Multi-Channel Operation (MCO); Part 1; Functional requirements

CAR 2 CAR Communication Consortium

About the C2C-CC

Enhancing road safety and traffic efficiency by means of Cooperative Intelligent Transport Systems and Services (C-ITS) is the dedicated goal of the CAR 2 CAR Communication Consortium. The industrial driven, non-commercial association was founded in 2002 by vehicle manufacturers affiliated with the idea of cooperative road traffic based on Vehicle-to-Vehicle Communications (V2V) and supported by Vehicle-to-Infrastructure Communications (V2I). Today, the Consortium comprises 61 members, with 11 vehicle manufacturers, 31 equipment suppliers and 29 research organisations.

Over the years, the CAR 2 CAR Communication Consortium has evolved to be one of the key players in preparing the initial deployment of C-ITS in Europe and the subsequent innovation phases. CAR 2 CAR members focus on wireless V2V communication applications based on ITS-G5 and concentrate all efforts on creating standards to ensure the interoperability of cooperative systems, spanning all vehicle classes across borders and brands. As a key contributor, the CAR 2 CAR Communication Consortium works in close cooperation with the European and international standardisation organisations such as ETSI and CEN.

Disclaimer

Document information

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Explanatory notes:	This paper focuses on the 5.9 GHz Safety related Band usage, based on the existing usage via ITS-G5 of the Control channel with focus on European deployment of C-ITS Day-1 applications and extended use for additional safety and Road Transport Automation applications in other channels. It expects that other communications may be used as part of a Hybrid communication for additional information exchange and to realize redundancy due to functional safety and other non-functional related requirements. This paper is part 1 of 3 with: 1. Functional requirements 2. Technology capabilities and limitations 3. MCO concept For MCO, the Release 1 [ER-63] and 2 applications, services and use cases are considered and it is assumed that prioritization is based on existing Release 1 ITS-G5 initial deployed applications.

Content

About the C2C-CC ... 1
Disclaimer ... 1
Document information ... 2
Changes since last version ... 2
Content ... 3
List of figures ... 5
List of tables ... 6
Definitions ... 7
Abbreviations ... 9
1 Introduction ... 11
1.1 Abstract ... 11
1.2 Survey of document ... 11
1.3 Background European developments ... 13
2 General considerations and requirements ... 22
2.1 Introductions ... 22
2.2 Business Requirements ... 22
2.3 C-ITS and CCAM Related Regulation Considerations ... 22
2.3.1 Technology Neutrality ... 22
2.3.2 C-ITS Interoperability ... 24
2.3.3 ITS Backward compatibility ... 25
2.4 EU General Data Protection Regulation (GDPR, [ER-50]) ... 25
2.5 Security services as related to the EU ITS certification and security policies [ER-51] 26
3 Applications and Service Communication requirements ... 27
3.1 Introduction ... 27
3.2 Basic Applications (Release-1) ... 27
3.2.1 Introduction ... 27
3.2.2 BSA Communication requirements ... 27
3.3 Extension of the use of Day-1 services (Beyond Release-1) ... 28
3.3.1 Introduction ... 28
3.3.2 CAM Extension ... 29
3.4 Basic CACC and Platooning Applications (Beyond Release-1) ... 29
3.4.1 Introduction ... 29
3.4.2 Communication requirements ... 29
3.4.3 CACC and Platooning System related Requirements ... 34
3.5 Vulnerable Road User Application (Beyond Release-1) ... 34
3.5.1 Introduction ... 34
3.5.2 VRU Communication requirements ... 35
3.5.3 VRU System related Requirements ... 37
3.6 Collective Perception Service (Beyond Release-1) ... 38
3.6.1 Introduction CPS ... 38
3.6.2 CP Communication requirements ... 38
3.6.3 CP System related Requirements ... 42
3.7 Cooperative Connected Automated Driving (CCAD) Applications (Beyond Release-1) 42
3.7.1 Introduction ... 42
3.7.2 CCAD Communication requirements ... 42
3.7.3 CCAD message exchange System Requirements ... 45
3.8 Other C-ITS Applications (Beyond Release-1) ... 46
3.8.1 Introduction ... 46
3.8.2 Other Communication requirements ... 46
3.8.3 Other System related requirements ... 51
4 General MCO System related requirements ... 53
4.1 Introduction ... 53

4.2 Service Announcement (SA) System Service (Beyond Release-1) 53
4.2.1 Introduction....53
4.2.2 SAS System requirements 54
4.3 Position Augmentation (PA) System Services (Beyond Release-1) 54
4.3.1 Introduction....54
4.3.2 PA Communication requirements....55
4.3.3 PA System Requirements 56
4.4 Security Certificate Exchange System Service....57
4.4.1 Introduction....57
4.4.2 Security Communication requirements 58
4.4.3 Security System requirements 59
4.5 Safety Relevant System requirements (Beyond Release-1) 59
4.5.1 Functional Safety (ISO 26262 [ER-53])....59
4.5.2 Safety of the Intended Functionality (SOTIF, ISO PAS 21448 [ER-54])....61
4.5.3 Functional Safety Communication related requirements....62
4.5.4 System related Communication Requirements....63
5 Some Conclusions....64
5.1 Introduction 64
5.2 Spectrum Legal aspects 64
5.3 Spectrum Functional aspects 64
6 Annex A – Message Priorities 66
7 Annex B – References....67
8 Annex C – ENSEMBLE Functional Safety and safety of the Intended Functionality analyses method....71

List of figures

Figure 1: TR 102 492-1 List of applications 14
Figure 2: TR 102 492-2 proposed spectrum allocation 14
Figure 3: Phases of the vehicular safety system (Ref: C2C-CC) 16
Figure 4: Merge of C-ITS and Vehicular Automation as agreed in the EU “Declaration of Amsterdam” 16
Figure 5: Car2Car CC Functional Roadmap 2019Q3 17
Figure 6: CACC is an in-vehicle driving assistance 29
Figure 7: Layer Architecture for multi brand platooning (ENSEMBLE) 31
Figure 8: PCM information exchange example (ENSEMBLE) 33
Figure 9: CPM message containers (ETSI TR 103 562). 40
Figure 10: LCA-B Situation description (ETSI TR 103 578). 44
Figure 11: MCM message containers (assumed) 45
Figure 12: Simplified diagram of the V2X based emissions crowdsourcing approach 47
Figure 13: RSU Placement and Message transmission patterns example 52
Figure 14: Certificate Trust Model Architecture 58
Figure 15: ISO 26262 set of specifications 61
Figure 17 Evaluation process determining the SOFIT and Functional Safety requirements (ENSEMBLE) 71

List of tables

Table 1: Safety related applications list 19
Table 2: Derived communication requirements for Platooning (Footnote*). 34
Table 3: Derived communication requirements for self-transmitting VRU’s (Footnote*). 37
Table 4: Derived communication requirements for CPM (Footnote*). 41
Table 5: Derived communication requirements for MCM (Footnote*). 45
Table 6: Communication requirements additional Infrastructure information exchange (Footnote*). 48
Table 7: Derived communication requirements for Agriculture Equipment (Footnote*) 50
Table 8: Derived communication requirements for SAS (Footnote*). 54
Table 9: Derived communication requirements for PAS services. 56
Table 10: Derived communication requirements for certificate exchange. 59
Table 11: Approximate cross-domain mapping of ASIL. 60
Table 12: Overview showing overall spectrum requirement. 65

Definitions

Unicast	Unicast is the term used to describe communication where a piece of information is sent from one point to another point. Unicast transmission, in which a packet is sent from a single source to a specified destination, is still the predominant form of transmission on LANs and within the Internet. All LANs (e.g. Ethernet) and IP networks support the unicast transfer mode, and most users are familiar with the standard unicast applications (e.g. http, smtp, ftp and telnet) which employ the TCP transport protocol.
Broadcast	Broadcast is the term used to describe communication where a piece of information is sent from one point to all other points. In this case there is just one sender, but the information is sent to all connected receivers. Broadcast transmission is supported on most LANs (e.g. Ethernet), and may be used to send the same message to all computers on the LAN (e.g. the address resolution protocol (ARP) uses this to send an address resolution query to all computers on a LAN). Network layer protocols (such as IPv4) also support a form of broadcast that allows the same packet to be sent to every system in a logical network (in IPv4 this consists of the IP network ID and an all 1's host number).
Multicast	Multicast is the term used to describe communication where a piece of information is sent from one or more points to a set of other points. In this case there is may be one or more senders, and the information is distributed to a set of receivers (there may be no receivers, or any other number of receivers). Multicasting is the networking technique of delivering the same packet simultaneously to a group of clients. IP multicast provides dynamic many-to-many connectivity between a set of senders (at least 1) and a group of receivers. The format of IP multicast packets is identical to that of unicast packets and is distinguished only by the use of a special class of destination address (class D IPv4 address) which denotes a specific multicast group. Since TCP supports only the unicast mode, multicast applications must use the UDP transport protocol. The majority of installed LANs (e.g. Ethernet) are able to support the multicast transmission mode. Shared LANs (using hubs/repeaters) inherently support multicast, since all packets reach all network interface cards connected to the LAN. The earliest LAN network interface cards had no specific support for multicast and introduced a big performance penalty by forcing the adaptor to receive all packets (promiscuous mode) and perform software filtering to remove all unwanted packets. Most modern network interface cards implement a set of multicast filters, relieving the host of the burden of performing excessive software filtering.
Integral Safety	In developed countries such as the USA or Europe, the risks of injury or fatality in traffic accidents have declined significantly in recent years. These reductions apply to both vehicle passengers and other involved persons. Much of this improvement has been attributable to progress in the field of passive safety, i.e., better protection of car occupants in

	situations where an accident is unavoidable. However, the marginal benefits resulting from additional efforts and expenditures in passive safety have begun to decrease; in other words, a classical "point of diminishing returns" has been reached. Increasing emphasis for achieving further significant improvements in vehicle safety will be placed on integral safety systems: Integral safety involves a concerted strategy of interlinking sensors and actuators of active and passive safety. The primary goal of this interlinking is optimization of performance and robustness of safety systems for occupants, but integral safety approaches can also achieve better protection of vulnerable road users than passive safety measures alone. In view of considerations such as reduction of CO2 and fuel consumption, there is another attractive benefit: integral safety can serve to reduce the steady weight increase of vehicles and thus provide an important contribution to the development of both sustainable and safe vehicles. In order to develop effective measures for mitigating the severity of traffic accidents or even completely avoiding them, it is essential to understand the mechanisms of accident events, including the processes and risks involved in traffic situations in which these accidents occur. A quantitative understanding of these processes and risks aids in assessing the potential effectiveness of vehicle safety measures. The automobile industry is faced with enormous challenges in discovering and implementing the most effective solutions. Assessment by legal authorities and/or consumer groups should concentrate on safety performance, not on specification of particular technologies or methodologies, and should encourage implementation of devices providing greatest safety benefits by mandating robust and standardized testing and assessment techniques that quantify and measure effectiveness independently of technological details.
Existing	Something Exists when it is actively in use now.
Similar	Something is Similar when it behaves, acts and/or looks almost the same
C-ITS Methodology	Sharing transport (traffic situation) related information among Road stakeholders, openly and for free, such that each stakeholder can improve its awareness about actual traffic situations with the sole aim of improving traffic safety and traffic efficiency.

Abbreviations

5GAA	**5G Automotive Association**
AC-BE	Access Category Best Effort
AC-BK	Access Category Background
AC-VI	Access Category Video
AC-VO	Access Category Voice
AEF	Agricultural Industry Electronics Foundation
AEM	**Agricultural equipment message**
ARP	address resolution protocol
ASIL	Automation Safety Integrity Level
BSA	Basic Set of Application
BSP	Basic System Profile
E2V	Everything to Vehicle
EATA	European Association of Telematic Applications
CA	Cooperative Awareness
CAM	Cooperative Awareness Message
CAS	Cooperative Awareness Service
CBTC	Communication Bases Train Control
CCAM	Connected Cooperative Automation Mobility
CCAD	Connected Cooperative Automated Driving
CCH	Control Channel
CIA	CAM Information Aggregation
C-ITS	Cooperative Intelligent Transportation Systems
C-ITS-S	Cooperative Intelligent Transportation Systems
CP	Collective Perception
CPM	Collective Perception Message
CPS	Collective Perception Service
DENM	Decentralized Environmental Notification Message
DSCO	Detected Safety-Critical Objects
EATA	European Association of Telematic Applications
ERS	Empty Road Segments
ETSI	European Telecommunications Standards Institute
GCM	GNSS Correction Message
GDPR	General Data Protection Regulation
GLOSA	Green Light Optimized Speed Advisory
GNSS	Global Navigation Satellite System
GPC	GNSS Positioning Correction
I2V	Infrastructure to Vehicle
IEEE	Institute of Electrical and Electronic Engineering
ISA	Integral Safety Awareness
ISO	International Organization for Standardisation
ITS	Intelligent Transportation Systems
ITS-S	Intelligent Transportation Systems Station
IVI	In Vehicle Information (The standard is an Dictionary)
IVIM	In Vehicle Information Messages
IVS	In Vehicle Signalling
MAP	Map (Messages)
MCO	Multi-Channel Operation
MCM	Maneuver Coordination Message
NC	Non-Connected
NTIA	National Telecommunication & Information Administration

PA	Position Augmentation
PAS	Position Augmentation Service
PAM	Position Augmentation Message
PCM	Platooning Control Message
PMM	Platooning management message
PoTi	Position and Time
P-ITS-S	Personal ITS-S
PTW	Power Two Wheelers
RSU	Road Site Unit
RAT	Radio access technology
RTCM	Radio Technical Commission for Maritime services
RTK	Real-Time Kinematic
RRM	Roadside Ranging augmentation Message
RRS	Roadside Ranging augmentation Service
R-ITS-S	Roadside ITS-S
SAM	Service Announcement
SAE	SAE International, formerly the Society of Automotive Engineers
SCH	Service Channel
SDO	Standard Development Organisation
SPAT	Signal Phase And Timing
STF	Special Task Force (Especially process used at ETSI)
V2E	Vehicle to Everything
V2I	Vehicle to Infrastructure
V2V	Vehicle to Vehicle
V-ITS-S	Vehicle ITS-S
VRU	Vulnerable Road User
WiFi	Wireless Fidelity
WLAN	Wireless Local Area Network

1 Introduction

1.1 Abstract

While pre-deployment of Cooperative Intelligent Transportation Systems (C-ITS) Safety related applications was established by front runners in 2018, followed by large scale deployment realized by different stakeholders groups as the C2C-CC and C-ROADS over the last year, at the end of 2019 real implementation has been confirmed by a press announcement by VW of the introduction of the new Golf 8 supported by safety related services based on ITS-G5 and road operators such as ASFINAG have started procurement for the implementation of safety related applications confirmed by the C-ITS Deployment Group [ER-6] statement. Day-1 applications as early identified in the ETSI Basic Set Applications (BSA) TR 102 638 [ER-68] have now been deployed and available for use. By this the steps from research to productization for the Release 1 applications has been completed.

While implementers were busy with pre-deployment and deployment, over the last 2-3 years researchers slowly started a new cycle of safety related and automated service developments in Car and Infrastructure industries, developments to result into the realization of a Release 2 set of specifications further increasing road safety and road automation.
As we know that the Release 1 applications at least require a single 5.9 GHz safety channel for the exchange of information to satisfy the Release 1 applications, the results of the Release 2 specification clearly show the requirement of additional channels, thus the development of a Multi-Channel Operational Concept is needed.

This paper is one out of 3 parts. This paper identifies the Functional and System requirements for the realisation of Release 2 applications. It also identifies trends towards later Releases to ensure that the concept defined is flexible enough to accommodate extensions of the MCO concept facilitating further developments towards Release 3 and beyond while ensuring Interoperability (2.3.2), Backward compatibility (2.3.3) and Technology Neutrality (2.3.1) according to European regulation.

This report provides an overview of the applications and relevant non-functional requirements to be recognized to be able to come to the MCO concept as defined in Part-3 also based on the MCO system capabilities and limitations as defined in Part-2. This paper only covers C-ITS and Automated Transport safety applications from a European perspective.

This report also provides some conclusions related spectrum management and spectrum requirements

1.2 Survey of document

After the development of a set of harmonized C-ITS interoperable (2.3.2) and backward compatible (2.3.3) Release 1 [ER-63] C-ITS standards, C2C-CC and C-ROADS profiles and C2C-CC papers based on EU regulations such as the EU Directive 2010/40/EU [ER-7], safety related C-ITS services, applications and use case have been realized and deployment by exchanging information over a single channel in the traffic safety 5.9 GHz spectrum band [ER-1].

This Release 1 and related C2C-CC and C-ROADS harmonized profiles are now being deployed by C2C-CC and C-ROADs members throughout Europe.

Current research and development work concentrate around the development of Release 2 services, applications and use cases. Release 2 service initiatives are taken by many stakeholder groups. The C2C-CC is working on a number of new services linked to Cooperative Connected Automated Mobility (CCAM) Platform [ER-32] initiative from the European Commission.

Following the C-ITS Methodology of maximizing the awareness started with sharing the position, speed and other elements of the dynamic state of ITS-Stations equipped road users. Having received this kind of initial awareness information some predictions can be made about the behaviour of others present and active on the road with the result of being able to make better decisions and be safer on the road. It would however be an improvement to know more about those non-equipped road users and get more predictive information to be able to anticipate for upcoming situations.

The CCAM [ER-32] platform initiative intends to address all automation mobility related aspects in general. As part of this CCAD considers only the vehicle automated driving aspect. Within C2C-CC, CCAD activities focus on that part of CCAD which is related to the information exchange to satisfy specific CCAD needs. This covers the exchange of information from the application perspective downward limited to the followed C-ITS methodology identified Safety related information exchange considered in the overall CCAD context.

This paper presents the high-level Traffic Safety C-ITS and CCAM [ER-32] communication and spectrum related functional requirements and dependencies to be taken in account when identifying Multi-Channel Operational (MCO) possibilities in a backward compatible approach enabling the exchange of information for the operation of Release 2 services, applications and use cases while ensuring the operation of Release 1 services, applications and use cases.

This paper is Part-1 from a set of 3, it considers an MCO concept in the context of an hybrid communication environment as defined by the EU commission and is based on Release 1 [ER-63] implemented systems. This paper Identifies the information exchange between Intelligent Transportation System Stations (ITS-Ss), system requirements and related functional and none functional requirements which needs to satisfy the operation of Release 1 and Release 2 C-ITS and CCAM services, application and use cases derived from the following organisations, roadmaps and standards.

- C2C-CC roadmap;
- Day-1 services as defined by the Amsterdam Group [ER-41];
- Day-1, Day 1,5 and beyond as defined by the EU ITS-Platform phase 1 and 2 [ER-40];
- The roadmap and extended use case list as realized in the EU project CODECS [ER-39];
- The use cases as considered in the C-ROADs Platform [ER-34];
- The use case list as considered by Eco-AT (Austria) [ER-37];
- The use case list as considered by Scoop@F (France) [ER-38] and
- The use case list as considered by the 5G Alliance.
- C-ITS Platform – Final Report – January 2016-11-26;
- CCAM Roadmap;
- C-ROADS service and use case roadmap;
- 5G Automotive Association;
- 5G Smart Cities and
- 5GAutoWP 30.09.2015.

In this release the following available specification are evaluated for their message exchange requirements:

- CAM (based on the EN 302 637-2 [ER-11]) + DENM (based on the EN 302 637-3 [ER-12])
- Platooning TR 103 298 [ER-15] (also based on input from the ENSEMBLE)

- CACC TR 103 299 [ER-16]
- SPAT/MAP/Pre-emption CEN TS 19091 [ER-13], TS 103 301 and SAE J2735,
- CPM ETSI TR 103 562 [ER-17] and TS 103 324 [ER-18] (Collective Perception Service)
- MCM TR 103 578 [ER-19] and TS 103 561 [ER-20] (Maneuver Coordination Service)
- VRU TR 103 300-1 [ER-21], TS 103 300-2 [ER-22] and TS 103 300-3 [ER-23] (Vulnerable Road Users)
- CBTC TR 103 580 [ER-24] services as identified in the TR relevance of coexistence.
- SAM EN 302 890-1 [ER-25] (Service Announcement Service)
- PoTi EN 302 890-2 [ER-26] (Position and Time Service)
- Other services and use cases identified in cooperation with the WG Functional.

