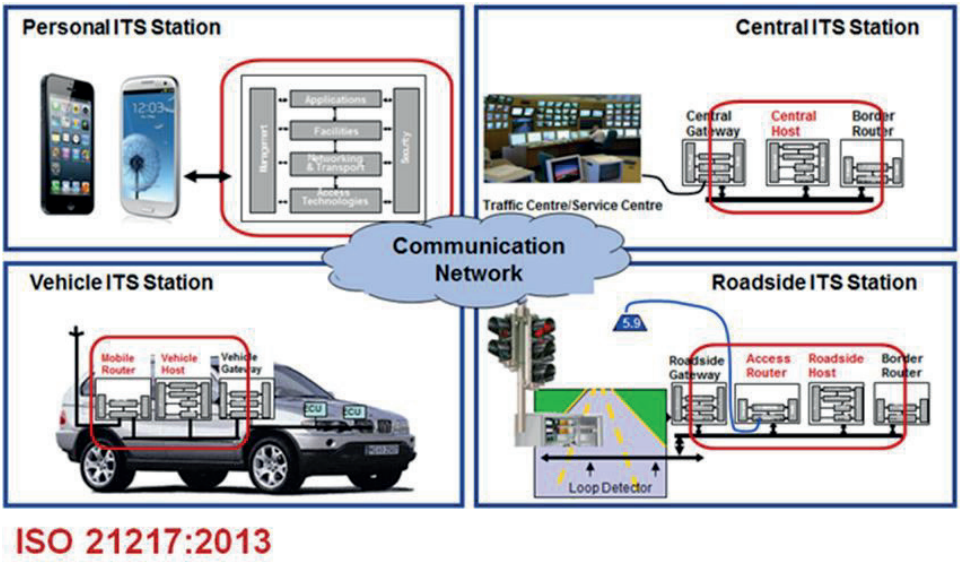

Figure 4 — High level C-ITS connectivity paradigm

In order to achieve *C-ITS service* provision, a combination of applications and systems are necessary to deliver the services that will realize safety, mobility and/or environmental benefits through the exchange of data between mobile and fixed transport system users. The principal system components are therefore:

— **Applications** – that provide functionality to realize safety, mobility and environmental benefits;

— **Equipped vehicles**– (mobile *ITS-stations*) vehicles equipped with the *communications* and data collection and processing capacity to perform in the *C-ITS* context;

— **Equipped persons** – (personal *ITS-stations*, personal mobile *ITS-stations*) persons with mobile phones, tablets or similar devices having *communications* and data collection and processing capacity to perform in the *C-ITS* context;

— **Mobility assistance** – (mobility assistance *ITS-stations*) equipment/systems to assist vulnerable road users (for example, sight impairment, hearing impairment, physical mobility impairment) who may be assisted by specially designed 'apps' that enable the user to better cope with their disability, and/or provide a safer travelling environment for the user especially by raising awareness of other road users. More advanced 'apps' may provide prioritization at road crossings and other assistances, or provide collision avoidance capabilities, etc. either as devices tailored to meet the special requirement, such as glasses, wheelchairs, etc., which may be equipped with *ITS-station* capabilities, or as specialized 'apps' on a smartphone;

— **Intermodal connection/display** – likely to largely be Internet based or *wireline* connections to an *application service* provider, then *ITS-station* or wireless Internet provision between the *application service* provider and personal *end user* of the *application service*. In other circumstances, they may simply be broadcast data interpreted by an 'app' on-board the device containing an *ITS-station*, usually, but not necessarily, a personal *communication* device such as a smartphone, or mobility assistance device;

— **Communications**– that facilitate data exchange between *ITS-stations*, including roadside *ITS-stations* where appropriate;

— **Core systems**– which provide the functionality needed to enable data exchange between and among mobile and fixed transport system users;

— **Static roadside equipment** – to provide *ITS-station communications* between mobile/personal/mobility users and/or the infrastructure/*CorSys* and connect with other 'Field' equipment;

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— **Support systems** – including security credentials certificate and registration authorities, that allow devices and systems to establish trust relationships.

See ISO 17427-1 contains an in depth analysis of the roles and responsibilities in *C-ITS*. Figure 5, from ISO 17427-1, provides an overview, in which it can be seen that *communications* take place in different security environments. ISO 17427-1 contains further details.