1.3 Background European developments

In the late 90s, it was recognized that information exchange could help improving road safety and support automation. In Europe in-depth spectrum analyses were based by findings by the National Telecommunication & Information Administration (NTIA) [ER-5] in the USA. The NTIA allocated 85 MHz for C-ITS. In Europe this led to analyses by ETSI TC ERM in the period of 2004-2006, leading to 2 reports, the TR 102 492-1 [ER-8] in 2005 and TR 102 492-2 [ER-9] in 2006. In the TR 102 492-1 [ER-8] an initial set of safety related applications were identified (see Figure 1), which are part of the Basic Set of Application (BSA) the TR 102 638 [ER-68]) to identify the spectrum requirements and the results in the TR 102 492-2 [ER-9] led to the first spectrum allocation proposal which is regulated in the Current Spectrum Regulation EC Decision 2008/671/EC [ER-27] (see Figure 2).

Application	Description
Cooperative Collision Warning	Cooperative collision warning collects surrounding vehicle locations and dynamics and warns the driver when a collision
Work Zone Warning	Work zone safety warning refers to the detection of a vehicle in an active work zone area and the indication of a warning to
Approaching Emergency Vehicle Warning	This application provides the driver a warning to yield the right of way to an approaching emergency vehicle.
Traffic Signal Violation Warning	communication to warn the driver to stop at the legally prescribed location if the traffic signal indicates a stop and it is predicted that the driver will be in violation.
Emergency Vehicle Signal Pre-emption	This application allows an emergency vehicle to request right of way from traffic signals in its direction of travel.
In-Vehicle Signage	The in-vehicle signage application provides the driver with information that is typically conveyed by traffic signs.
Road Condition Warning	to nearby vehicles when the road surface is icy, or when traction is otherwise reduced.
Low Bridge Warning	especially to commercial vehicles when they are approaching a bridge of low height.
Highway/Rail Collision Warning	Railroad collision avoidance aids in preventing collisions between vehicles and trains on intersecting paths.
Wrong Way Driver Warning	This application warns drivers that a vehicle is driving or about to drive against the flow of traffic.
Emergency Electronic Brake Lights	Brake light application sends a message to other vehicles following behind.
The Left Turn Assistant	The Left Turn Assistant application provides information to drivers about oncoming traffic to help them make a left turn at a signalized intersection without a phasing left turn arrow.
Curve Speed Warning	Curve speed warning aids the driver in negotiating curves at appropriate speeds.
Vehicle-Based Road Condition Warning	conditions using on-board systems and sensors (e.g. stability control, ABS), and transmit a road condition warning, if required, to other vehicles via broadcast.
Low Parking Structure Warning	This application provides drivers with information concerning the clearance height of a parking structure.
Lane Change Warning	intended lane change may cause a crash with a nearby vehicle.
Highway Merge Assistant	another vehicle is in its merge path (and possibly in its blind spot).
Cooperative Glare Reduction	automatically switch from high-beams to low-beams when trailing another vehicle.
Control	Alerts driver to other vehicles at intersections.

Figure 1: TR 102 492-1 List of applications

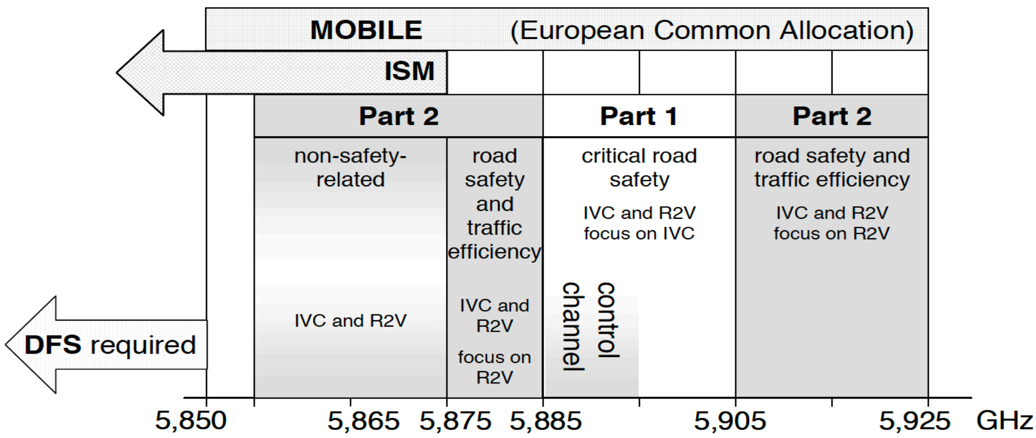

Figure 2: TR 102 492-2 proposed spectrum allocation

To support the identified applications in the TR 102 638 is supported by information exchange identified by 2 message types. The Cooperative Awareness Message (CAM, ETSI EN 302 637-2 [ER-11]) which provides other road users awareness information about the location and traffic behaviour of the transmitting road user and the Decentralized Environmental Notification Message (DENM, ETSI EN 102 637-3 [ER-12]) to notify others about safety situation recognized by the transmitting road user. These 2 message types are the bases for the first set of applications as identified in the TR 102 492-1 [ER-8] and TR 102 638 [ER-68]. Three channels between 5875-5905 MHz were designated to facilitate this required information exchange and 2 additional channels at 5905-5925 MHz were allocated to facilitate future use. Beside these 5 safety channels, 2 additional channels in 5855-5875 MHz were allocated for non-safety (no prioritisation possible as in SRD band).

Many projects e.g. CVIS [ER-49], Safespot [ER-48], SIMtd [ER-47] and SCOOP@F [ER-38] have evaluated the possibilities and tested the applications to be supported in a single channel at small and at large scale. At the moment a second channel is used for the exchange of certificates in the SCOOP@F project and current RSUs being deployed are dual-channel systems. For additional applications, other channels will have to be used. The Day-1 list of applications as defined in the EC C-ITS Deployment Platform report phase 1, also includes the green wave optimisation (GLOSA) application which makes use of the Signal/Phase and Timing (SPAT) and MAP messages as defined in the ISO TS 19091 [ER-13]/SAE J2735 [ER-14]. As these messages may be complex these are limited in size at initial deployment but are expected to also make use of one of the other channels. By the end of 2019 first large scale deployment are realized while the development of new (Release 2) applications started in 2017.

Currently just closed and running project enhanced our view showing a large extended list of safety related applications coming up. These are not only C-ITS related but also cover CCAM related use cases and requirements, C-ITS and automated/autonomous driving applications far beyond the original list as identified in the TR 102 638.
Today we distinguish 4 ITS levels, information, active safety, integral safety and passive safety phases such as shown in Figure 3.

- The information Phase in which general information is provided to drivers or to the automated system. This is normal information exchange to considered as part of the ITS related infotainment system and not considered in this document.
- The “Active Safety” phase in which in the normal driving mode the driver and its ITS-system is informed or warned. All application as defined for Day-1 or as identified in the TR 102 492-1 [ER-8] are C-ITS Active Safety related.
- The “Integral Safety” phase in which the vehicle can intervene or take reversible preventive actions. This is the period before possible impact in which Automation aspects have a key role and are seen as C-ITS Integral Safety.
- The Passive Safety” phase in which the accident severity reduction and non-reversible measured take place. When needed this includes Rescue Facilities. This is after crash information exchange and not considered in this document although possibly (not defined application yet) an E-CALL information exchange may be defined making use of the C-ITS system.

For the Passive safety phase, the information exchange is intended for none-versatile measures and rescue facilities such as E-call. In case the E-call can’t be executed via the standard cellular networks forwarding via ITS-G5 could be an option but isn’t considered at the moment and is excluded from this analysis. ITS-G5 is in the first place intended for Active and Integral Safety information exchange.

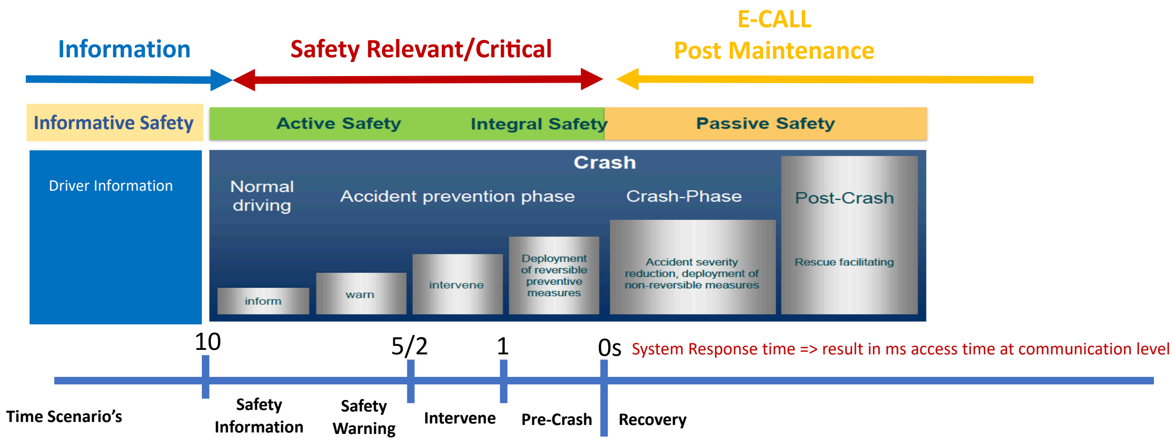

Figure 3: Phases of the vehicular safety system (Ref: C2C-CC)

In parallel with the innovation of advanced C-ITS applications, related aspects will merge with Vehicle Automation/Autonomous as identified in the Declaration of Amsterdam [ER-28] (see Figure 4). Effort into both Active Safety as well as Integral Safety applications has been increasing.
Many innovative projects are looking at beyond Day-1 applications. Just finished or currently active are for example: VRUITS, AutoNet, HIGHTS, TIMON, RoadArt and there are new ones upcoming. There is quite a grow of applications and new possibilities are getting recognized. There are several application lists going around.

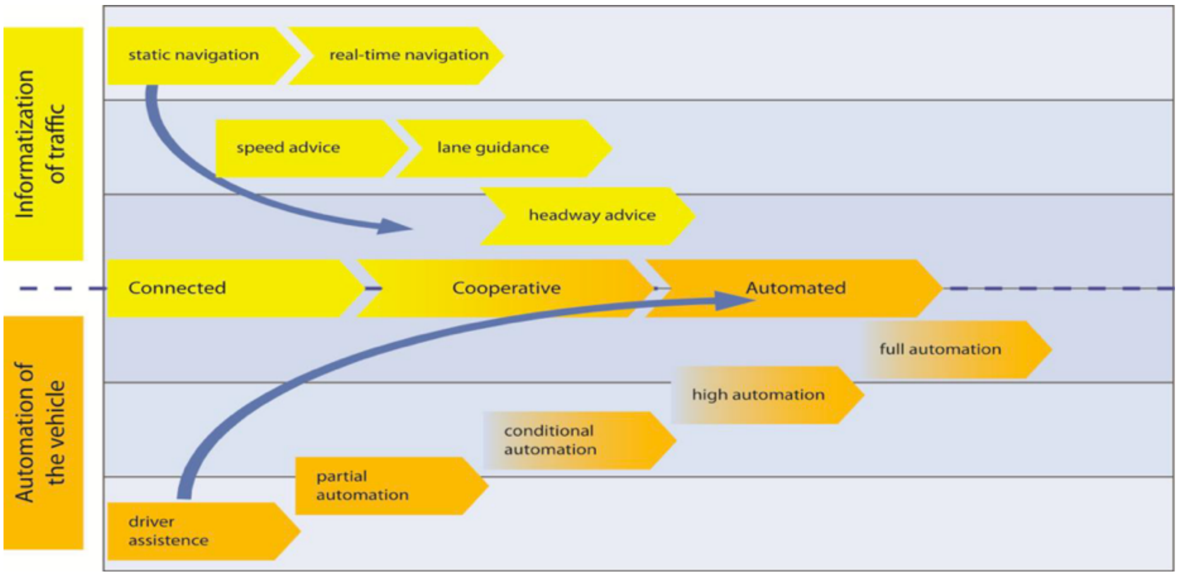

Figure 4: Merge of C-ITS and Vehicular Automation as agreed in the EU "Declaration of Amsterdam".

For instance, there is the EC C-ITS Deployment Platform Phase 1 report with Day-1.5 applications which will have an extension in the Phase 2 report this year included more Urban applications.

The C2C-CC Release 1 Basic System Profile (BSP) has been released in September 2019 and is currently only being maintained while for the support of new applications the work on Release 2 has started. Figure 5 shows the C2C-CC Functional Roadmap from 2019Q3.

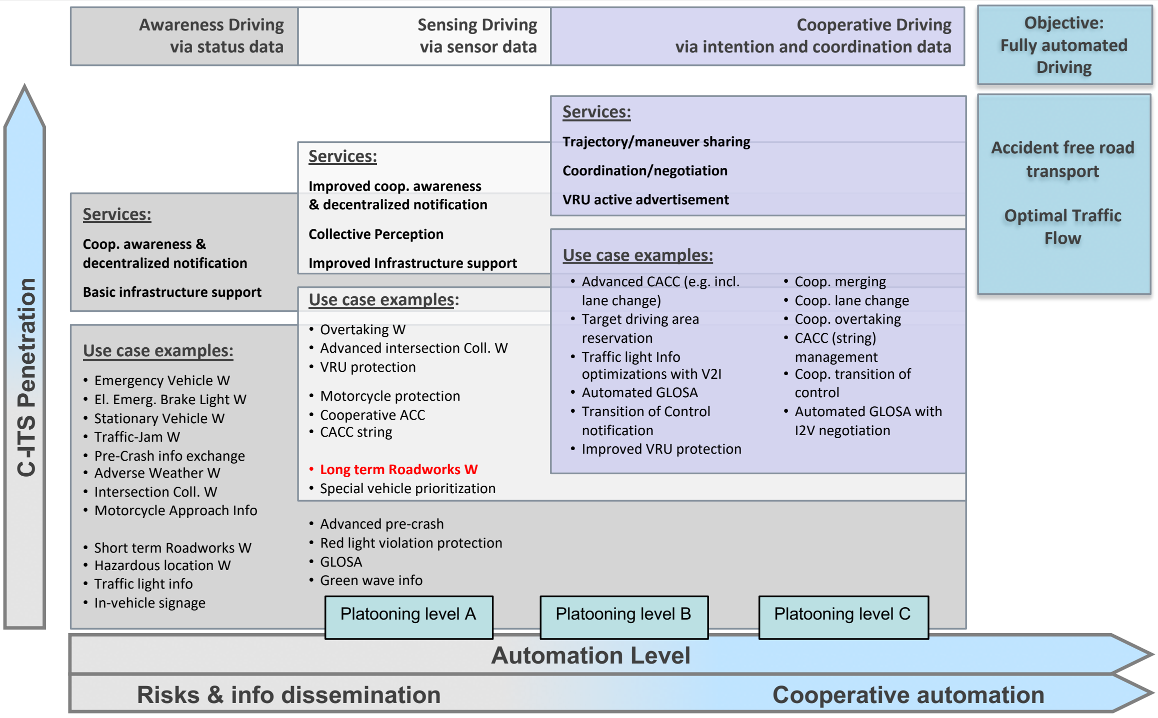

Figure 5: Car2Car CC Functional Roadmap 2019Q3

The EU project HIGHTS (Deliverable D2.3) identified a large list of C-ITS applications/use cases. The HIGHTS list is derived from roadmaps as provided by the European commission C-ITS platform phase I report, the Amsterdam Group (AG, [ER-41]), C2C-CC, ACEA [ER-42], 5GAA [ER-43], EATA [ER-44], and the European projects C-ROADS, InterCor [ER-45], CODECS [ER-39] and country specific overviews (see Table 1) in 2018Q2.

Group	Applications
Traffic Safety Avoidance 1 &2	Traffic Jam Ahead Warning
	Hazardous Location Warning
	Emergency Vehicle Warning
	Emergency Brake Light
	Slow Vehicle Warning
	Stationary Vehicle Warning
	Overtaking Warning
	Intention Sharing
	Overtaking Assistance
	Overtaking Assistance Advances (including Motor Cycles
	Collision risk warning
	Intersection collision warning
	Wrong Way driving warning
	Motorcycle Approaching Indication
Cooperative Awareness	Behaviour CAM (awareness)
	Road Status (awareness) holes in the road etc by Infra
	Driver Status CAM (awareness)
	Vehicle Status CAM (awareness)
Intervene Awareness	Cooperative Intension CIM (awareness)
	Collective perception CPM (awareness)
	Pre-crash mitigation,
	Advanced crash notification
	Critical Speed advisory
Vehicular Automation	Basic ACC (level 2)
	Basic (level 2-3) C-ACC
	Advanced (level 3-4) C-ACC (Increase 20Hz small CAMs + CIM + CLP)
	Basic (level 3-4) Platooning (Increase 20Hz small CAMs + Platoon Management)
	Advanced (level 4-5) Platooning (as Basic including CIM + CPM Camera/Radar sensor data)
	Automation level 4- 5 Vehicles (As Advanced C-ACC + Camera/Radar sensor data)
	Basic Merging Assistant (inter Vehicular nigotiations / Roadside management)
	Advanced Merging Assistant (As Basic + increase ≤10Hz small CAM's)
	Automatic parking (Basic and Automated Parking)
	Automation assist in Tunnels (Location precision assist)
	Automation level road assignment Static and Dynamic
Road Works Warning	Short Term Mobile
	Basic Short Term Static (only road allocation awareness)
	Advanced Short Term Static (as basic + dynamic speed management depending on traffic density)
	Basic Long Term Static (only road allocation awareness)
	Advanced Long Term Static (as basic + dynamic speed management depending on traffic density)
	Emurgency road works Mobile (As Short Mobile with Additional Notifications)
Traffic Flow	In Vehicle Signage Navigation (MAP-Cloud services)
	In Vehicle Signage Local (Dynamic or not managed by Traffic Management)
	Dynamic Speed (Direct + MAP-Cloud service)
	Dynamic Sign Information (Short-Term Direct + MAP-Clous service)
	Road Topology (MAP) provisioning by authorities
	Network Flow Optimization
	Shockwave Damping
	Efficient traffic flow Urban/HighWay
	Complex Lane Marking
	Regulatory / contextual speed limits notification
	Traffic light optimal speed advisory
	Zone access control for urban areas notification
	Zone access control for urban areas enforcement
	Enhanced route guidance and navigation
	Public Transport Vehicle Approaching
	Green Light Optimal Speed Advice

Group	Applications
Intersections Safety	Energy Efficient Intersection Service
	Stopping Behaviour Optimization
	Red Light Violation Warning
	Intersection Obstacle indication
	Queue Warning
	Left Trun assist
	Stop sign assist
	Disabled vehicle warning
Traffic Priority	Priority Request Business Transport Local
	Priority Request Publik Transport Local
	Priority Request Emurgency Local
	Priority Request Group of Cyclists Local
	Priority Request Publik Transport Via Emergency centre
	Priority Request Emurgency Via Emergency centre
	Priority Request Group of Cyclists Via Emergency centre
Vulnerable Road Users (VRU)	Bicycle Safety Awareness (CAM or CPM)
	Bicycle Priority
	Bicycle Approaching Indication
	Pedestrian Awareness (CAM or CPM)
	Motorcycle Awareness (CAM)
Traffic Information	Virtual VMS
	Traffic Information Service
	Virtual VRI in Traffic center
Incident Management	Automatic Incident Detection (Detection by Vehicle)
	Automatic Incident Detection (Detection by Infrastructure)
	Incident Warning
Navigation	Intermodal Route Planner
	Standard Navigation
	HD-MAP general MAP updates
	HD-MAP local updates by vehicles and Infrastructure for Autonomous driving Strategic (Cloude)
	HD-MAP local updates by vehicles and Infrastructure for Autonomous driving Tactile
	HD-MAP and Navigation MAP updates
	Highway Chauffeur (L2/3)
	Rerouting
	Eco Route Planner
	Basic Parking Assist (directions)
	Advanced Parking Assist (specific parking lot)
Media	Point of interest notification
	ITS local electronic commerce
	Media downloading
	Multimodality support
	Information on AFV fuelling & charging stations
Vehicle Services	EV Charging Point Planner
	Insurance and financial services
	Pay How You Drive
	Probe Vehicle Data
	IMMA Interface
	Fleet management
	Loading zone management
Railway	Railway-Road Crossing
	Urban Rail safety
Security Privacy	Sequrity Key updates
Geolocation referencing	Geolocation improvement info exchange (POTI) 2Hz
System Operations	Vehicle software / data provisioning and update
	Vehicle and RSU data calibration and system management
	Vehicle and RSU data calibration and system management ITS-G5 specific
	ITS system management

Table 1: Safety related applications list

When looking at this table in more detail we see that about 80% of the applications benefit from safety related short-rang Active or Integral Safety information exchange. Further detailing allows us to identify the key applications and message services which have biggest impact on the safety spectrum usage. The list confirms the C-ITS services list recognized by the C2C-CC functional roadmap. Based on this at the moment a number of key applications and services are dominating the information exchange based on their requirements.