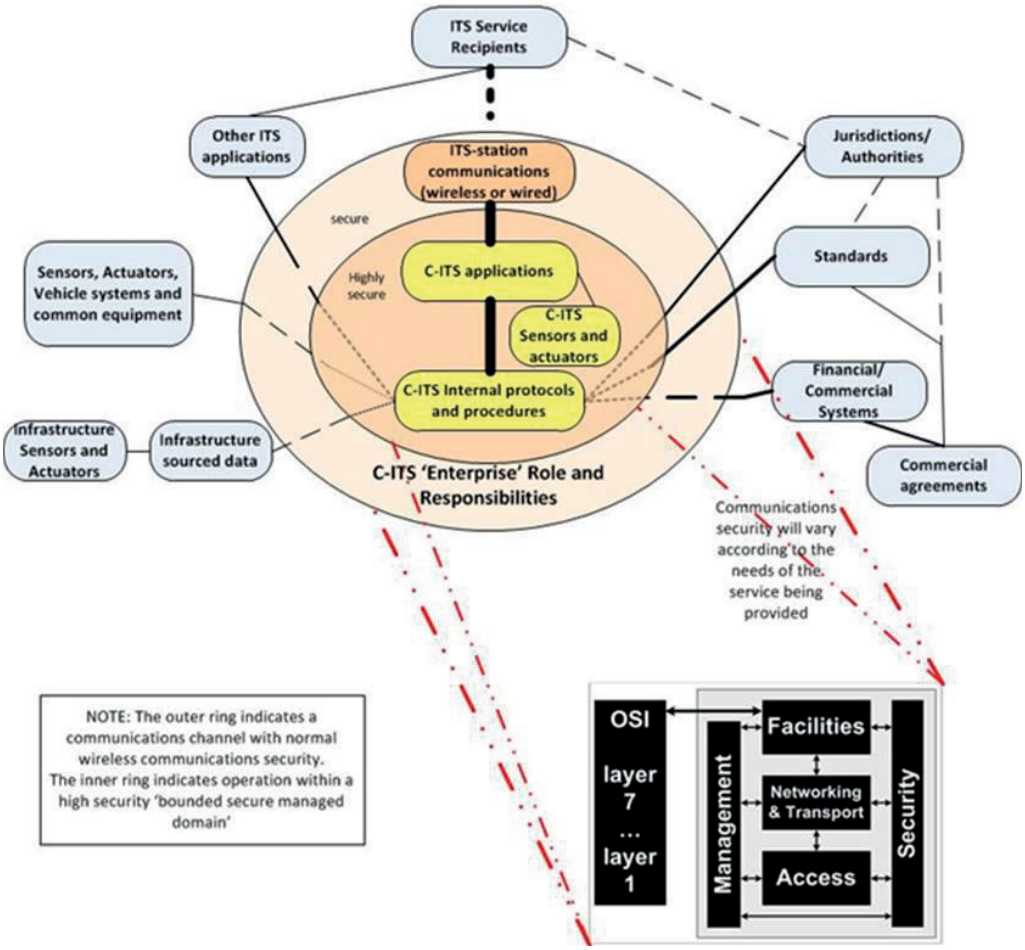

Figure 5 — 'External' and 'Internal' enterprise objects in a C-ITS Community

NOTE Standards are included in Figure 5 because they enable meaningful *communications* and comprehension of messages and data.

The provision of the essential 'enabling' services are known as *CorSys*, and are the subject of this Concept of operations.

CorSys are an essential component in the case of the provision of some *C-ITS services* (for example, intelligent ramp access to highways, level (grade) crossing management, etc.), where it is essential that data can be provided securely and speedily. *CorSys* can provide also more capable and comprehensive provision of some other *C-ITS* assisted services (for example 'ice', 'obstacle' and other road condition alerts).

Figure 5 therefore shows the context for which a "Concept of operations" for such *CorSys* is required.

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In terms of *communications* sessions across wireless *communications*, it is important to understand that most *actors* in *C-ITS* implementation communicate wirelessly (over whatever wireless medium is available) in the same way, in a peer-to-peer *communication* dialogue (see ISO 21217).

NOTE In some instances, existing *wireline* links are used, e.g. roadside to *centre/centre* to *centre,* etc.

6.8 C-ITS enabling data

In respect of enabling *C-ITS*, vehicle ad hoc networks (VANETs) require the support of a *core system* to provide the aspects that are not directly related to the application data but are essential to enable the service provision to take place safely, reliably and successfully. These services may generally be categorised as: user permissions management, user trust management, data distribution, misbehaviour management, network services, service monitoring, time synchronisation.

These may be described as '*core system* support services and are based on the exchange of relevant data.

These data messages that will be transmitted and received by *C-ITS* devices are planned to be aligned with international *C-ITS* message set standards. However, at the time of writing this 'Concept of operations', there is still debate regarding the exact content and frequency of such messages. To consider the basic requirements for the provision of 'core' services, it is not necessary to wait until the exact content and frequency of such data are finally agreed internationally. At this level of abstraction, it is adequate to understand that provision has to be made to handle data of these types. But in order to comprehend the general required tasks, it is perhaps useful to summarize the main contenders at the time of developing this deliverable. The following primary message types are examples of likely 'core' messages, and are likely to include all or some of the following, or some internationally agreed variant thereof:

— BSM: basic safety message

One of three messages outlined in SAE J2735, the others being the roadside alert (RSA) message (BSM) and probe vehicle message (PVM). The BSM message is used to communicate safety messages from vehicles to vehicles and infrastructure (e.g. V2V and V2I), and from infrastructure to vehicles (I2V). BSM is the US equivalent of the CAM and DENM message. The EU-US harmonization task force currently works on harmonizing the BSM with the CAM and DENM message sets.