- Truck Platooning: The Truck manufactures are expecting to use multiple ITS-G5 channels. Multiple platooning project such as the EU project Ensemble [ER-29] works on a first version of Platooning. There are several deliverables available and at ETSI a study includes the results of this and other projects ETSI TR 103 298 [ER-15] and related basic CACC specification ETSI TR 103 299 [ER-16].
- The project VRUITS was one of the early EU projects with focus on Vulnerable Road User (VRU) use cases and showing it importance as VRUs are victims in many of the accidences. This project has been followed by many other initiatives leading to use case and requirements gathering at ETSI standardisation in an ETSI Special Task Force (STF) is realizing the VRU specifications ETSI TR 103 300-1 [ER-21], ETSI TS 103 300-2 [ER-22] and -3 [ER-23]. At the Car2Car a VRU White Paper has been realized.
- Cooperative Awareness, letting others know the dynamic state of your own vehicle was step one and it has been recognized that for Integral Safety Awareness (ISA) more awareness such as awareness of none C-ITS connected road users is desired. With regards to this we speak about Collective Perception. The projects IMAGinE [ER-30] and ICT4CART [ER-31] are projects which are realizing innovations in this field. Within C2C-CC with white papers and ETSI TC ITS a lot of progress has been made and as reference the ETSI TS 103 561 [ER-20] and the Collective Perception Service (CPM), ETSI TS 103 324 [ER-18]) are of importance.
- CCAD as part of CCAM [ER-32] introduces Automation use cases such as active Maneuver use cases like lane change and overtake. More of such use cases related to automation have been recognized. Initial research such as executed in the AutoNet2030 EU project [ER-33] focusses on these aspects as well as projects further introduced in the coming years all leading to standardisations such as of Maneuver Coordination Service (MCM) TR 103 578 [ER-19] and TS 103 561 [ER-20].
- Not on the C2C-CC roadmap but of relevance when looking at MCO are the intersection safety and traffic prioritisation use cases which are reflected by the cooperation with C-ROADS [ER-34] and other transport stakeholders such as Agriculture (AEF, [ER-35]), Train and Urban Rail will have to be considered.
- Indirectly the above-mentioned applications and use cases require additional support by system services for improvement of the system as these services have increase system requirements here further not considered. One of the crucial aspects is the support for position augmentation services. Augmentation services such as developed in different EU project such as HIGHTS, leading to standardisation in the ETSI TS 103 301 [ER-36] and EN 30-2 890-2 [ER-26]. In the paragraph System Services these are analysed.

This list also covers most of the use cases as identified in the 5GAA paper “5GAA Releases White Paper on C-V2X Use Cases: Methodology, Examples and Service Level Requirements” [ER-72]. Those being different or do not make use of ad-hoc communication or need further analyses to see whether related requirements have additional MCO requirements. For the time being as more concrete information is not present these are not considered but could lead to an update of this deliverable based on work at ETSI.

This list of applications, services and use cases is inexhaustible and will be extended in future. We know that areas such as Railway-Road Crossing; Urban Rail; Intersection Safety; Enhanced Traffic Safety Avoidance; Tunnel Safety; extended roadworks warning; Parking Assist and Traffic Flow applications will require additional information exchange but are not considered at this moment.

For now, to get to an MCO approach the key recognized applications, services and use cases are seen sufficient for further investigation of their communication requirements and characteristics identified as input for later definition of an MCO approach to be specified in part 3.

2 General considerations and requirements

2.1 Introductions

For the realization of an implementable MCO concept not only system, functional and technical requirement but also business or legal related aspects need to be considered. In this chapter general aspects are analysed, and related requirements identified which may have conceptual impact. The more system and general technical aspects are considered in chapter 4. In this chapter , the Business Requirements, C-ITS and CCAM Related Regulation, EU General Data Protection Regulation (GDPR, [ER-50]) and Security services as related to the EU ITS certification and security policies [ER-51] are considered and requirement relevant for the definition of an MCO concept are identified.

2.2 Business Requirements

Release 1 [ER-63] has been realized, is in the market, and by definition sets the initial C-ITS business case making use of a single 10 MHz safety related channel in the 5.9 GHz. From a Business and technical perspective here after next releases need to be backward compatible with existing and allow differentiation in an open market. Next releases should therefore allow intermediary implementation to be realized with a minimum set as defined in Release 1 with extensions to the maximum specification in next Release 2. Additional releases thereafter will have to enable further innovation as open as possible and always backward compatible.

An MCO concept should therefore support the realisation of extensions and changes as much as possible such that backward compatibility is maintained and that new developments can be introduced as evolutions instead of revolutions. In line with that Release 2 has to be a superset of Release 1, The MCO concept is an extension (super set) of the communication architecture of the single channel concept as specified in Release 1. The MCO concept should support the realisation of implementations in an open, competition challenging market where all players can make their own choices and are only bound to specifications there where Interoperability is required.

The MCO concept should allow the functional owners to identify individually what business case they want to implement and therefore what set of services and use cases to offer.

It therefore is an MCO requirement to take the applications, services and use cases as starting point to come to an MCO concept. It is also a requirement that the MCO concept fulfils Interoperability only at those levels where this is really needed and the MCO concept should support the realisation of variations of implementations supporting those applications, services and use cases desired by any functional owner.

> Note: For example, the MCO concept should allow implementers to make choices related to the number of channels they would like to support/implement.

2.3 C-ITS and CCAM Related Regulation Considerations

2.3.1 Technology Neutrality

European Regulation 2015/2120 [ER-2] is laying down principles concerning open internet access, amending directive 2002/22/EC [ER-3] and Regulation No 531/2012 [ER-4] on roaming on public mobile communication networks in the EU.

Many articles have been interpreting these laws for which the development already started in 2003. Articles like “Technology and Neutrality….” by Peter Alexiadis and Miranda Cole [ER-

55] and one in Hogan Lovells "Global Media and Communications Watch" by Winston Maxwell "Technology Neutrality in Internet, telecoms and data protection" [ER-56].
The objective of the principle of technology neutrality is to ensure that EU regulation and related other legal directives or statement enable an open market according to antitrust and competition laws [ER-57]. Winston Maxwell identifies 3 meanings, showing that depending on the context 3 different meanings can be recognized, something which clarifies that when you need to project this on a specific case it is not enough to just say it needs to be technology neutral but related requirements need to be made specific.

The regulations specify that it must be ensured that Internet and mobile communication regulation realizes conditions to ensure open competition in open markets. It is a business and not technical oriented regulation, and in accordance with this principle "Technology Neutrality" needs to be business wise assessed. Technology neutrality is one of the means to realize an open market under agreed competition laws.

In spectrum regulation this business objective and "Technology Neutrality" is principally realized by functional allocation of spectrum and coexistence rules made verifiable by the harmonised standards specifications for those spectrum bands applicable. For the cellular bands this is not done according Technology Neutrality principles but via an open market business process of bidding.

In standardisation this "Technical Neutrality" is realized by writing maintainable world-wide standards in an "backward compatible open way" as living documents open for additions, open for new features and open for new technologies to allow business in an open market. Standards are not technical neutral as technical aspects need to be specified to realized conformity and interoperability but provide means that all stakeholders can realize solutions in an open competitive market and therefore also comply to the European legislation.

Acceptance of "Technology Neutrality" can be handled different ways.
Example 1:
In managed (cellular) markets it is realized business wise at spectrum level coexistence is organized by sales of specific peace's of spectrum in specific areas to specific stakeholders. Commonly among all users of such peace of spectrum the operation is in consensus agreed what technical solution to be used according to harmonised and standardized specifications based on as specific cellular communication architecture.
Example 2:
In un-managed (any other) markets it is realized by the functional allocation, "listen before talk" rules and coexistence rules. This may result in realizing a specific non-technical neutral set of specifications and standards supporting one specific group of stakeholders while another set of specific non-technical neutral set of specifications and standards supporting another specific group of stakeholders. As long as listen before talk" rules and coexistence rules are applied by each of the groups the legislation "Technology Neutrality" principle is supported. Each of the solutions should allow the other to have similar access to the spectrum when there is no priority is regulated. In that case the different solutions should not use mechanism which brings benefits over the other solution to have access to the spectrum.

In principle the current coexistence rules are sufficient to ensure good operation of different technology to operate in the same spectrum however it may need to be considered that in non-organized spectrum, organized systems may not be allowed to ensure fair use of the spectrum.

As the definition of an MCO concept is composed out of one or more technical specifications related drafting rules apply to realize “Technology Neutrality”. Technical specifications may be technically limiting as long as a this supports related business regulations.

2.3.2 C-ITS Interoperability

Technical standards include uniformed requirements which are Interoperable or can be profiled such for the purpose of realising interoperability. In most cases Interoperable profiles include more technical restrictions then just uniform standards. In most cases Interoperability restricts technical freedom but as such it allows every player to make an interoperable competitive product in an open market and therefore supports the spirit of “Technology Neutrality” as required and reduces the fragmentation of the market (EU COM(2016) 766 [ER-59]). A good example is IoT standardisation providing a platform realizing economies of scale which has also been the scope of C-ITS.

In the EU Directive 2010/40/EU [ER-7] Interoperability is very generally defined. It defines interoperability as the capacity of systems and the underlying business processes to exchange data and to share information and knowledge. EU COM(2016) 766 [ER-59] identifies Interoperability at all levels, infrastructure, data, services, applications and networks. It may also require additional specifications (profiles) to ensure interoperability on top of the standards as standards may require to be none specific for all aspects. According to EU COM(2016) 766, the interoperability needs to be region (Europe) deterministic.

In regulation Interoperability is generally specified, it does not specify what this means for specific application areas or so. For each application area, it needs to be evaluated what needs to be functional and technically interoperable to ensure a similar behaviour of applications in the application area.

When you look for a definition of C-ITS, whether you check Springer or the Eu commission or Wiki they do have a common view. C-ITS is a system of multiple dynamic entities that share information or tasks to accomplish a common objective. By common objective in C-ITS we mean a common society objective of safety. In the European common society (according to European regulation [ER-60]) everyone has the same principle rights of life, so also equal rights to have access to safety.

Based on the above to be able to speak about C-ITS interoperability the right of life, having equal right of having access to safety, needs to be evaluated for the C-ITS applications. A road user may or may not have a C-ITS station function but in case it does it needs to have similar access to safety information as any other road user having a C-ITS station. This right is therefore an interoperability requirement.

Besides interoperability compliance with the EU Directive 2010/40/EU solutions also need to be compliant with a number of other principles specified in this regulation which are not directly related to interoperability. Any functional interoperability solution needs also to comply principles such as cost-effective (to maximize the access to the solution for all or at least as many as possible citizens), promote equality of service, continuity of service, facilitate inter-modality. The ITS deployment Report II [ER-72] additionally confirms that data needs to be accessible and shared in an easy, cost-effective and non-discriminatory manner. Before solutions can be really found interoperable in this regulatory sense, they need to comply to all principles. It therefor is possible that functional interoperable solutions envisioned are not supporting the other EU regulated principles and therefore are not acceptable interoperable solutions.

The ETSI TR 103 576-2 [ER-69], Interoperability among heterogeneous ITS systems and backward compatibility, identifies some functional interoperable solutions including the implementation of 2 technologies but does not take the other regulatory principles into account. When doing so the functional interoperable concept presented does not comply to cost effectiveness principle and therefore can't be seen as a liable solution to be considered.

A to be defined MCO concept must fulfil the European principles and specifications need to realize C-ITS interoperability enabling an open market.

2.3.3 ITS Backward compatibility

Article 4 in the EU ITS regulation Directive 2010/40/EU [ER-7] is defined as "the ability of a device or system to work with another device or system without modification". In Annex II of this Directive the support as ensuring where appropriate is defined as the capability for ITS systems to work with existing systems that share a common purpose, without hindering the development of new solutions (technologies).
Article 4 speaks in general terms and is not specific in the relation of time and therefore does not describe it useful. Annex II is more specific and brings the relation with earlier implementations but does not specify it enough towards the different levels, to system, to applications and to services. No measurable statement is formulated.

The Xbox today speaks about backward compatibility being the possibility of games staying playable on an updated or different platform. This does not mean "the same" but clearly states an experience kind of quality measurably value.
Wiki defines "Backward compatibility as the property of a system, product, or technology that allows for interoperability with an older legacy system, or with input designed for such a system, especially in telecommunications and computing" and by that is specific in general terms.
More specific another explanation refers to a hardware or software system that can use the interface of an older version of the same product.

When we can assume that the main objective for C-ITS is to improve safety for all road users whatever ITS-Station (ITS-S) is used and we share the Xbox view that that for C-ITS the applications should stay working at least similar on updated or new released ITS-S's.

C-ITS backward compatibility is the ability of the newer versions of the ITS and its ITS-Stations, being interoperable at any time with previous versions of the ITS and its ITS-S's, ensuring the correct operations of previous versions of C-ITS-Applications, C-ITS-Services, C-ITS-Functions to operate similar and interact with road users similar on newer versions of the ITS and its ITS-S's. New ITS specifications shall be backward compatible with previous versions of the same ITS specifications.

MCO concepts for Release 2 and beyond need to ensure this backward compatibility with previous Releases.

2.4 EU General Data Protection Regulation (GDPR, [ER-50])

The GDPR handles the protection of natural persons in relation to the processing of personal data as a fundamental right. The regulation Article 8(1) of the Charter of Fundamental Rights of the European Union (the 'Charter') and Article 16(1) of the Treaty on the Functioning of the European Union (TFEU) provide that everyone has the right to the protection of personal data concerning him or her forms the bases for this.

The GDPR handles about information/data shared by whatever system this is realized. Its focus therefore is functional towards applications and service which are sharing data. It therefore is related to Facility and Application entities and therefore it is to the concern of systems who are realizing these entities and specific parts of the systems such as storage to ensure the GDPR is met.

MCO concepts may need to consider being of influence in the process of charring data but have no role in the process itself. In the MCO definition process only a check needs to be performed to check whether there are privacy related sensitivities. In case there are, they need to be resolved. It is not expected to have a big impact on the MCO concept.

2.5 Security services as related to the EU ITS certification and security policies [ER-51]

The EU commission has defined Security and Certification policies. The Certification policies are system as a hole oriented and not MCO specific. The Security policies are of direct influence on the implemented security aspects and do not directly influence any MCO approach. It may influence the MCO approach indirectly through Security requirements put onto the applications and facility services and therefore need to be evaluated application by application.

For the realisation of an MCO concept, it needs to be verified whether the applications and facility services to be supported include related requirements and whether they have effect on the MCO approaches.

3 Applications and Service Communication requirements

3.1 Introduction

In the following paragraphs the application and service communication requirements are identified according to the analysed documents and references identified in 1.3 Background European developments.

3.2 Basic Applications (Release-1[1])

3.2.1 Introduction

Day-1 Applications[2] supported by C2C-CC Release-1 have been tested and being validated by Vehicular and Road Authorities over the years and found ready for implementation under a number of boundary conditions set over the years. The following paragraphs 3.2.2 and 0 reflects findings during the definition of the specifications of the requirements to exchange the information in the given 5.9 GHz spectrum single 10MHz control band (band 180).

3.2.2 BSA Communication requirements

The Basis set of Applications (BSA) as specified in the ETSI TR 102 638 [ER-68] technical report was the starting point of many functional and technical developments and evaluations in Europe. Car industry oriented projects such as SIMtd [ER-47] and general oriented EU projects such as CVIS [ER-49] and Safespot [ER-48] were important to allow different stakeholders to work together and realize interoperable standards and specifications. All TR 102 638 related applications were based on the exchange of 2 basic message facility services, Collective Awareness message (CAM) as defined in ETSI EN 302 637-2 [ER-11] and the Decentralised Environmental Notification Message (DENM) [ER-12] message sets providing Cooperative Awareness and Decentralized Notifications.

The basic operation of these message sets in a single 10 MHz channel in the 5.9 GHz safety related spectrum was identified and led to the specification of a set of Communication parameters, system conditions, standards and C2C-CC white papers. All communication settings are depicted from released standards and made interoperable in the first Release-1 C2C-CC Basic System Profile (BSP).

> Note: One of the issues during initial evaluations especial during the CVIS evaluations was that in many situations channel congestion occurred even with a limited number of ITS stations in the area. This resulted in extended methods to ensure proper operation with regards to the number of participants and resulted in large scale tests both in Europe as in the USA and realisation of Decentralized Congestion Control mechanisms to manage the traffic in the channel.

For the purpose of creating an MCO concept the following Release-1 aspects need to be considered.

- Release-1 identified communication parameters are based on expected C-ITS penetration in the coming 5-10 years of about 60-70% (mainly CAM's and DENM's) market penetration

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[1] C2C-CC Release-1 refers to the latest version of the Release-1 specifications. At release of this document practically we speak about Release -1.5, not to be confused with Release- 1.5 as defined by the EU commission documents.

[2] The Day-1 Applications are all the basic applications identified in the ETSI TR 102 638 [ER-68] but also includes initial Vehicle Signage (IVS) applications supported by message standard IVI (ISO TS 19321 [ER-46]) and Traffic light priority applications supported by message standards SPAT/MAP (ISO TS 19091 [ER-13] and SAE J2735 [ER-14] as supported by the C2C-CC V1.5 and aligned C-ROADs V1.4 profiles.

level. For higher penetration levels a single channel or the release-1 services may not be sufficient.

- Current congestion level is set to 60% (6 MHz functional use of a 10 MHz channel).
- It is further assumed that DENM's are rarely transmitted so that CAM transmission is very dominant in the channel. Aspects at least confirmed by the applications knowledge and large-scale tests at that time.
- Later as proposed by authorities based on simulations and expectations the transmission in the same control channel of IVI, SPAT and MAP was agreed under the condition that the size and transmission frequencies will stay low and that the transmission priority should be lower than CAM and DENM. These aspects have not been verified on large-scale but assumed not to be problem during the initial years of deployment.

These considerations show that congestion is at least expected after a penetration of 60% and for use above such penetrations alternative MCO schemes may need to be realized to ensure robust operations of related applications. As congestion leads to not sending lower prioritized messages in the first-place mechanisms improving the robustness of these applications in an MCO environment needs to be considered.
At full ITS-Station (ITS-S) connected road user equipment penetration levels, it could be so that when also new use cases will find their way it can be expected that not all CAMs can be transmitted and therefore even for CAM transmission offloading may be considered.
All message exchange required to facilitate the operation of Release-1 applications and services covered by current versions of the C2C-CC BSP Release-1.5 and C-ROADs Release-1.4 shall be exchanged on the CCH channel (band 180) in the 5,9 GHz traffic safety band.
For BSA Release-1 support the MCO requirements are provided by the Release-1 profiles as mentioned above. Additionally, it can be stated the use of the CCH channel should stay restricted for the use of the BSA applications and only by exception new applications should be allowed. Additional use by other applications will lead to degradation of the BSA applications.

BSA System related Communication Requirements
All Release-1 data is shared through multicast transmissions and are interoperable covered by the Basic System Profile (BSP) Release-1.5 as released. No additional requirements need to be covered.

> NOTE: The way privacy is included by design, may need to be formulized to have a reference for other services (By design = based on current specified interoperable BSP for the Release-1 applications),
> NOTE: For each new method of sharing Release-1 application data, such as through hybrid communication supported cellular networks, the GDPR [ER-50] requirements need to be checked.
> NOTE: For each new beyond Release-1 application or service shared data, the GDPR [ER-50] requirements need to be checked (For instance for distribution of data via different networks using a different business model).

3.3 Extension of the use of Day-1 services (Beyond Release-1)

3.3.1 Introduction

The Day-1 services such as CAM and DENM are used for warnings Day-1 services, however these same services can also be used for the extension towards automated driving. No discussions have taken place within C2C-CC on this topic yet but for MCO some assessment for CAM has been done.

3.3.2 CAM Extension

For Day-1 only warnings to the driver are considered but for Day-2 a vehicle could control the brake in certain cases. In those cases, the assessment of the situation is expected to be based on own sensors and the CAM could be seen as an additional sensor. Although it may be assumed that the information provided in CAMs will not be the only source of information used the decision of braking falls under Functional Safety levels higher than QM and therefore the question is whether this results into additional requirements to the CAM and to MCO.

Investigations do need to take shape but initially we think that in the first place the confidence of the information in the CAM should comply to the appropriate ASIL level to be supported depending on the use case. ISO 26262 identifies that only at ASIL level D redundancy will be required and as we are currently only at QM level support by CAM it will take some time before ASIL level D needs to be supported.

Recommendation: As this is just an assumption it is advised to realize a study on this topic.

For more detail on Functional Safety MCO consequences see 4.5.

3.4 Basic CACC and Platooning Applications (Beyond Release-1)

3.4.1 Introduction

There are 2 parallel developments ongoing.

- The extension of ACC towards Cooperative ACC (CACC) current specification covers Automation levels 1 and 2 (SAE J3016, [ER-52]) there where CCAD is expected to cover the levels 3 to 5. Current CACC communication requirements are captured in the ETSI TR 103 299 [ER-16] report.
- Truck Platooning is currently mainly driven by the alignment between all Truck manufacturers in the ENSEMBLE EU project [ER-29] expected to lead to implementation by 2022-2025. Communication requirements are derived from the Ensemble deliverables and ETSI TR 103 298 [ER-15] report and may be further developed in coming years.

In the following paragraphs. 3.2.2 and 0 related early requirements are identified based on these developments. Related stakeholders are obliged to provide further information about the development when of importance for the development of an MCO concept.

3.4.2 Communication requirements

3.4.2.1 *CACC Communication requirements*

Definition (TR 103 299): CACC is an in-vehicle driving assistance system that adjusts automatically the vehicle speed to keep a target time gap Δt_{target} with a target vehicle (TV) while keeping a minimum safety distance with it.

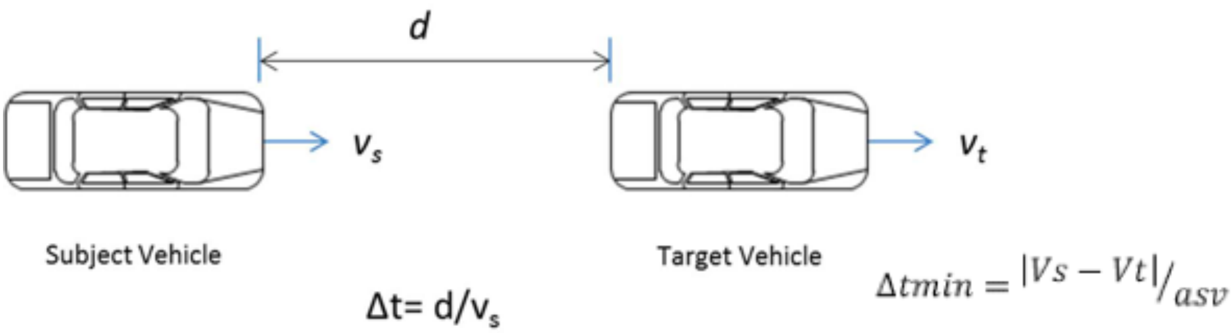

Figure 6: CACC is an in-vehicle driving assistance

As Identified by the Use case descriptions in the ETSI TR 103 299 report, only one-use case (UC007) requires some additional short-range data sharing besides SPAT/MAP messages received from the infrastructure. This information exchange requires only very limited bandwidth in a relatively small relevance area in a message broadcasting setup. The information may be included as part of the CAM (in a backward compatible way) or be an additional message type with small message size. It is assumed not using significant more bandwidth.
In principle Current CACC functional requirements as depicted in TR 103 299, do not require more accurate requirements compared to what is covered by the BSP 1.5 except for an higher CAM rate similar to the extended CAM rate presented as PAM's in the platooning use case in Table 2 realizing a maximum CAM rate of 30Hz in total, leading to a drastically increases MCO requirement on the CAM transmission as noted by the TR in 9.1.2.2. It will double the channel requirements.

Increased Lane level position accuracy will be required for advanced CACC and therefore may require more stringent system positioning accuracy leading to integrate additional position augmentation methods with the support of additional C-ITS information exchange, see Chapter 4.3.

3.4.2.2 *Platooning Communication requirements*

ENSEMBLE does not clearly define what platooning is but does define platooning levels are defined.

Within the ENSEMBLE project 3 platooning levels A, B and C are defined.

- Level A attributes
    - Longitudinal coordinated automated control for the whole velocity range from 0 to maximum cruise velocity (depending on country regulations). The longitudinal control remains the driver's responsibility;
    - Maximum number of trucks of 7 is considered for platoon level A in ENSEMBLE;
    - A minimum time gap of 0.8 seconds @ maximum cruise velocity (depending on country regulations)
    - New members of a running platoon can only join from the rear;
    - Under adverse conditions like bad weather, slopes, etc.… the drivers have the responsibility to increase the time gap or disengage the platoon completely;
    - The driver is responsible for the dynamic drive task in case of system failures. The system needs to be fail-safe and
    - Interaction with platooning services and infrastructure is technically available.
- Level B, t.b.d. ENSEMBLE deliverable D2.3
- Level C, t.b.d. ENSEMBLE deliverable D2.3

With regards to the concern of communication the ENSEMBLE Communication Model is of interest to look at. The following layers have been defined see Figure 7:

- Service
- Strategic
- Tactical
- Operational
- System Elements

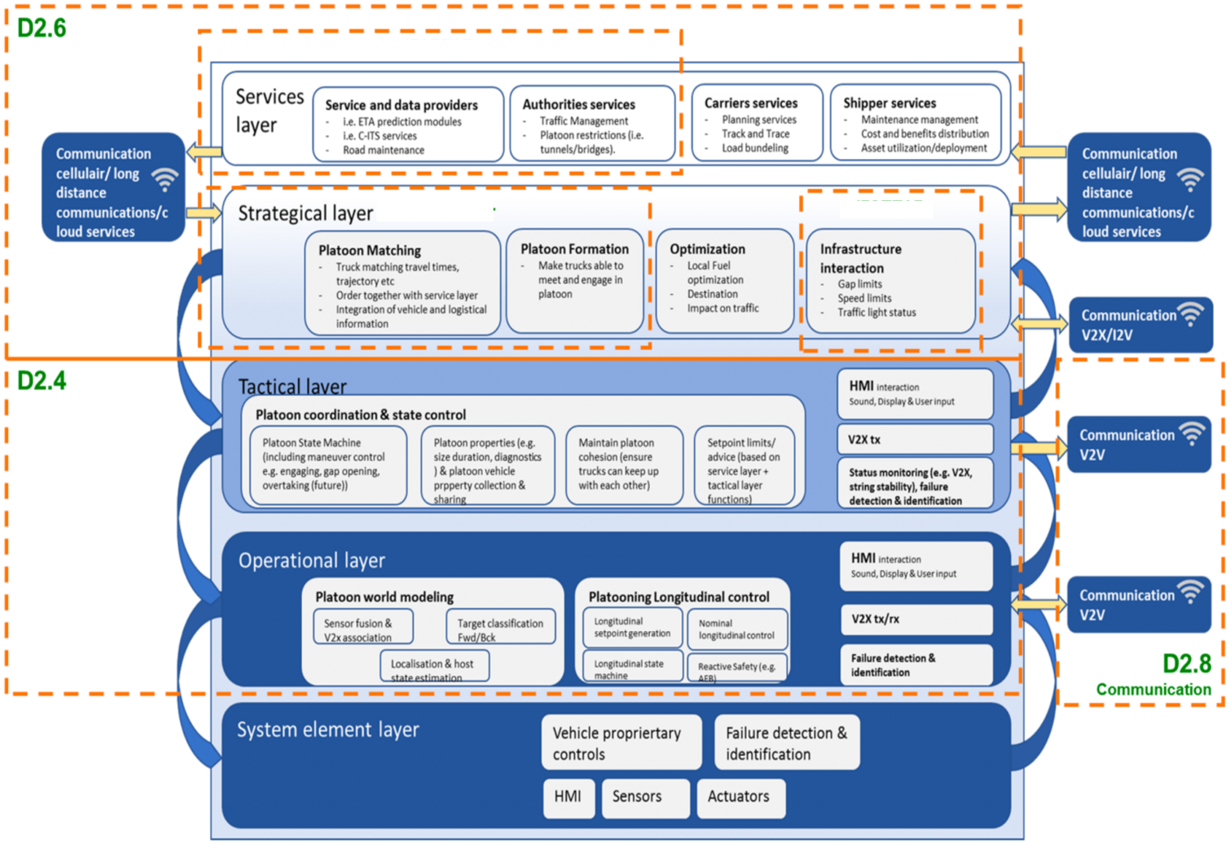

Figure 7: Layer Architecture for multi brand platooning (ENSEMBLE)

It clearly identifies different communication layers with different functional as well as none functional (Functional Safety (ISO 26262 [ER-53]), Safety of the Intended Functionality (SOTIF, ISO PAS 21448 [ER-54]), Privacy and security related) requirements. Communication with infrastructure both on strategic as service level is recognized. For the purpose of MCO these are not considered. Only the Tactical and operational layer communication requirements are considered.

For platooning the CAM is extended with a Platooning Container to show the platooning capabilities and platooning status (this is also good for other vehicles so they can identify platoons when they meet any).
Platooning requires increased awareness from members of the platoon. Information which may also help other road users. This could be just Small CAMs send with different generation rules (based on early analyses but not specified in the current released deliverables from ENSEMBLE the rate may go up to twice the normal maximum CAM rate in addition to the already standard CAMs sent). The definition of these CAM's could be realized by extending the current CAM specification or defining a separate Platooning Awareness Message (PAM). For readability of the document and keeping standard CAM information exchange separate from the extended Platooning awareness, in the following PAM is used. It is not advised to combine this awareness information as part of the Platooning Control Message (PCM) because of the data nature and way of transmission. PAM's are sent in Multicast and PCM's in unicast.

There are different ways the PAM's can be transmitted:

- The PAM's can be seen as an extension of the CAM and transmitted as such with a different generation rule and a different priority.
  - In case of no congestion all PAM's are sent.

  - In case of congestion
    - The PAM's can be negated and not transmitted and CACC deactivated. This possibly as it is so crowded that it has no sense to have the CACC activated.
    - The PAM's can be automatically forwarded to a specific agreed channel.
- All PAM's can be transmitted statically on a specific channel and when congestion in this channel occurs:
  - All others are not transmitted and CACC is degraded.
  - All others are forwarded statically to a different channel. This forwarding could be depending on congestion levels in the appropriate channel(s).
- ALL PAM's are sent in channel selected by Service announcement message (SAM). PAM's may also be sent in another specific channel assigned fixed or by mains of Service Announcement (SAM, ETSI EN 302 890-1 [ER-25]) assignments even for each platoon specified by the platoon leader. The assignment could for instance depend on the congestion ratio's in the channels.

PAM's have similar dynamic and safety impact risks as standard CAM's and therefore it is assumed that for the transmission and use of these messages no additional Functional Safety or SOTIF requirements need to be realized.

PAM's may be sent in a smaller relevance area then standard CAM's, maybe dynamically depending on the size of the Platoon in case of IEEE 802.11bd.

Based on the expected message exchange a 100% single channel (of the 60% DCC level as defined for Release-1 systems) occupation may be expected when there are only a few platoons are in the same areas. This channel occupation is only in the area where active platoons are present. Initially this will be only on the highway's but indications showing that a certain level of platooning may also be expected in urban areas. As highways also go through urban areas, it is not clear but currently not assumed that other information exchange could exists in the same channel as PAM's are transmitted. Although only level A platooning on highways only is considered today, for an MCO concept also level B and C expectations need to be considered.

Platoons are controlled by means of a platoon control state machines and required Platooning Control Messages (PCM) exchange. A typical exchange flow is presented in Figure 8. PCM's may be exchanged in a specific channel but also use a channel selected by the platoon leader announced via an Service Announcement (SAM, ETSI EN 302 890-1 [ER-25]), similar or the same as for the PAM's. PCM's are sent in a unicast or broadcast transmission mode (in ENSEMBLE unicast is specified at the moment). For the operation of the platoon the operation of the platoon state machine is essential and not properly working has safety relevant consequences. It is essential for this information exchange that the Safety of the Intended Functionality (SOTIF) and Functional Safety requirements identified. **Which may lead to additional communication requirements.** This is addressed in Chapter 4.3.

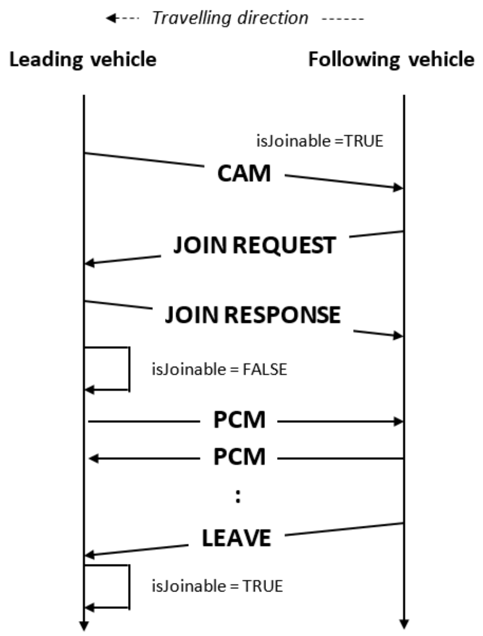

Figure 8: PCM information exchange example (ENSEMBLE)

As Level B and C are not yet defined it is assumed that future developments require additional information exchange and therefore flexible extendibility of the channel usage must be encouraged. Mechanisms such as SAM assignment where the service can be found could be considered.

The following communication requirements have been derived from the documents reviewed.

More accuracy related to the derived requirements are not required for the definition of an MCO concept except for Functional Safety and SOTIF as these are system configuration dependent. It can be recognized that although the PAM's are a necessity for the correct operation of a Platoon, they have a similar relevance as CAM and require a similar ASIL QM level. PCMs however are part of the control-loop and information transmitted has influence on safety relevant decisions and therefore are part of the safety critical decision process and need to be Functional Safety and SOTIF assessed. Requirements handled in Chapter 4.5.

Note: In this paper there is a distinguish made between standardised CAM and non-standardised PAM's for Platooning to show the difference. In practice the PAM could be a smaller CAM realized based on an update of the current CAM specification. This however is out of scope of this paper.

Platooning Use cases		Awareness		Control		Comment
Requirements	Messages	CAM	PAM	SAM (option)	PCM	PAM could be simple CAM
Transmission Rate		1-10 Hz	10-20 Hz	1Hz	1-50 Hz	PCM's are very dynamic and depending on level
Transmission dynamics		low-high	static	low	low-high	CAM's + PAM's = Total awareness required.
Area of relevance		Standard	70-100m	200m	70-100m	Platooning members 2-3
Area of relevance		Standard	200m	200m	200m	Platooning members 2-7
Message Size		200-800 Bytes	200 Bytes	300 Bytes	400 Bytes	
Message Latency, According to Current		CAM	CAM	SAM		
Message Priority to be defined						(on a level from 0-16, with 0 highest) See Annex A
Transmission mode		Multicast	Multicast	Multicast	Unicast	PCM's could also be Broadcast
Transmission type		repetitive	Sequencial	Event	repetitive	
Urban network message channel load Rural roads network message channel load Highway network message channel load		see C2C-CC position paper on "Road Safety and Road Efficiency			see C2C-CC position paper on "Road Safety and Road Efficiency	
V2V		X	X	X	X	
I2V and V2I		-	-	-	-	
V2E and E2V		-	-	-	-	
Reception Propability Requirement		Standard	Standard	Standard	High	
Security requirements		C-ITS	C-ITS	C-ITS	High	PCM's to include encription
Liability Impact		NO	NO	NO	High	
Functional Safety Requirements						Functional safety requirement is derived from application
SOTIF		NO	NO	NO		See Related chause
Position Accuracy level A		a<1m	a<1m	X	X	Only level A is identified

Table 2: Derived communication requirements for Platooning (Footnote* [3]) **[ER-76].**

With regards to channel use, there have been questions about whether platooning is a safety use case. Which channel to use therefore needs to be further evaluated. At least it is clear that a separate channel will be needed for the awareness part and for the PCM's it really depends on the ASIL level required.

3.4.3 CACC and Platooning System related Requirements

CACC and Platooning as the derived communication requirements show, higher position accuracy than current specified lane accuracy is required to realise the more advanced CACC and Platooning use cases. Introduction of additional augmentation services are therefore required.
For Platooning compliance to SOTIF and Functional Safety is depending how the responsibilities are shared between ITS-S's. Assessment is required but handled in Chapter 4.5.

3.5 Vulnerable Road User Application (Beyond Release-1)

3.5.1 Introduction

Early EU projects such the EU project VRUITS are focused on Vulnerable Road User (VRU) use case identification and basic functional needs, as death of VRU's in traffic form a significant part of all road fatalities. Authorities are very interested in reducing these VRU related fatalities. Authorities see the Traffic ICT Infrastructure as main facilitator to reduce the fatalities in urban areas. Based on especially the developments within the VRUITS project a European Commission financed Special Task Force (STF) at ETSI was installed. The Cellular technology providers picked up this sensitivity and have the ideas that this is an application on a mobile phone.

[3] Note: % channel load is the allocated % of the channel load where 100% represents the maximum channel load before the channel congestion state is reached.

The ETSI Special Task Force (STF) is realizing the VRU specifications, ETSI TR 103 300-1 [ER-21], ETSI TS 103 300-2 [ER-22] and -3 [ER-23]. At the Car2Car CC a VRU White Paper (C2C_RD_VRU_v13) has been realized. No specific input from 5GAA is available. In the following paragraphs the available communication requirements are identified. Current status of the documents provides limited information, there are therefore in following paragraph several assumptions made.

3.5.2 VRU Communication requirements

Many types of VRU's are recognized, from Pedestrians, PTW to Animals. From the perspective of finding Communication requirements for VRU's, PTW's are seen as special case of Vehicles and therefore here further not considered.
Further we can distinguish VRU's which makes use of the same part of the road as Vehicles and VRU's which do not. Pedestrians including joggers for instance are most of the time make use the sidewalk, only when they cross the road, they are active in the road traffic process. All VRU's should only send awareness messages when they are taking part in the active traffic process.

For the purpose of this analyses VRU's can be classified in the following categories and be connected or non-connected with ITS-Stations (ITS-S):

- Power Two Wheeler's (PTW's) have similar behaviour as Vehicles, send awareness (CAM), warnings (DENM) and Maneuver Coordination Messages (MCM), according to the current BSP specifications including PTW adjustments. They are characterized as "VRU profile 3" in ETSI TR 103 300-1 [ER-21].
    - In Case connected, the PTW will act similar to a vehicle and transmit similar CAM's and other messages. Based on this assumption the PTW does not need to be further considered in these analyses. In case the present density of PTW exceeds the normal expected number of vehicles and therefore may require additional measures such as grouping (also identified for Pedestrian clustering) or DCC measures but are not expected to lead to additional MCO requirements. It may result in additional DCC requirements, but these need to be handled elsewhere.
    - In case not connected, the PTW can be recognized by other road users or smart infrastructure who send Collective Perception Message including the PTW (see 3.6)
- All types of bikes and mopeds (here after called bikes) may behave similar to PTW's in urban situations but on Highways they are not allowed. They however are slower depending on their motor configuration and have lower speeds as well as lower legal status than PTW's. Instead of current specified CAMs other type of CAMs or Bike specific messages could be used. They may transmit MCM's. They are characterized as "VRU profile 2" in ETSI TR 103 300-1 [ER-21].
    - In Case connected, they could respond similar as PTW's and use awareness and sending warnings as PTWs may do. This however has not been considered for Day-1 spectrum use and as there are some behavioural differences with PTW's this needs to be considered in these analyses.
    - In Case not connected, the bike or moped can be recognized by other road users or smart infrastructure who send Collective Perception Message including the bike or moped (see 3.6).
- At this time Skaters, Skateboards and Segways are considered as pedestrians for MCO considerations. They are characterized as "VRU profile 2" in ETSI TR 103 300-1 [ER-21].
- For the purpose of this analyses we consider all other road users as pedestrians (except Animals), including children, elderly, disabled (such as wheelchairs or blind), prams, skaters, skateboards and Segways. When we speak about a vehicle, PTW or bike type of road user it implicitly identifies the active state as when we are using a bike, we will drive

the bike. For a pedestrian this can't be implicitly assumed. Furthermore, although a bike may drive on a normal road and therefore in the same lane as a vehicle it may also make use of specific bike lanes separated from vehicle and PTW traffic. Wherever the bike drives the safety aspect and therefore the awareness situation does not change. For the pedestrian this is very different. A pedestrian mostly stays away from that part of the road where the other road users are present. In general, pedestrians make use of the sidewalk or pedestrian areas. Only when it needs to cross the road or change status (step on a bike or in/out a vehicle or bus) it gets an active role in traffic and therefore part of the C-ITS environment. When pedestrians are on the sidewalk they are not participating in traffic and therefore should not participate in the exchange of C-ITS safety related information exchange. They are characterized as "VRU profile 1" in ETSI TR 103 300-1 [ER-21].