— CAM: cooperative awareness message

The CAM message is a periodically transmitted message containing transient data on the vehicle status. The CAM message is designed primarily for *communication* from vehicles to vehicles and infrastructure (e.g. V2V and V2I), but may also be sent from infrastructure to vehicles (I2V). The CAM message is defined by the ETSI/TS 102 637-2.

— DENM: decentralised environmental notification message

A DENM messages is an event triggered message which is generated upon detecting an event and containing information about the event. DENM messages are typically relevant for a defined geographic area. The DENM is sent from vehicles to vehicles (V2V), vehicles to infrastructure (V2I), and from infrastructure to vehicles (I2V). DENM is defined by the ETSI/TS 102 637-3.

— RSA: roadside alert message

One of three messages outlined in SAE J2735, the others being a basic safety message (BSM) and a probe vehicle message (PVM). The RSA message is used to communicate traveller information applications from roadside infrastructure.

— PVM: probe vehicle message

One of three messages outlined in SAE J2735. The PVM message is used to communicate probe information obtained from the vehicle to roadside infrastructure.

— PVD: probe vehicle data

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PVD is used to communicate the status of a vehicle to the roadside *ITS-station* to allow the collection of information about vehicle movements along a segment of road. The PVD message will be defined by CEN and ISO standards.

— PDM: probe data management

PDM is used to control the type of data collected and sent by the vehicle to the roadside *ITS-station*. PDM is sent from the roadside *ITS-station* to the vehicle. PDM message will be defined by CEN and ISO standards.

— Map: geometric intersection description

A message containing geometric details of the road such that the vehicle can cross-reference information contained in other messages sent from the roadside *ITS-station* against the map message to determine how to apply the message (e.g. determine if the message applies to the lane the vehicle is currently in).

— SPaT: signal phasing and timing

A SPaT message contains information about the signal phasing and timing including current phase and time remaining so that it can be used by a vehicle to provide warnings about potential red light violations or advice on optimal speed. The SPaT message is sent from a roadside *ITS-station* integrated with a traffic signal.

— SRM: signal request message

SRM is sent by a vehicle to a roadside *ITS-station* at a signalised intersection [or *central system* (3.7)]. It is used for either a priority signal request or a pre-emption signal request depending on the way the message flag is set. In either case, the vehicle identifies itself, its current speed, heading and location, and makes a specific request for service, as well as an anticipated time of service.

— SSM: signal status message

SSM is sent by a roadside *ITS-station* at a signalised intersection (or *central system*). It is used to relate the current signal status of the signal and any collection of pending or active pre-emption or priority events acknowledged by the controller. The data contained in this message allows other users to determine their 'ranking' for any request they have made.

— IVI: in-vehicle information

The in-vehicle information (IVI) data structures specifies the data required to be transmitted between *ITS-station*s (I2V) in order to deliver in-vehicle signage associated with various *ITS service*s (e.g. contextual speed, roadwork warning, vehicle restrictions, lane restrictions, road hazard warning and re-routing). The information will be specified in terms such as content/data elements and data structures. A technical standard is being developed that will specify a general data structure that is future proof, extensible and *communication*s agnostic.

— TPEG: Transport Protocol Expert Group

TPEG produced a set of specifications addressing the transmission of language independent multi-modal traffic and travel information. They are standardised through CEN and ISO and consisting of the following applications:

— RTM - Road Traffic Message

— PTI - Public Transport Information

— Loc - Location referencing, used in conjunction with applications

Other applications are under development including parking information, congestion and travel time and weather information for travellers.

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6.9 Cooperative ITS applications and services

The emerging cooperative intelligent transport paradigm will provide a platform on which service providers can use their initiative to develop and deploy a wide range of applications services. While it may be difficult to predict the full range of applications that we may see in future, it is possible to categorize the types of applications that are currently under development.

A typical categorization is by policy impact area, distinguishing safety, traffic efficiency and environmental impacts. However, there are several ways to categorise *C-ITS applications* and services, for example, by the following:

— policy impact area : traffic safety, traffic efficiency or environmental impacts

— *communication* latency requirements : time critically or non-time critical, or the possible value range in ISO/TS 17423 on *ITS application* requirement for selection of *communication* profiles (smaller than 1 ms, 10 ms, 1 s, 10 s, 1 min, 10 min or 1 h)

— positioning : accuracy requirements

— safety-of-life and property risk : safety critical and non-safety critical

— level of guidance : informing, warning or automated

— driving task : strategic driving tasks (navigation, trip planning), tactical driving tasks (lane choice, speed choice) or operational driving tasks (steering, braking).

— type of user : fleet management, traffic management or consumer market applications

A common categorization used by ERTICO and other stakeholders is based on the applications' influence on the driving task. These categories include the following:

— Information – e.g. travel time services

— Awareness – e.g. road works warning

— Assistance – e.g. intelligent speed adaptation

— Warning – e.g. collision warning

— Avoidance – e.g. electronic break assist

— Automated – e.g. cooperative adaptive cruise control

Figure 6 shows a modified version of a diagram from ERTICO, which plots these application categories on a graph based on their latency and spatial accuracy requirements. While this is a useful representation, it is noted that there may be some types of application that do not fit neatly in this categorization.

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