  - In Case connected, the equipment must ensure that participation in the exchange of safety related information only takes place when participation in traffic is intended or takes place and that the provided information has a high enough confidence level that the information can be used. Currently this can't be achieved by standard cellular phones as the position accuracy required to realize sufficient confidence is not present. Also, current mobile phones have not the ability to identify the active or passive state of a pedestrian. At the moment it is not foreseen when a personal device is able to identify when a pedestrian change state from being on the sidewalk and when being intended to cross or move onto the road.
    There is a group which could be seen as an exception. This is the group which may have special equipment such as, road workers, disabled and others. These pedestrians may use via HMI controlled equipment as they are conscious about their state and therefore may send VRU Awareness Messages (VAM) as well as warnings (DENM) and show intension (MCM).
  - In Case not connected, pedestrians can be recognized by other road users or smart infrastructure who send Collective Perception Message including the pedestrian (see 3.6).

- Animals are a special case. We can distinguish 2 classes, owned and wild animals. They are characterized as "VRU profile 1" in ETSI TR 103 300-1 [ER-21].
  - Wild animals may be tagged but the amount is very limited, and these will not use ITS-Stations to realize awareness as these will use too much power and are not the right technical solution, Other methods are also not ITS based and therefore for this analysis can be ignored.
  - Owned animals can be classified as pets and transport. A horse, for example, may have the state of being a pad at one moment and be used for transportation at another.
    - In Case Connected:
      - As Pet in principle it legally needs to be on a leash but private owns may use a specialised ITS device to bring awareness of the dog for road users. As for pedestrian equipment this may not be likely for the coming years but is theoretically possible and the number of users can be assumed very low, no special treatment in this analysis is required.
      - As Transport in principle (for example in the case of a horse) they can be seen similar as a vehicle or bike and therefore may send awareness and warnings. As it behaves similar as these other road users and the amount is not high it is expected not to be of importance to this analysis.
    - In Case not connected, animals can be recognized by other road users or smart infrastructure who send Collective Perception Message including the animal (see 3.6).

VRU use cases are C-ITS focussed, warning oriented and therefore Functional Safety and SOTIF do not need to be considered for the currently foreseen use cases.
Table 3 provides an overview of the considered VRU use cases.

In case VRU's participate in traffic and by doing so are integral part of Road Safety focussed improvement, for these participants the same safety use cases apply as for the other road users. Although there are specific VRU use cases of special interest with regards to road safety, such as, road crossing (especially at bus or tram stops, schools and other educational or pedestrian concentrating road crossing locations), intersection safety, in and out of parked vehicle, collision avoidance, speed difference warning, visibility safety and dangerous situation (example: pedestrian on Highway), these use cases are seen being covered by technical use cases identified in
Table 3 such that the MCO requirements can be identified sufficiently to support these functional use case.

VRU use cases		PTW (vehicles)	Bikes		Pedestrians		Comment
Requirements	Messages	All Messages	CAM like	DENM	VAM	DENM's	VAMs can be a separate set or could be CAMs
Transmission Rate		PTW's behave like vehicles and with respect to the requirements targeted in this report no additions are expected here except higher position accuracy	1-5Hz	-	1-10Hz	-	VAM 10 Hz for Roadworkers on Highway
Transmission dynamics			low	high	low	high	
Area of relevance urban			70m	70m	70m	70m	
Area of relevance rural roads			>150m	>150m	>150m	>150m	
Area of relevance rural highways			>500m	>500m	>500m	>500m	
Message Size			350 Bytes	350 Bytes	350 Bytes	350 Bytes	
Message Latency, according to current			CAM	DENM	CAM	DENM	For MCM to be defined
Message Priority to be defined							(on a level from 0-16, with 0 highest) See Annex A
Transmission mode			Multicast	Multicast	Multicast	Multicast	
Transmission type			Repetitive	Event	Repetitive	Event	
Urban network message channel load			50%	>'3%	see C2C-CC position paper on "Road Safety and Road Efficiency Spectrum Needs in the 5.9 GHz for C-ITS and Cooperative	>1%	As the density of Bikes can be accepted some factors more then vehicles but the rate is a lot less.
Rural roads network message channel load			>5%	>1%		>1%	See Footnote*
Highway network message channel load			>1%	>1%		>1%	See Footnote*
V2V			-	-	-	-	
I2V and V2I			-	-	-	-	
V2E and E2V			X	X	X	X	
Reception Propability Requirement			Standard	Standard	Standard	Standard	
Security requirements			C-ITS	C-ITS	C-ITS	C-ITS	
Liability Impact			NO	NO	NO	NO	
Functional Safety Requirements							Functional safety requirement is derived from application
SOTIF			No	No	No	No	See Related chause
Position Accuracy level A			a<0.5m	a<0.5m	a<0.5m	a<0.5m	

Table 3: Derived communication requirements self-transmitting VRU's (Footnote* [4]) [ER-76]

With regards to channel use, in case VRU's send information by themselves or other stations provide VRU information via CPM, it is advised to provide this information in the same channel. As the CCH is full it is advised to use a separate channel for VRU related information exchange.

3.5.3 VRU System related Requirements

As stated in the derived communication requirements, all VRU use cases require higher position accuracy than current specified lane accuracy to be able to distinguish them from each other and

[4] Note: % channel load is the allocated % of the channel load where 100% represents the maximum channel load before the channel congestion state is reached.

facilitate VRU use cases. Additional Augmentation services are required. As Augmentation services are much more easily (low cost) implement in RSU's, while very difficult to be realized in handhelds. VRU applications are expected most effective when realized in roadside ITS stations (R-ITS-S's) instead of personal ITS Stations (P-ITS-S's).

3.6 Collective Perception Service (Beyond Release-1)

3.6.1 Introduction CPS

Several projects, such as IMAGinE [ER-30], PRoPART [ER-72] and MAVEN [ER-31] realized innovations in the area of collective perception, while at C2C-CC and ETSI TC ITS progress has been made with related specifications. Current technical report ETSI TR 103 562 [ER-17] outlines a potential specification for the Collective Perception Service (CPS). Current work within ETSI TC ITS focuses on the normative specification of the CPS as ETSI TS 103 324 [ER-18]). The standard introduces the Collective Perception Message (CPM) which can be employed to share kinematic and attitude state information about objects (other road users, obstacles and alike) detected by local perception sensors connected to ITS-Ss.

The Cooperative Awareness Service (CA service) lets other road users know about the dynamic state of ITS-S itself. This was a first step bringing awareness. It has been recognized that for further Integral Safety Awareness (ISA) even more information is needed. Collective Perception (CP) will further increase awareness and may address the following use-cases:

- Create Awareness about n**on-connected road users** of any kind which could be subdivided in:
  - **Non-connected vehicles**
  - **Non-connected other road users (mainly VRU's)**
- Create Awareness about **Detected Safety-Critical Objects** (DSCO): these objects are not a recognized as active road users but can be seen as object influencing road situations and related resulting traffic behaviour.
- Create Awareness via **CAM Information Aggregation** (CIA): CAM's received from connected by infrastructure components from connected road users which are possibly not received by other connected road users due to radio propagation of the surrounding environment can be aggregated in a CPM.
- Create Awareness about **Empty Road Segments** (ERS): provide recognized areas which are not occupied by any of the known objects as referenced in previous categories.

Although Collective Perception is a single service it is not a single use case such as CA as can be seen from the list above it could provide data and information for a plethora of use-cases. While the CAS provides the dynamic state of a single actor only, the CPS may provide the dynamic state about multiple detected actors. The urgency for the information to be exchanged may thereby depend on the situation/scene (scenes not yet recognized but possibly later defined).

The above classification identified a certain priority in terms of safety. Of cause the Non-connected VRU may be seen as higher priority than the non-connected vehicle by one group while another group may see it opposite. Some of these aspects are further considered.

3.6.2 CP Communication requirements

The ETSI TR 103 562 [ER-17] introduces and analyses a number of possible different parameters for message configuration (i.e., message generation rules) to corresponding radio / transmission configuration. In the following, these are referenced and considered. The assumptions in the ETSI TR 103 562 reflect the current available technical specifications such as included in the IEEE 802.11 release 2018 [ER-61] and ETSI Release 1 [ER-63] standards With upcoming new technical solutions, these current references will have to be reconsidered.

The ETSI TR 103 562 considers the CPM dissemination via ITS-G5 Release 1. It does not specify what method(s) to use but identifies the required choices to make. When identifying the MCO concept also newer technologies currently being developed such as IEEE 802.11bd and 5G-NR needs to be considered.

CPM transmission activation (message generation rules) may vary for different types of ITS-S, e.g. vehicle ITS-S, roadside ITS-S, personal ITS-S. As long as the CP Service is active, the CPM generation should be managed by the CP Service.

The TR 103 562 provides the option to classify detected objects. Depending on the assigned object class, such as *vehicle*, *pedestrian*, *animal* and *others*, message generation may differ. Within the context of MCO, the differentiation of these classes is relevant as for different reasons both functional as business wise it may be of interest to use separate transmission approaches and channels for each of these classes. For this purpose, here the following classes are considered:

- Non-connected vehicles (passenger cars, vans, trucks and PTWs);
- Non-connected Others
    - Non-connected all types of bikes and mopeds;
    - Non-connected pedestrians (standard);
    - Non-connected prioritized 1 pedestrians (road workers, and related);
    - Non-connected prioritized 2 pedestrians (disabled and alike);
- Detected safety-critical objects;
- CAM Information Aggregation and
- Empty Road Segments (ERS).

The detailing of the classes is driven by the differentiation as recognized in the VRU analyses. Non-connected objects above identified as “Others” would functionally preferable be handled as subclasses but for the consideration of business cases these are expected not to be seen as subclasses but just as a different business case and therefore we may consider to only have a single level as identified in the following single level classification:

- Non-connected vehicles (passenger cars, vans, trucks and PTWs);
- Non-connected all types of bikes and mopeds;
- Non-connected pedestrians (standard);
- Non-connected prioritized 1 pedestrians (road workers, and related);
- Non-connected prioritized 2 pedestrians (disabled and alike);
- Non-connected others
- Detected safety-critical objects;
- CAM Information Aggregation and
- Empty Road Segments (ERS).

One additional reason to differentiate into classes is that simulation and validation of each of the classes themselves allows easier evaluations. As understood, the simulations in TR 103 562 are vehicle-based scenario’s also fitting to such an approach.

Note: it is assumed that CAM Information Aggregated CPMs are directionally transmitted in the applicable direction where the messages from other directions are not detected.

The size of the message depends on the number of objects and free spaces recognized and the confidence level chosen to share or not share related information. As depicted in Figure 9, the message consists of multiple containers that can be concatenated to form the CPM. The resulting message size increases with the number of objects to be reported within a CPM. It therefore can be inferred that in cities and other very dynamic traffic scenarios, the resulting message size may vary significantly.
However, the dynamic behaviour may be different compared to the CAM rate generation as the CAM is mainly depending on the dynamics of the transmitter. For the CPM generation depends on the dynamics of the detected objects and is therefore expected to vary to a higher degree.

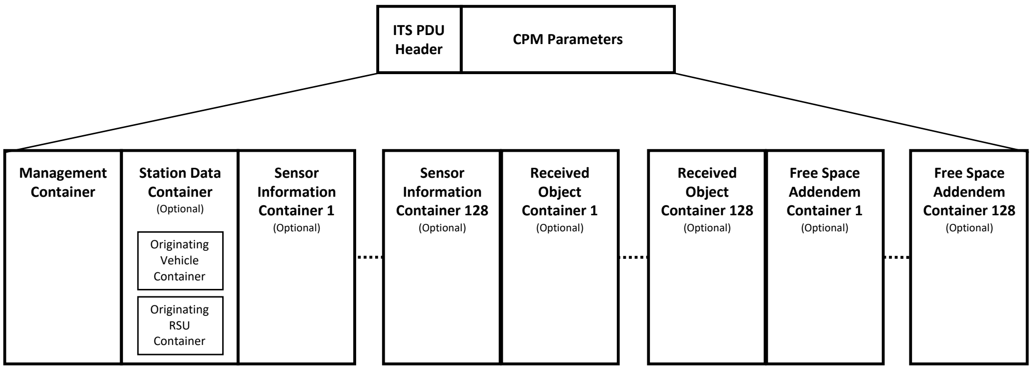

Figure 9: CPM message containers (ETSI TR 103 562).

ETSI TR 103 562 identified that the size may increase above the possibilities of the physical layer capabilities as specified in the IEEE 802.11p and therefore may require the support for segmentation and the transmission of multiple packets. Simulations as well as research show that CPM message has in general a size between 1000 – 1900 Byte including vehicles as well as other traffic participants.

As identified all CPM generation policies improve the Object Awareness Ratio (OAR) but differ depending on the scenario. It therefore may be desired to use that policy which is best suited for the specific scenario. As stated in the summary 5.4.1.4 in the ETSI TR 103 562 [ER-17], "The dynamic generation rules take into account the vehicles' dynamics and is more scalable than the periodic approaches that include all the perceived objects in all CPMs. As a result, the dynamic generation rules reduce the channel load generated compared to a periodic solution operating at 10 Hz, especially when considering the mechanism to reduce the CPM frequency (this mechanism can both reduce the channel load generated and improve the awareness). Although the periodic approach is able to outperform the dynamic generation rules proposed in terms of awareness, it comes at the cost of significantly higher channel load. Further analysis would be needed to understand the potential benefits (if any) of the higher awareness achieved by the periodic approach operating at 10Hz, since the interference generated is much higher than for the dynamic generation rules." For the context of MCO, further analysis should also be extended to further use cases. The ETSI TR 103 562 also assesses an MCO option, in which the CAM is disseminated in the CCH, whereas the CPM is transmitted in the SCH1. It is observed that the resulting channel load on both channels is reduced significantly. Especially when sharing the same channel, it is found that in situations of high message generation rates for both CAM and CPM, increased number of messages are dropped (at the DCC gatekeeper) for either message is observed. This behaviour is even more prominent, when applying the same transmission priority to both messages.

Consider the following case:
When considering MCO, in case more than one of the channels are in the relaxed mode it may be considered to use the more awareness delivering periodic mode although more channel capacity is used. The main aspect for an MCO approach is that either methods should be implantable. For the receiving side this would mean that they should just be able to receive the related information and be able to process them whatever mode is used.

In addition, redundancy mitigation techniques are an important mechanism to further reduce the resulting message size and therefore channel utilization. As objects may be either detected multiple times by multiple stations or even disseminate CAMs themselves, redundancy mitigation techniques can be exploited to further reduce resource requirements.
Within MCO, the Redundancy mitigation techniques are seen as part of the CPS and only the output as presented by the CPM service is the reference for any MCO definition. Table 4 represent the assumed CPM related MCO requirements.

Collective Perception Classes		Non-Connected Vehicles	Non-Connected Others				Detected Objects	CAM Aggregation	Emty Segments	Comment
	Objects		Bikes/Mopeds	Pedestrians	Road Workers	Disabled				
Requirements	Message	CPM-V	CPM-B	CPM-P	CPM-W	CPM-D	CPM-D	CPM-A	CPM-E	one CPM message can contain all listed object typ
Transmission Rate		1-10Hz	1-10Hz	1-10Hz	1-10Hz	1-10Hz	1-10Hz	1-10Hz	1-10Hz	all sensed and relevant objects within the set limits
Transmission dynamics		depends on speed of objects and own speed as well as protection level (e.g. high for VRU), CPM Tx rates can rapidly change								
Area of relevance urban		>150m	>150m	>150m	>150m	>150m	>150m	>150m	>150m	
Area of relevance suburban		>150m	>150m	>150m	>150m	>150m	>150m	>150m	>150m	
Area of relevance highways		>500m	-	-	>500m	-	>500m	>500m	>500m	
Message Size Urban		CPM 1000 - 1900 Byte; one CPM contains all sensed objects and package size Message size changes depending on number of detected objects, including vehicles, pedestrians, cyclists, all seen by the in-vehicle-perception sensors such as cameras and radars. including security certificate.								
Message Size Rural roads										
Message Size highways										
Message Latency, According to Current		CPM	CPM	CPM	CPM	CPM	CPM	CPM	CPM	
Message Priority to be defined										(on a level from 0-16, with 0 highest) See Annex A
Transmission mode		Multicast	Multicast	Multicast	Multicast	Multicast	Multicast	Multicast	Multicast	
Transmission type		Repetitive	Repetitive	Repetitive	Repetitive	Repetitive	Repetitive	Repetitive	Repetitive	
Urban network message channel load		see C2C-CC position paper on "Road Safety and Road Efficiency Spectrum Needs in the 5.9 GHz for C-ITS and Cooperative Automated Driving"								
Rural roads network message channel load										
Highway network message channel load										
V2V		X	X	X	X	X	X		X	
I2V and V2I		X	X	X	X	X	X	X	X	
V2E and E2V										
Reception Propability Requirement		Same Release 1	Same Release 1	Same Release 1	Same Release 1	Same Release 1	Same Release 1	Same Release 1	Same Release 1	
Security requirements		C-ITS	C-ITS	C-ITS	C-ITS	C-ITS	C-ITS	C-ITS	C-ITS	
Liability Impact		NO	NO	NO	NO	NO	NO	NO	NO	
Functional Safety Requirements										Functional safety requirement is derived from application
SOTIF		NO	NO	NO	NO	NO	NO	NO	NO	See Related chause
Position Accuracy level A		Same Release 1	Target <0.5m Minimum same as Release 1]	Target <0.5m Minimum same as Release 1]	Target <0.5m Minimum same as Release 1]	Target <0.5m Minimum same as Release 1]	Same Release 1	Same Release 1	Same Release 1	

Table 4: Derived communication requirements for CPM (Footnote* [5]**).**

Values provided in Table 4 are derived or based on simulation results provided in ETSI TR 103 562. It has to be considered that the resulting message sizes and generation frequency will be highly dependent on the traffic scenario.

With regards to channel use, there is no clear direction set but indicated it could be considered to identify that the CPM is used for different use cases and therefore could reside on the channel fitted to the specific use case.

[5] Note: % channel load is the allocated % of the channel load where 100% represents the maximum channel load before the channel congestion state is reached.

3.6.3 CP System related Requirements

As the purpose and operation of the CP service is similar to CAM the same System requirements are applicable and no SOTIF. Higher Functional Safety requirements must be derived by application and can be expected in future by more demanding applications.
As the confidence level is one of the parameters to identify whether an object is included no "Non-Connected Others" objects are included as long as they do not comply to the minimum Position Accuracy requirements.

3.7 Cooperative Connected Automated Driving (CCAD) Applications (Beyond Release-1)

3.7.1 Introduction

There where the Connected and Cooperative Automated Mobility (CCAM) [ER-32] initiative by the European Commission intends to address all Mobility related aspects in general, Cooperative and Connected Automated Driving (CCAD) considers only the Automated driving with focus on the vehicle specific aspects. Within C2C-CC, CCAD activities focus on that part of CCAD which is related to the information exchange to satisfy specific CCAD needs.

Following the C-ITS Methodology for MCO the focus is on maximizing the awareness which started by sharing own position, the speed and other elements of the road user own dynamic state via CAM now begin extended by CPM to share information about objects around and in the following extended with sharing of information about the predicted behaviour of the road user own dynamic state.

As human road users, we know where we are going, when we make a turn, we in principle inform others by initiating the blinker. For automated vehicles this is not so much different. Just sharing own intensions is a step to cooperative automated driving, it is seen as a basic form of Maneuver Coordination. With regards to CCAD initial projects like AutoNet2030 EU project [ER-33] focus on several of these aspects and is providing an increasing view on this kind of extension of the awareness. Important work for Maneuver Coordination is ongoing in German research project IMAGinE [ER-30]. Analyses in these projects also show that Maneuver Coordination applications while being used for automated driving they increase road safety.

Whereas CAM is bringing general awareness, the Maneuver Coordination service (MCS) provides behavioural prediction as captured in the ETSI report MCS TR 103 578 [ER-19]. This report provides initial basic information about this kind of information exchange and is used as reference in the following paragraph.

3.7.2 CCAD Communication requirements

The general intension is to improve the predictability of the road traffic in the vicinity of vehicles by using direct communication. At the moment we identify two types of predictions: predictions with passive interaction and prediction with active interaction.

Passive interaction considers for instance the right of way rules of keeping a safety distance. Active interaction is, if one vehicle retreat from its right-of-way to render possible a Maneuver of another vehicles (for instance, if a vehicle on a highway increases the distance to the vehicle in front of it, to allow a third vehicle to merge).

To improve the prediction with passive interaction, connected and automated vehicle share their short-term driving intentions with other connected and automated vehicles in their proximity so that those vehicles can take this intention into account in their automation process. Furthermore, the concepts provide means to improve the prediction with active interaction, so that all involved vehicles have a common understanding of the upcoming active interaction before they initiate any physical actions. This includes a possibility to request an active interaction, which includes an exact description of the envisioned active interaction and also includes means to indicate whether such a request is accepted or denied. A nice example is provided in 5.2.3 of the TR 103 578 [ER-19] report.

While current vehicle developments focus of bringing more predictive awareness, Authorities expect to provide assisting regulatory guidance increasing time gaps between vehicle for instance to initiate merging of other traffic (merge assist use case). As this is described in the TR 103 578 [ER-19], it may be considered as part of the MCS specification although this may end up in another message set specification. For the purpose of this analyses it is considered in 3.7.2.2.

The additional MCS communication related aspect which can be considered at this moment is that it may be expected that future Maneuver Coordination Messages (MCM's) may be used for negotiation purposes similar to PCM. However, MCM are considered not to be part of the decision state machine but are just safety automation information and therefore are expected to be ASIL QM level while PCM's have higher ASIL level. All other use cases should be covered by existing DENM or other messages.

The Maneuver Coordination Service (MCS) is intended to provide information about intensions of the driver or the vehicle (when automated). The following behaviour levels are distinguished:

- Planned Trajectory
- Intended Trajectory
- Proposed Trajectory
- Mandatory Trajectory

3.7.2.1 *Planned Trajectory*

Automated vehicle usually implements the sense-plan-act principle with an additional prediction step. At first, they have to perceive (sense) their area of relevance and predict the behavior of dynamic objects. Thereafter they compute a plan how to and finally act according to the plan. Adoption of the plan can be caused by many reasons and be recalculated every 1/10 of a second. It could be imagined to only share changes in the plan however road users entering the area of relevance will not know all and therefore the complete planned trajectory should be provided. The transmission rate depends on the dynamic state of the vehicle and possibly the general dynamic situation in the relevance area may have to be considered. The MCM rate therefore has some similarities with from a capacity point of view although the dynamics will be different. For example, when in front of a traffic light the planned trajectory is in general known and when accelerating nothing changes in the trajectory which is different from the CAM behaviour. The planned trajectory covers the short term (e.g. 5 sec) driving depending on the speed in a proximity of about 100 meters. The MCM size varies as it depends of the trajectory complexity. This is similar to the variation in the CAM trajectory representation. Not only Vehicles but also VRUs or RSUs may send MCM's.

3.7.2.2 *Intended Trajectory*

A Vehicle or other road user may have a Plan, but it may interfere with other road user planned trajectories. For instance, when a vehicle would like to merge when on a ramp and going onto the highway while there is a lot of traffic. In those cases that based on the dynamic situation detected a Vehicle may send intended trajectories to show its interest beside the Planned

Trajectory which may be shorter in these occasions. The Transmission of an Intended Trajectory may be seen as a single additional Planned Trajectory for the purpose of this analyses.

3.7.2.3 *Proposed Trajectory*

In the TR 103 578 [ER-19] an Infrastructure based flow optimizing MCM based concept is presented in 5.3 in which a mixture of SAE level 1-5 vehicles is expected to participate in traffic. As for instance as presented in Figure 10 Lane Change Assist at Bus stop (LCA-B), Vehicle S wants to overtake the stationary Bus. Any Road user or other ITS-S equipped road safety stakeholder could analyse the road traffic situation based on received C-ITS information combined with other sensor data and advice or manage the road users how to act to realize an efficient and safe resolution of the situation.
Instructions on legal bases could be provided by providing IVI and DENM messages but also suggestions could be made how to behave. This could be done by providing proposed trajectory patterns to the road users in the relevance area.

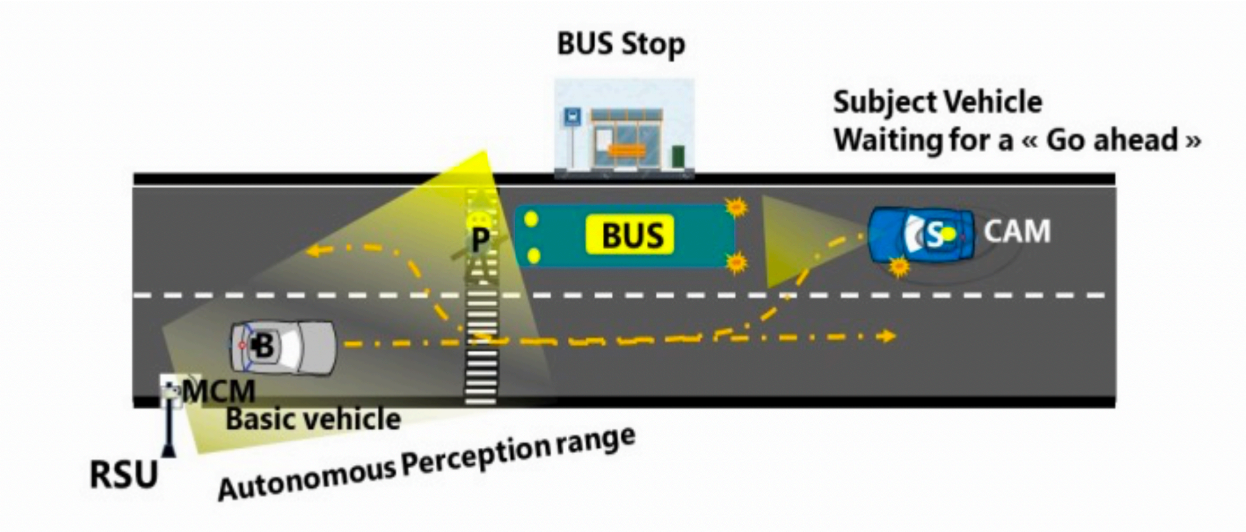

Figure 10: LCA-B Situation description (ETSI TR 103 578).

By using one of these methods the situation of shared liability is avoided. The legal binding methods based on IVI and warning based on DENM are not covered here but are covered as part of Day-1 services operation.
Proposed trajectories are expected to be mostly used in specific use cases for instance at dangerous crossovers, schools and bus stops as in Figure 10. As the nature of use is similar to that of an intended Trajectory it may be assumed that for the purpose of this report the communication requirements are similar.

3.7.2.4 *Mandatory Trajectory*

The TR 103 578 [ER-19] currently does not identify Mandatory Trajectories but these could imagine for the purpose of prioritized traffic. For these also several different types could be imagined, such as police, fire brigade and public transportation. For the purpose of the MCO concept this is considered as one of the trajectories required message exchange only.

3.7.2.5 *Expected MCM Message requirements.*

Based on the analyses in the previous paragraphs the MCM behavior lead to projected communication requirements are represented in Table 5.

Manoeuvre Coordination Service	Planned Trajectory	Initiated Trajectory	Proposed Trajectory	Mandatory Trajectory	Comment
Requirements / Message	MCM	MCM	MCM	MCM	
Transmission Rate	1-10Hz	1-10Hz	1-10Hz	1-10Hz	
Transmission dynamics	Medium	Medium	Medium	Medium	Depends on vehicle's own speed
Area of relevance urban	>150m	>150m	>150m	>150m	
Area of relevance rural roads	>150m	>150m	>150m	>150m	
Area of relevance highways	>500m	>500m	>500m	>500m	
Message Size Urban/Rural/Hiughway	1000 - 1300 Byte. Message size changes depending on length of predicted vehicle's own trajectory and number of alternative trajectories. All trajectories included in one MCM				
Message Latency, According to Current					To be diefined in MCM
Message Priority to be defined					(on a level from 0-16, with 0 highest) See Annex A
Transmission mode	Multicast	Multicast	Multicast	Multicast	
Transmission type	Repetitive	event, repetitive	event, repetitive	event, repetitive	the most important MCM for planned and alternative trajectories must be sent repititive
Urban network message channel load	see C2C-CC position paper on "Road Safety and Road Efficiency Spectrum Needs in the 5.9 GHz for C-ITS and Cooperative Automated Driving"				
Rural roads network message channel load					
Highway network message channel load					
V2V	X	X	X	X	
I2V and V2I		X	X	X	
V2E and E2V					
Reception Propability Requirement	Same Release 1	Same Release 1	Same Release 1	Same Release 1	
Security requirements	C-ITS	C-ITS	C-ITS	C-ITS	
Liability Impact	NO	NO	NO	NO	
Functional Safety Requirements					Functional safety requirement is derived from application
SOTIF	NO	NO	NO	NO	See Related chause
Position Accuracy level A	Depending on Use Case	Depending on Use Case	Depending on Use Case	Depending on Use Case	In most cases it moves to 0.5 m

Table 5: Derived communication requirements for MCM (**Footnote* [6]**) [ER-76].

With regards to channel use, there is no clear direction set and further message analyses should be realized however it can be expected to realize this in a service channel.

The Assumed MCM Message should include just a basic set of containers such as the ITS PDU header, Management Container and may consists of a Planned Trajectory container, an Intended Trajectory container and a Proposed Trajectory container (Figure 11).

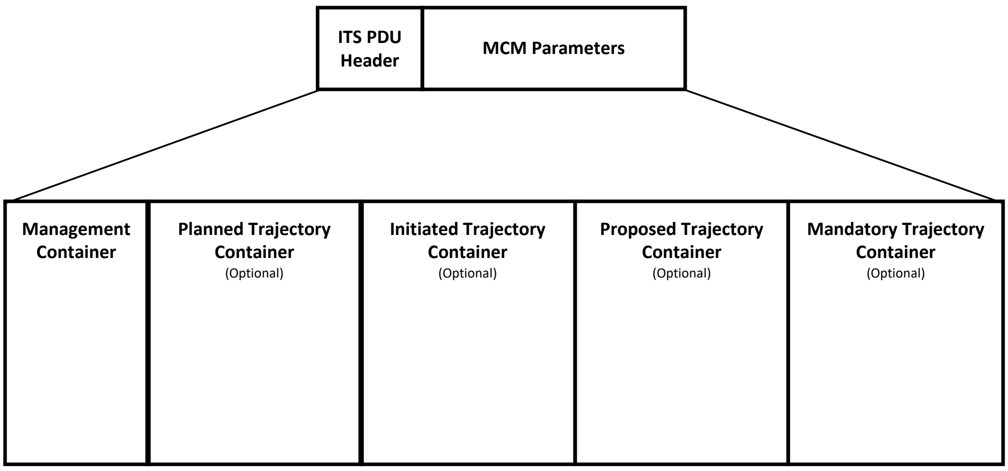

Figure 11: MCM message containers (assumed)

3.7.3 CCAD message exchange System Requirements

When specifying the system requirements, it needs to be noted that this only concerns the C-ITS related information exchange supporting CCAD applications. In many of the use cases it is not

[6] Note: % channel load is the allocated % of the channel load where 100% represents the maximum channel load before the channel congestion state is reached. There are no messages and therefor assumed similar to CAM.

sufficient to provide a Release-1 level of position accuracy. Some use cases will require an accuracy of better than 0.5 meter. As long as it is awareness only an ASIL level QM is required. Depending on the exact use case the functional safety requirements needs to be derived.

3.8 Other C-ITS Applications (Beyond Release-1)

3.8.1 Introduction

In the previous paragraphs the Vehicle related functional communication related requirements are identified. In the next paragraphs other C-ITS Applications relevant to other C-ITS stakeholders which may have impact on an MCO concept are considered.

Only currently known application areas are covered such as Infrastructure, Agriculture, Special Vehicles and Urban-Rail are considered.

3.8.2 Other Communication requirements

3.8.2.1 *Infrastructure safety Communication requirements*

There are 4 areas of improvement foreseen.

- Extensions on SPAT/MAP including support for Vehicle automation (Road Intersection Safety)
- Vehicle Prioritisation for emergency and public transport
- Pedestrian Safety
- Transport pollution management
- Other Regulatorily information

Currently Basic SPAT/MAP Traffic light signalling is part of Release-1 deployment providing some basic Intersection services. Different projects especially in Germany focus on optimizing this kind of information exchange to support automation applications also to realize efficient Intersection crossing and GLOSA related applications.

Further detailing and improving of this kind of information exchange will lead to addition information exchange. As current SPAT/MAP message exchange doesn't have a significant high priority to be transmitted it needs to be considered how to increase this for instance to provide it with higher priority in a different channel. Intersection safety will partly consist of making use of additional awareness applications supported by message services as CPM, IVI and DENM. For these applications additional more and more prioritisation related applications are being developed.

Vehicle Prioritisation has two elements:

- Warning others for arriving prioritized vehicles, which is supported by current CAM and DENM sets for which no new requirements need to be fulfilled. This is applicable for all emergency vehicles. In CAM the status of the Vehicle can be included and in a DENM message other road users may be warned to go aside for instance for realisation of a safety corridor. In a later stage a mandatory trajectory could be provided (no evaluation on going), see 3.7.2.
- Prioritisation to realize way through at intersections. Bringing awareness by the priority vehicle via Pre-emption information exchange between prioritized vehicles and RSUs/Traffic Lights. This is specialized information exchange which requires a high priority level.

Infrastructure systems are ITS systems which can, as they have a fixed position, identify their position quite accurately and therefore can provide information with high position accuracy. Additionally, Infrastructure systems can be equipped with advanced behavioural analyses software for the identification of road crossing pedestrians. These 2 factors make infrastructure systems the excellent candidate to realize intersection and road crossing safety for VRU's. The VRU related communication requirements are captured in Chapter 3.6.

In Vehicle Signage (IVS) by the exchange of In Vehicle Information (IVI) is providing information about speed limits and other road signs as part of Day-1 Applications. As new application for instance information about environmental restricted areas or limitations of heights of bridge's or restrictions for platooning require additional legal awareness. This kind of awareness is expected to be realized by extension of the IVI service. The additions in general have similar priority then current provided IVS information but is some occasions me need to have higher priority.

For the protection of our environment, pollution limitations are being set and pollution values should be shared such that estimation can be realized through crowdsourcing (Figure 12).

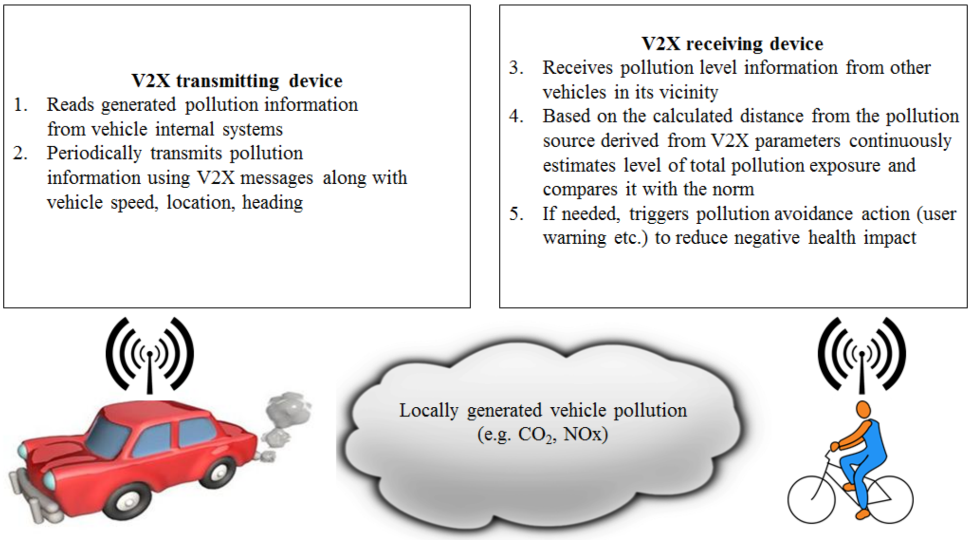

Figure 12: Simplified diagram of the V2X based emissions crowdsourcing approach

For the support of transport pollution management applications, the ETSI TR 103 496 ([ER-64]) identifies methods to exchange related information. The exchange of this information as another use case which will make use of extended existing messages sets. For the purpose of this use case the CAM should be extended with a pollution container allowing road users to provide information about their own pollution levels statically and dynamically. Via DENM extensions in the form of an additional CauseCode and SubCauseCode awareness of current or expected pollution levels can be shared which may facilitate the change of the driving mode. As third the IVIM should be extended to include legal environmental area restrictions with an additional pollution container. The required behaviour of the messages does not need to change, depending on the message type only message length and transmission frequency are influenced.

While current vehicle developments focus of bringing more predictive awareness, Authorities expect to provide assistant regulatory guidance increasing time gabs between vehicle for instance

to initiate merging of other traffic (merge assist use case), as described in the TR 103 578 [ER-19]. This may result in additional Infrastructure message sets and behavioural requirements. Most of the expected additional are regularly and warning related messages and therefore should be seen as event-oriented messages, requiring same bandwidth but not a major about additional to the awareness messages already identified and similar to IVS.
Other vehicle automation related information exchange is related to Maneuver Coordination and Proposed Trajectory information exchange such as described in Chapter 3.7.2.3.

The significant increase in Infrastructure related applications will mostly result in local and specific information exchange but not in quantitative additional information exchange. For these applications it is more important to realize a robust information exchange not too much depending on possible radio congestion situations. As many applications are traffic efficiency and less safety oriented it would still be preferred to provide some priority for these information exchanges.
Table 6 provides an overview of additional messages to be exchanged for the Authority Infrastructure direct communication information exchange.

VRU use cases	Infrastructure Safety				Prioritized Traffic					Environmental Polution			Legal	Comment
Requirements / Messages	SPATEM	MAPEM	DENM's	IVIM	CAM	DENM's	MCM	SPAT	MAP	CAM	DENM's	IVIM	IVIM	
Transmission Rate	1-10Hz	1-10Hz	-	-	1-10Hz	-	1-10Hz	1-10Hz	1-10Hz	1-10Hz	-	-	-	
Transmission dynamics	low	high	high	high	high	high	Medium	low	high	low	high	high	high	
Area of relevance urban	150m	150m	150m	150m	150m	150m	150m	150m	150m	70m	>70m	>70m	>70m	
Area of relevance suburban roads	150m	150m	150m	150m	150m	150m	150m	150m	150m	>150m	>70m	>70m	>70m	
Area of relevance highways	500m	500m	500m	500m	500m	500m	500m	500m	500m	>200m	>70m	>70m	>70m	
Message Size	1200 Byte		1000 Bytes	400 Bytes	average 400 Byte (250-800 Bytes)	1000 Bytes	1000 Byte	1200 Byte		average 400 Byte (250-800 Bytes)	1000 Bytes	400 Bytes	400 Bytes	for spectrum needs a combined message size for SPATEM, MAPEM, IVIM of 1200 Byte
Message Latency, According to Current	SPATEM	MAPEM	DENM	IVIM	CAM	DENM	MCM	SPAT	MAP	CAM	DENM	IVIM	IVIM	
Message Priority to be defined														(on a level from 0-16, with 0 highest) See Annex A
Transmission mode	Multicast	Multicast	Multicast	Multicast	Multicast	Multicast	Multicast	Multicast	Multicast	Multicast	Multicast	Multicast	Multicast	
Transmission type	Repetitive	Repetitive	Event	Repetitive	Repetitive	Event	event, repetiive	Repetitive	Repetitive	Repetitive	Event	Event	Event	
Urban network message channel load	see C2C-CC position paper on "Road Safety and Road Efficiency Spectrum Needs in the 5.9 GHz for C-ITS and Cooperative Automated Driving"				<1%	<1%	<2%	<3%	<0%	<80%	<2%	<2%	<2%	For the awareness type of messages The amount of messages effected is identified but the amount of messages is not increasing only the size of the message is. See Footnote*
Rural roads network message channel loa					<1%	<1%	<2%	<5%	<0%	<80%	<2%	<2%	<2%	
Highway network message channel load					<1%	<1%	<2%	<5%	<0%	<80%	<2%	<2%	<2%	
V2V	-	-	-	-	X	X	X	-	-	X	-	-	-	
I2V and V2I	X	X	X	X	X	X	X	X	X	X	X	X	X	
V2E and E2V	-	-	-	-	-	-		-	-	-	-	-	-	
Reception Propability Requirement	Standard	Standard	Standard	Standard	Standard	Standard	Same Release 1	Standard	Standard	Standard	Standard	Standard	Standard	
Security requirements	C-ITS	C-ITS	C-ITS	C-ITS	C-ITS	C-ITS	C-ITS	C-ITS	C-ITS	C-ITS	C-ITS	C-ITS	C-ITS	
Liability Impact	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	
Functional Safety Requirements														Functional safety requirement is derived from application
SOTIF	unknown	unknown	unknown	unknown	unknown	unknown	unknown	unknown	unknown	unknown	unknown	unknown	unknown	See Related chause
Position Accuracy level A	Standard	Standard	Standard	Standard	Standard	Standard	Standard	Standard	Standard	Standard	Standard	Standard	Standard	

Table 6: Communication requirements additional Infrastructure information exchange (**Footnote*** [7]) [ER-76].

With regards to channel use, currently most message is provided in the control channel (CCH). For the introduction of more complex SPATEM and MAPEM as well as prioritisation the use of another channel needs to be considered. Prioritisation may not necessarily be recognized as safety relevant.

3.8.2.2 *Agriculture Communication requirements*

The Agricultural Industry Electronics Foundation e.V. (AEF) recognizes the potential of ITS-G5 in combination with their current use cases based on other protocols. They are currently starting to engage with C2C-CC, but no concrete expectations have been expressed. For the purpose of having an indication of possible MCO requirements the following has being identified.

[7] Note: % channel load is the allocated % of the channel load where 100% represents the maximum channel load before the channel congestion state is reached. There are no messages and therefor assumed similar to CAM.

Tractors and other Agricultural equipment make use of roads (highways only in special cases). For that and their special nature it is relevant for this road user to bring awareness to other road users that they are present and therefore the AEF finds it important to realize C-ITS for this type of vehicle. From this perspective there is no difference with other vehicles and therefore it is not seen as a special case needing additional messages having additional MCO requirements.

As Agriculture equipment is used for specific purpose other than for on the road, for relevant agriculture related use cases new/additional information exchange is of interest to the AEF community. In most cases these use cases are executed off-road but as off-road areas are in many cases a side a road these need to be considered as part as a general MCO conceptual approach and agricultural use cases should be considered being part of an overall MCO approach. Therefore, the following active states are relevant to be recognized:

1. The agriculture equipment is participating in normal vehicle in road traffic;
2. The agriculture equipment is not participating in normal vehicle in road traffic and only in specific agriculture related areas without having influence on normal road traffic and
3. The agriculture equipment is participating as normal vehicle in road traffic and is actively executing agricultural processes.

These different states need to be clearly identified and correct active state communicated in the CAM message.

As AEF equipment is used in controlled environments the liability is within the hand of a single stakeholder and less complex to manage then for normal road traffic. In this special case central control for automated use cases can be considered resulting in possible exceptional unicast information exchange and control.

Depending on the active state specific Functional Safety and SOTIF requirements are expected to be applicable specifically in active state number 3. We have to assume that agriculture equipment is expected to use existing message sets such as CAM, DENM, SPAT/MAP, IVIM, PAM, PCM and SAM where possible and introducing extensions there where relevant.

For the specific agricultural information exchange, it may be assumed to define a specific information exchanging message set Agriculture Equipment Messages (AEM) to be specified by agriculture stakeholders.

For the time being the MCO requirements as identified in Table 7 are considered.

What is known is that for high precision work on off road areas high position accuracy is required and related RSU like equipment is used. For the moment no other use cases are known.

The AEF should provide a list of use cases and ideas of expected required communication enough to identify the MCO requirements. This may include message set specifications.

Agriculture / Special Vehicles			Comment
Requirements / **Messages**	**All vehicle related messages**	**AEM**	
Transmission Rate	Agriculture and Special Vehicles are recognized as standard Vehicles when particpating in road traffic and therefore should share the same information. This needs to include the active operational state in the CAM.	1Hz	
Transmission dynamics		high	
Area of relevance urban		100m	
Area of relevance rural roads		100m	
Area of relevance rural highways		100m	
Message Size		<1000 Bytes	
Message Latency, According to Current		?	To be defined in Message specification
Message Priority to be defined			(on a level from 0-16, with 0 highest) See Annex A
Transmission mode		Unicast	
Transmission type		Repeditive/Event	
Urban network message channel load		<10%	See Footnote*
Rural roads network message channel load			
Highway network message channel load			
V2V		X	
I2V and V2I		X	
V2E and E2V		-	
Reception Propability Requirement		Standard	
Security requirements		Advanced C-ITS	
Liability Impact		NO	
Functional Safety Requirements		ASIL ?	See Related chause
SOTIF		unknown	See Related chause
Position Accuracy level A		<10 cm	

Table 7: Derived communication requirements for Agriculture Equipment (Footnote* [8]**).**

With regards to channel use, there is no clear direction set at this point of time and this needs to be done by Agriculture representatives. The only aspects to recognize is when it is only used to precisely Maneuver over the land this may be considered as non-safety.

3.8.2.3 *Special Vehicles Communication requirements*

Under special vehicles all heavy and specialized other vehicles which are not covered by previous paragraphs such as harbour load and unload equipment and terrain trucks for the transport of sand or other similar materials other than those which are covered by the general truck description, road work equipment, etc are identified.

When actively participating in normal road traffic they are not expected to provide significant MCO requirements. There Vehicles may use special specific message sets for direct communication with other special Vehicles but as these type of vehicles are mostly individually present in an specific area of relevance, it is not expected that they contribute significantly to information exchange and may only require to exchange their specific data on an agreed specific channel.

For the moment no other specific information exchange requirements are known. For the purpose of the creation of an adequate MCO concept supporting special vehicles for the moment similar requirements as recognized for agriculture equipment are considered.

[8] Note: % channel load is the allocated % of the channel load where 100% represents the maximum channel load before the channel congestion state is reached. There are no messages and therefor assumed similar to CAM.

3.8.2.4 *Urban Rail and Rail Communication requirements*

CBTC systems for the moment are not expected to use any ITS-G5 protocols. CBTC systems is Train to Ground (T2G) communication. It makes use of GSM-R (GSM for Railways) or IEEE 802.11 and other technologies and solutions.

While GSM-R is built based on a GSM network, the 802.11 solution makes use of the private network of wayside units. Both technologies ensure connectivity of the trains with the control centre in order to receive control information.

Various application-oriented control networks were defined over those wireless access technologies in the past decades. For the purpose of MCO for the use of Road Transport only coexistence with Urban Rail needs to be ensured. Urban Rail solutions make use of non-harmonized private protocols which do not interoperate or cooperate. These are specific for specific urban rail tracks and trains. Cooperation with ITS-G5 nor C-V2x for Road Transport is therefore not possible and only technical coexistence functional requirement are required to be considered as identified in spectrum Part 2. under the ECC DEC (08)01 [ER-65] and REC (08)01 [ER-66] spectrum regulation.

For the definition of an MCO concept the coexistence in the traffic safety band 184 needs to be considered. This includes the coexistence and precedency as specified in the ECC DEC (08)01 regulation currently being updated.

3.8.3 Other System related requirements

3.8.3.1 *Infrastructure Safety System requirements*

Road users are making use of the road physical infrastructure to move from A to B, when sharing safety related information to others they do not know for whom this may be of relevance and they have no notion of radio properties of the physical area they are in at any given time. They may have notion about their own dynamic state only and may transmit specific information just around or in a single specific direction.

Infrastructure equipment is placed in specific known road physical infrastructure and therefore it can know for each use case the specific relevance area and the physical infrastructure radio properties and by this may specify specific transmission patterns to satisfy specific use cases.

For example, on a road crossing (Figure 13) it could be possible to use specific placed RSU's which focus on specific areas of relevance. A more centralized, for instance the traffic light system or the traffic centre can use case specifically direct information to a specific area without effecting other areas and realize spectrum efficiency and reduce the change of spectrum congestion. To realize such more complex radio reception areas active antennas could be used.

In general, As RSUs are placed in a controlled environment these can be tailored for specific use and therefore may be an effective solution to specifically increase safety in urban areas for VRU's and lesser but also for Vehicles. Because RSUs have a fixed location, CBTC interfering paters are known and therefore coexistence with CBTC can be managed and easier for RSU's to use the CBTC priorities channel.

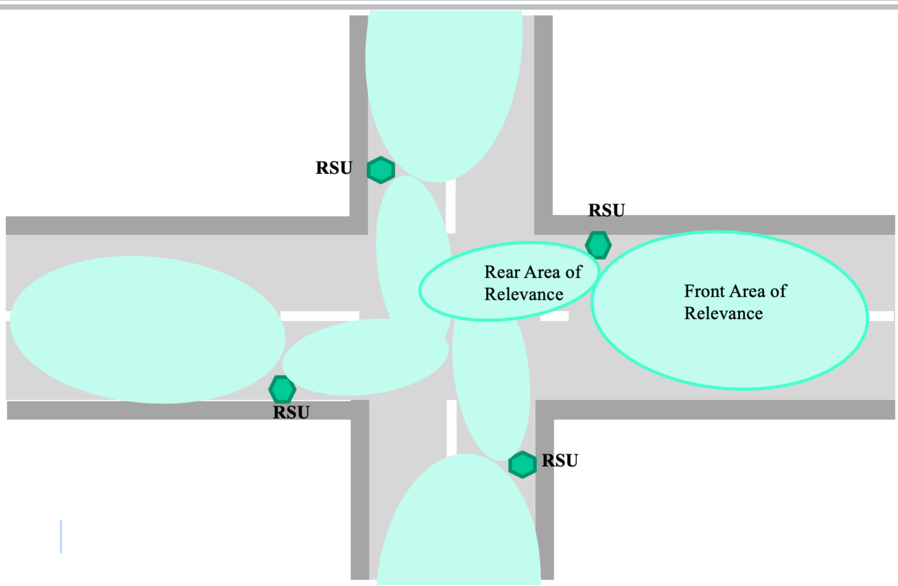

Figure 13: RSU Placement and Message transmission patterns example

3.8.3.2 *Agriculture System requirements*

For Agriculture equipment there are 2 situations to be recognized.

- The equipment participates in normal traffic. In this case no specific measures are needed except that agriculture equipment should operate as normal vehicles of special vehicle type.
- The equipment is active on private area. As such they should not send any standard Road awareness messages but only specific private area related messages. Take the following scenario in consideration: A lawn mower mowing the grass close to roads. A clear difference must be made when it is or isn't on the road. It is suggested not to transmit the agriculture equipment relevant messages not in the CCH.

The work on agriculture specific private areas often require high position accuracy, it therefore may make use of local RSU stations to support this position accuracy requirement. 2 use cases are initially considered:

- Staying on an accurate trajectory to work on the land.
- To highly accurately let one agriculture equipment, follow the other equipment automatically.

Other requirements are not known at the moment.

3.8.3.3 *Special Vehicles System requirements*

For the moment the same system requirements as for agriculture system requirements are assumed.

3.8.3.4 *Urban Rail and Rail Systems related System requirements*

These are not of relevance for the definition of an Road Transport MCO concept except for the aspect of interference. Interference between C-ITS and CBTC systems can be best managed as identified in 3.8.3.1.

4 General MCO System related requirements

4.1 Introduction

For the realization of an implementable MCO concept not only functional requirements but also system technical aspects need to be considered. This also include services for the operation of the system. In this Chapter only those aspects are considered which are expected to have influence on the MCO concept. The following aspects are considered:

- Service supporting services
  - Service Announcement Message (SAM)
  - Position Augmentation Message (PAM)
  - Security Certificate Exchange
- Functional use of Spectrum;
- Safety System requirements
  - Functional Safety (ISO 26262 [ER-53]) and
  - Safety of the Intended Functionality (SOTIF, ISO PAS 21448 [ER-54]).

4.2 Service Announcement (SA) System Service (Beyond Release-1)

4.2.1 Introduction

The use of the Service Announcement Service (SAS) as specified in ETS EN 302 890-1 [ER-25] provides a method to be informed where and when a service can be used. The only thing needed is that it is agreed where the Service Announcement Message (SAM) is shared such that all ITS-S's when of interest have access to the interested services.

The use of SA brings flexibility to how and where the exchange of information may take place. It can be the main information provided by the initiating station, the station who also transmits the SAM, or it can be by the reacting station. The SA service may lead to the reception of broadcasted or multicasted information by the initiating station, but it may also initiate an unicast communication between the initiator and the specific receiver. The SA service is a flexible and technology neutral mechanism which allows systems to be connected through Internet mechanisms or just providing a link to a radio and specific protocol.

For the purpose of the exchange of relevant safety related information exchange between C-ITS stations the use of the SAS needs to be carefully considered.

For Platooning all negotiations and control information exchange requires handshaking and a number of alliterations and continues information exchange. In addition, this application has extended safety requirements compared to the basic Release-1 awareness applications. SOTIF and Functional Safety requirements require a more robust communication path. The SAS itself is just an announcement and therefore does itself not have influence of safety and therefore there has no critical safety level.

The SAM is an awareness message as it makes ITS-S aware of the specific existing services in the area of relevance identified by the SAM. The use, of SAS can to be considered for applications which require larger files to be exchanged or for instance have specific other application which for instance require higher security of privacy requirements.

The SAS can be used as generalised service reference point for offering services to C-ITS stations whether those services require information exchange through the C-ITS specific services themselves of whether it concerns services making use of any other kind of communication (DAB+, Internet, etc. It therefore requires having a single point of access within the C-ITS environment. This means that SAS should be offered on a fixed channel and never change.

Best is to realize this on the CCH, but another fixed channel is also possible. It is a difficult business case but in case that in a specific area a lot of SAS's are offered, businesses could agree to realize an SAS which provides information on which channel or reference other SAS's can be found. It is not expected that such redirecting SAS services will be used often if ever, but the mechanism supports it. In principle in an area the amount of SAS's should be limited to just a few as depicted in Table 8.

Service Announcement		Comment
Requirements / **Messages**	**SAM**	
Transmission Rate	1 Hz	
Transmission dynamics	Low	
Area of relevance urban	200 m	
Area of relevance rural roads	200 m	
Area of relevance rural highways	200 m	
Message Size	300 Bytes	
Message Latency, According to Current	SAM	
Message Priority to be defined		(on a level from 0-16, with 0 highest) See Annex A
Transmission mode	Multicast	
Transmission type	Repeditive	
Urban network message channel load	<2%	
Rural roads network message channel load	<2%	
Highway network message channel load	<2%	
V2V	-	
I2V and V2I	X	
V2E and E2V	-	
Reception Propability Requirement	Standard	
Security requirements	C-ITS	
Liability Impact	NO	
Functional Safety Requirements	ASIL QM	
SOTIF	NO	
Position Accuracy level A	Standard	

Table 8: Derived communication requirements for SAS (Footnote* [9]**).**

With regards to channel use, the SA services may support safety related services but also non-safety related services. Possibly in future there could be differentiated SA's in different channels but for now it is foreseen that only a general one will be installed. As the SA service may be used for safety services the SA services shall reside in one of the safety channels.

4.2.2 SAS System requirements

No SAS specific system requirements are defined nor foreseen at this time.

4.3 Position Augmentation (PA) System Services (Beyond Release-1)

4.3.1 Introduction

By means of GNSS systems ITS-S's can determine their position depending on the access to GNSS satellites. In open field this is simpler than in urban areas, mountains and forests, where this may be much more difficult, and in tunnels impossible. As result the position accuracy

[9] Note: % channel load is the allocated % of the channel load where 100% represents the maximum channel load before the channel congestion state is reached. There are no messages and therefor assumed similar to CAM.

depends on the accuracy of the GNSS system and the environment the information needs to be received in.

Analyses done in Europe showed average variations between 1-7 meter. The 7 meter accuracy is in urban areas there where you would like to have a much better accuracy then in open field.

Release-1 applications result in basic generic warnings and awareness information exchange, for which current GNSS capabilities are seen as sufficient. VRU and Automation services for instance have extended position accuracy requirements of better than <25 cm.

GNSS will develop further and higher accuracies also enabled by Galileo can be expected, however it is not foreseen that this <25 cm can be realized in those scenarios as mentioned above.

Position Augmentation Services (PASs) are used to improve the position accuracy. Different types depending on different methods are known. For a few the exchange of information between ITS-Ss is essential. The ETSI EN 302 890-2 [ER-26] (Currently in final draft) includes the way such services can be used and includes the description of 2 methods. One is fully included and another reference to the Infrastructure protocol specification ETSI TS 103 301 [ER-36].

There will be several types of Position Augmentation Messages (PAMs). In the EN 302 890-2 the Roadside Ranging augmentation service (RRS) is specified, and for differential mode there is the GNSS Positioning Correction (GPC) augmentation service based on RTK in the TS 103 301 resulting in GNSS Correction Message (GCM) exchange.

4.3.2 PA Communication requirements

GNSS differential mode is a known augmentation method and is defined in different standards such as RTCM 1005, 1077, 1087, 1097 [ER-67]. It is based on providing additional information via ground stations. This could be RSUs but also cellular base stations. The EN 302 890-2 and TS 103 301 specify how to implement it in the ITS-Station Architecture when using ITS-G5.

For the distribution of the RTK RSU broadcast the related information in their area for the use in a larger area up to 5000 meters (see Table 9).

The Roadside Ranging augmentation service (RRS) is triangulation based requiring RSU's not to be in a straight line, which is foreseen as an issue for use on highways. It therefore is more usable in urban environments, there where also the additional accuracy is required.

Both Infrastructure and Vehicle ITS-S's are active, but a security header is not applicable for RRM, because RSU just sends back a MAC acknowledgement, it depends on the CAM security that a vehicle know (and trusts) the RSUs. So, the RRM unicast must be sent without Security header by the vehicle, and even so the wireless congestion issue is a problem (see below). The RRM messages are short, but the effect of contention window is not negligible (take up almost same time for the unicast + ACK as the data transmission itself). It is recommended to limit the transmission rate to "An ITS-S shall transmit no more than 1 probe frame in any 1 sec period to an R-ITS-S" while not using a security header.

With regards to channel use, PA services may be considered as not safety related as they do not direct have effect on safety situations. As they may be essential for the operation of specific safety related use cases such as VRU's they may be considered still as safety related.

GNSS Positioning Correction (GCM) & Roadside Ranging Augmentation (RRM)			Comment
Requirements / Messages	GCM	RRM	
Transmission Rate (RTCM 1077+1087+1097)	1*3 Hz	Typical 9~12 Hz, Max'20Hz.	GCM: 1 Hz each for three payload types. The GCM service announcement (RTCM 1005) is also 1 Hz, but much shorter message type. RRM: Max 20 Hz but will vary from 3~12Hz. Typically like CAM generation rules (range measurements will align with vehicle dynamics). There is a max limit of 20Hz as per EN 302 571, so even if the application is going to request 60Hz the DCC is going to drop the packets (and limit it to 20Hz). Which RSUs to range to and how much to range is left as a differentation feature for product developers. The standards sets the max limits only (which is the same as curent EN 302 571 and later will be capped by the usage rate of a car to be specified as less than 3% in the new EN 302 571).
Transmission dynamics	Average	Not	The GCM message has a length variation (see the message size information below), while the RRM has fixed size.
Area of relevance urban	1000 m	300 m	Multi-hop broadcast can be used in GCM case, and single-hop unicast in RRM case
Area of relevance rural roads	+/- 5000 m	700 m	Estimation: half-distance between roadside units. RRM: used in Tunnels.
Area of relevance rural highways	+/- 1000 m	1000 m	Estimation: half-distance between roadside units. RRM: not applicable because there will be no triangulation possibility along one line.
Message Size	200 - 1100 Byte	32 Bytes	Estimation includes 96 bytes security header for GCM (400 average). RRM messages are short, but effect of Contention Window size must be included. (20 bytes data + Contention Window size). RRM: Fixed sized packet, MAC layer data frame with zero length. PHY MCS r-1/2 16QAM assumed and should be used (64 us on air time). Total Data-Ack is around 160us (per range measurement).
Message Latency, According to Current	?	?	To be defined in Message specification
Message Priority to be defined			(on a level from 0-16, with 0 highest) See Annex A
Transmission mode	Broadcast	Unicast	
Transmission type	Repetitive	Repeats (as CAM)	
Urban network message channel load	<2.5%	<100%	Based on 6 mb/s channel capacity. GCM: 3*1 Hz rate for RTCM 1077+1087+1097, 6 rebroadcasts from various directions. RRM: In a typical deployment around 200~250 vehicles will use this service with a channel load of 40~50%.
Rural roads network message channel load	<1%	<25%	Based on 6 mb/s channel capacity. GCM: 3*1 Hz rate for RTCM 1077+1087+1097, 2 rebroadcasts from the two directions. RRM: 0.1% (only in tunnels where this serive will be typically used). Only range to 1 or 2 R-ITS.
Highway network message channel load	<1%	<1.0%	
V2V	-	X	
I2V and V2I	X	Yes	
V2E and E2V	-	X	
Reception Probability Requirement	Standard	Standard	Transmission rate is sufficiently high for packet loss to be tolerated.
Security requirements	C-ITS	C-ITS	Main risk is spoofed position data by fake RSU.
Liability Impact	No	No	Low - Augmentation service -- requires other sensors for integrity check
Functional Safety Requirements	not applicable	not applicable	
SOTIF	unknown	Unknown	
	-	-	

Table 9: Derived communication requirements for PAS services.

4.3.3 PA System Requirements

PAS is a generic service, it may be used by non-safety, standard safety or advanced safety such as automated driving and platooning to improve the position accuracy awareness. As so PAS is just an awareness service. As it is an awareness service it just provides the information and does not know where it is being used for, whether this is used for automation or not.
When it would be only for non-safety applications no specific system requirements would be required but as C-ITS CCAM principles are targeted the related conditions need to be considered. As business cases still influence and therefore it is a community decision based on interested use case (sets) what minimum requirements to choose. For consideration here the 3 known main C-ITS levels are identified.

1. Basic Set of Applications (BSA), Release 1, BSP 1.4 related. This would require no requirements related to PAS as no PAS is expected.

2. Extension of the BSA with additional applications without change of lower layer capabilities to facilitate additional safety awareness for VRU's, requires to improvement of the position accuracy and therefore the use of PAS services. It however leaves the liability completely at the receiver side and does not introduce higher than ASIL QM level of Functional Safety related requirements onto the communication system.
3. Supporting extended Automation levels as Platooning, Applications which may require ASIL levels or higher support. Whether higher ASIL levels are applicable to the C-ITS communication system depends on the use of the shared information.
    a. If only awareness information is used the safety/liability responsibility may stay within the vehicular system and will than not require any additional system requirements to realize Functional safety. It therefore can be expected to stay at ASIL QM level for its communication system requirements.
    b. If coordination between vehicles (sharing of information via communication networks) have direct influence on safety related decisions within the vehicle, it can be expected that higher ASIL levels result in additional requirements to the communication system. ASIL B, C or D could be applicable.

As can be seen, only in case 3b additional C-ITS system, FS requirements need to be supported. As an MCO concept should be future prove as much as possible case 3b needs to be considered.

4.4 Security Certificate Exchange System Service

4.4.1 Introduction

To be able to trustworthy communicate with other C-ITS stations the trust is verified by means of certificates being exchanged. To allow this process to be realized certificates need to be provided to C-ITS stations, something which can be realized statically as well as dynamically by an Authorisation or other certified authority (see Figure 14). Updates of certificates can be initiated by the equipment itself or by the authorisation authority.

Statically the certificates can be installed at the moment of installation of the C-ITS equipment's and updates can be installed when the equipment is under maintenance service.

Updates can also be realized dynamically when equipment is operational, a car is driving and communicates via cellular or other means to the trusted authorisation authority or a roadside unit (RSU) does it through private networks.

With regards to MCO only dynamic certificates provisioning needs to be considered in the case this is realized by ad-hoc communication. Within MCO communications standards cellular network mechanisms are not considered.

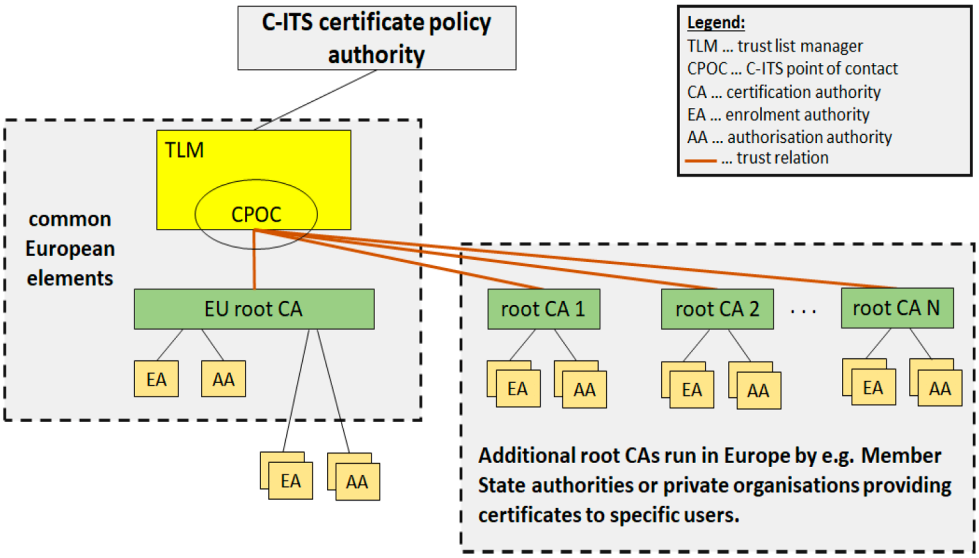

Figure 14: Certificate Trust Model Architecture

4.4.2 Security Communication requirements

In case the certificate exchange is enabled through ad-hoc networks, the communication from authorisation authority to the C-ITS equipment is in most cases handled through more than one type of communications. One between the authorisation authority and an RSU which could be wired or cellular and from the RSU to other C-ITS equipment through ad-hoc communication. In the context of MCO we only consider the ad-hoc communication.
Such ad-hoc communication may be realized via agreed direct communication in a single fixed channel, but it can also be realized through a none fixed approach making use of the Service Announcement mechanism. In the last case the service could be moved to any available channel. Although the certificates are being used by safety services, the certificate exchange itself may be considered as non-safety and therefore being shared on a non-safety channel.

Experiments within Scoop@F of sharing certificates by Ad-hoc networks have been done but not final specification created. For MCO however the following capability requirements will be referenced.

- In case Ad-hoc communication is used for the exchange of certificates these are exchanged on an EU harmonized channel or assigned through the SAM mechanism. As the SAM mechanism is most flexible and makes most clear where the providing service is available, the SAM method is preferred and seen as MCO requirement.
- As in the Scoop@F project it was already assumed that certificate exchange would not happen in the CCH and that this exchange is not safety related by itself. The certificate exchange is not realized in the CCH and preferably in one of the 2 non-safety channels.

The following further early requirements are being considered.

Certificates update				Comment
Requirements	Messages	SAM	?	
Transmission Rate		1 Hz	-	
Transmission dynamics		Low	Low	
Area of relevance urban		200 m	200 m	
Area of relevance rural roads		200 m	200 m	
Area of relevance rural highways		200 m	200 m	
Message Size		300 Bytes	2000	
Message Latency, According to Current		SAM	?	
Message Priority to be defined				(on a level from 0-16, with 0 highest) See Annex A
Transmission mode		Multicast	Multicast	
Transmission type		Repeditive	Bulk	
Urban network message channel load		<2%	<2%	
Rural roads network message channel load		<2%	<2%	
Highway network message channel load		<2%	<2%	
V2V		-	-	
I2V and V2I		X	X	
V2E and E2V		-	-	
Reception Propability Requirement		Standard	Standard	
Security requirements		C-ITS	C-ITS	
Liability Impact		NO	NO	
Functional Safety Requirements		ASIL QM	?	
SOTIF		NO	NO	
Position Accuracy level A		-	-	

Table 10: Derived communication requirements for certificate exchange.

With regards to channel use, certificate update services can't be seen as safety relevant. They are supportive to safety services but themselves not functionally safety relevant. They are only system relatively relevant.

4.4.3 Security System requirements

There are no additional system requirements assumed.

4.5 Safety Relevant System requirements (Beyond Release-1)

4.5.1 Functional Safety (ISO 26262 [ER-53])

Functional safety is that part of the overall safety of a system or piece of equipment that depends on automatic protection operating correctly in response to its inputs or failure in a predictable manner (fail-safe). The automatic protection system should be designed to properly handle likely human errors, hardware failures and operational/environmental stress.

Functional safety is a known requirement within the vehicle industry. There is an extensive set of ISO 26262 [ER-53] Functional Safety for Road Vehicle standards (see Figure 15). These specifications are tailored to systems in a box configuration, systems where a single stakeholder can be responsible for a single solution. Approximate cross-domain mapping of ASIL can be found in Table 11.

Automotive Safety Integrity Level (ASIL) is a risk classification scheme defined by the ISO 26262 standard. This is an adaptation of the Safety Integrity Level used in IEC 61508 for the automotive industry. This classification helps defining the safety requirements necessary to be in line with the ISO 26262 standard. The ASIL is established by performing a risk analysis of a potential hazard by looking at the Severity, Exposure and Controllability of the vehicle operating scenario. The safety goal for that hazard in turn carries the ASIL requirements. The ASIL level needs to be identified on a use case scenario basis.

There are four ASILs identified by the standard: ASIL A, ASIL B, ASIL C, ASIL D. ASIL A dictates the lowest integrity requirements on the product while ASIL D the highest.[1] Hazards that are identified as QM do not dictate any safety requirements.

ASIL D refers to the highest classification of initial hazard (injury risk) defined within ISO 26262 and to that standard's most stringent level of safety measures to apply for avoiding an unreasonable residual risk (see ISO 26262-3:2011, Part 3: Concept phase). In particular, ASIL D represents likely potential for severely life-threatening or fatal injury in the event of a malfunction and requires the highest level of assurance that the dependent safety goals are sufficient and have been achieved (see ISO 26262-3:2011, Part 3: Concept phase).

Domain	Domain-Specific Safety Levels				
Automotive (ISO 26262)	QM	ASIL-A	ASIL-B/C	ASIL-D	-
General (IEC-61508)	-	SIL-1	SIL-2	SIL-3	SIL-4
Aviation (ED-12/DO-178/DO-254)	DAL-E	DAL-D	DAL-C	DAL-B	DAL-A
Railway (CENELEC 50126/128/129)	-	SIL-1	SIL-2	SIL-3	SIL-4

Table 11: Approximate cross-domain mapping of ASIL.

As stated, functional safety is the part of the overall safety of a system or piece of equipment that depends on automatic protection operating correctly in response to its inputs or failure in a predictable manner (fail-safe). In case of a vehicle this implies in general pieces of equipment in the vehicle or the vehicle as a hole.

From the perspective of the vehicle system, shared C-ITS information is seen as external information. From a functional safety perspective point of view this means that the system to evaluate is extended to external parts (parts of other systems), something which is not yet considered in any standard and therefore need to be evaluated use case by use case and may fall under any ASIL classification.

Release-1 C-ITS use cases are safety related driver awareness oriented, none of the use cases are automation oriented and information received is nothing more than additional information for the driver to make a decision and is therefore categorized as ASIL level QM providing on additional requirements to the system. In case the information is used for Automated driving each of the use cases need to be assessed to identify the ASIL level. An MCO concept needs to be able to accommodate possible ASIL level related requirements at least at first at conceptual level.

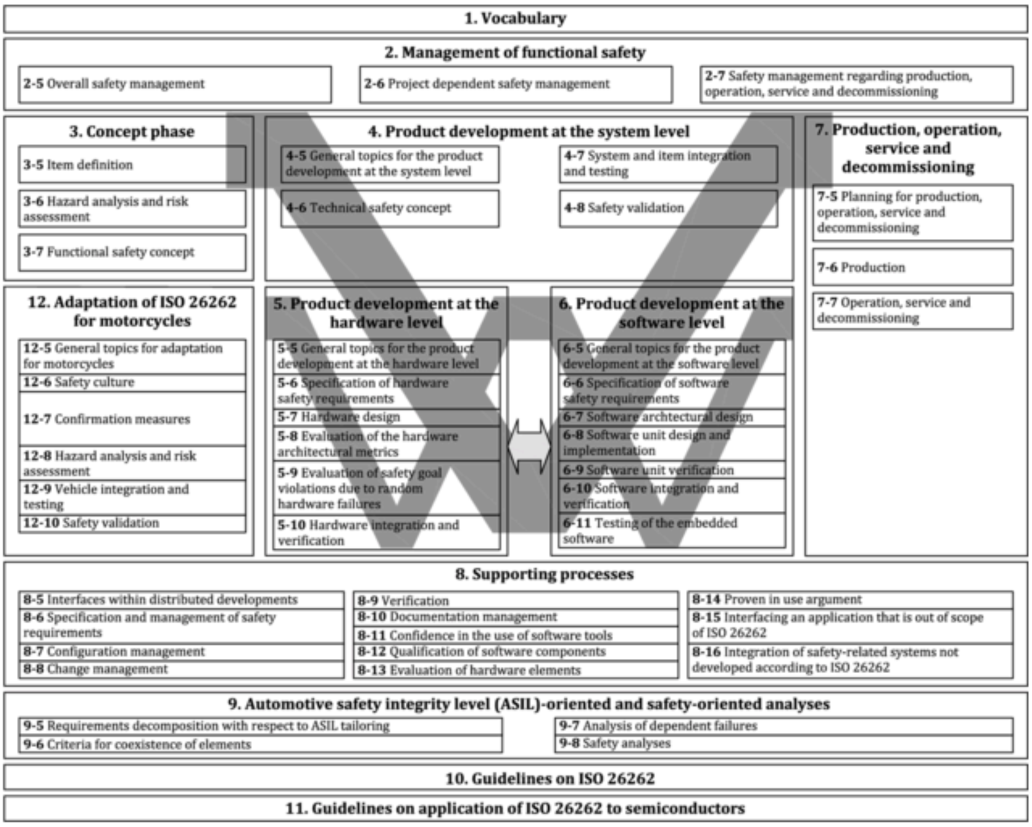

Figure 15: ISO 26262 set of specifications

4.5.2 Safety of the Intended Functionality (SOTIF, ISO PAS 21448 [ER-54])

The ISO/PAS 21448: Road Vehicles — Safety of the Intended Functionality, applies to functionality that requires proper situational awareness in order to be safe. The standard is concerned with guaranteeing safety of the intended functionality — SOTIF — in the absence of a fault. This is in contrast with traditional functional safety, which is concerned with mitigating risk due to system failure. SOTIF provides guidance on design, verification, and validation measures. Applying these measures helps you achieve safety in situations without failure.

ISO/PAS 21448 was originally intended to be ISO 26262: Part 14. Because ensuring safety in situations without a system failure is so complicated, SOTIF is now a standard on its own.

The Functional safety standards ISO 26262 applies to existing, established systems, such as dynamic stability control (DSC) systems or airbags. For these systems, safety is ensured by mitigating the risk of system failure. ISO/PAS 21448 applies to systems such as emergency intervention systems and advanced driver assistance systems. These systems could have safety hazards without system failure and therefore may also require some consideration.

Automated systems have huge volumes of data — and that data is fed to complex algorithms. AI and machine learning are critical for developing these systems. To avoid potential safety hazards, AI will need to make decisions. This includes scenarios that require situational awareness. Using ISO/PAS 21448 will be key to ensure that AI is able to make decisions and avoid safety hazards.

SOTIF applies to safety violations that occur without the failure of a system.
The road is icy. An AI-based system might be unable to comprehend the situation and respond properly. This impacts the vehicle's ability to operate safely. Without sensing the icy road condition, a self-driving vehicle might drive at a faster speed than is safe for the condition.

Fulfilling ISO/PAS 21448 means taking that situation into account and making decisions based on probability.

The goal of SOTIF is to reduce potential unknown, unsafe conditions. However, that definition is very broad. And it's difficult to show that you've accounted for all potential edge cases. SOTIF has influence on the Functional Safety requirements and need to be assessed in a common SOTIF-Functional Safety process use case by use case.

For the purpose of MCO only the consequences of the ASIL level related requirements are considered as it is assumed that SOTIF analyses have direct influence on the Functional Safety related requirements and that for the realisation of an MCO concept only those requirements need to be considered to cover also the SOTIF requirements.

4.5.3 Functional Safety Communication related requirements.

At the moment there is no common practice not enough evaluation information available from European projects available to come to clear conclusions what the impact on MCO should be, however the Functional Safety standards do provide enough information to do a general assessment. A detailed impact assessment of Functional Safety will be realized by the C2C-CC Work Item (WI) T0017 on "Functional Safety". Later in 2020 we may expect some result of this WI and will consider this for MCO when applicable.

For now, the analyses of the ISO 26262 analyses show that Functional Safety requirements could be expected in the area of information quality, product quality and system redundancy.

Evaluating these areas then we come to the following:

- For information quality as example, the current CAM information could be used not just to warn the driver but could be used by the automated system to do a hard break. In such case the information, when received, should be of a higher level of trust, integrity and quality then the information which was used for a warning. Currently the CAM message definition and format does not support such use cases. What can be seen is that this required improved definitions for parameters as confidence, which may come out of the T0017 study, but has no effect on MCO.
- Product quality is implementation specific; it may have impact on the technical requirements of a product such as temperature range and others but should not have architectural nor functional MCO consequences and therefore are not considered at the time. Results of WI T0017 will have to be monitored during the MCO definition.
- System redundancy may have larger impact and may have architectural consequences. In Functional Safety it is only mentioned as a method to realize an ASIL level D. As this is an ASIL level only to be reached for fully autonomously driving vehicles, this not really need to be considered for an Release 2 specifications. In the MCO concept definition it however needs to ensure that redundancy method is not blocked such that at later stage redundancy methods can be incorporated.

While realizing an MCO concept at least the following redundancy methods should not be blocked:

- Increase robustness of the transmissions by selecting the most robust method for information sharing on all safety channels simultaneous.
- Multiple transmissions of the same information in the same and or different channels in the same spectrum and or different spectrum.
- Information exchange in more private and predictable use case available channel via licenced business models.

- For especially higher ASIL levels transmission of information on 2 different channels (at least 1-2 GHz apart) may be required via also 2 different technologies.

The last most secure communication method requires new spectrum at least 1-2 GHz away from the 5.9 GHz band. As this is only for specific use cases, may be such as mobile licenced bands or a new assigned band could be applicable.

4.5.4 System related Communication Requirements

Higher ASIL levels may require additional security measures and separation of functions. A Functional Safety analyses is needed to detail the related requirements. At the moment it is not known what consequences other than described in 4.5.3 need to be considered if any.

5 Some Conclusions

5.1 Introduction

Based on the analyses done in this report some conclusions can be made and are therefore included in this report.

5.2 Spectrum Legal aspects

Current spectrum coexistence and sharing rules and principles are sufficient to accommodate business open market "Technology Neutrality" requirement EU laws. Based on these there are 2 rules to be considered in further ITS spectrum discussions.

1. Coexistence needs to be ensured such that todays and future technologies can coexist while the operation of existing equipment is not influenced by new coming technologies.
2. That in shared spectrum (same spectrum in which 2 or more technologies are active) none of the technologies have a higher chance to have access to the spectrum then others.

As in the current situation ITS-G5 technology is used in the CCH in the 5.9 GHz safety band. According to the spectrum rules this technology is incumbent and therefore may not be interfered when in operation.

For other channels in the 5.9 GHz safety band there are different test ongoing based on different technologies and therefore the equal rights should apply, and all should have equal opportunity to have access. There is one functional aspect to consider here.

5.3 Spectrum Functional aspects

Current spectrum regulation does specify functionalities in different spectra but not technologies. Coexistence is seen as a lower layer aspect and is assessed as such however conceptual aspects such as whether one technology makes use of scheduling/organized access may be in advantage compared systems which only makes use of "listen before talk" mechanisms.
Although coexistence rules are sufficient, coexistence assessment should further recognize such aspects as of influence on the possible limitation of access to the spectrum.

Spectrum analyses in the report are based existing standards, specifications and functional analyses results from projects and standardization activities. This Spectrum analyses confirms the spectrum requirements analyses from 2006 in the TR 102 492-2 [ER-9] later confirmed by the Basic Set of Application (BSA) the TR 102 638 [ER-68]) legislated in the spectrum Regulation EC Decision 2008/671/EC [ER-27] (see Figure 2). Years of experience and current analyses shows that allocated spectrum is not even sufficient and about 100 MHz (see Table 1) would be required. Something also confirmed by the 5GAA spectrum paper. It needs to be noted that the analyses of C2C-CC and 5GAA do not completely overlap and could even result in additional needs later.

Service type	Use case	Description Reference.	Deployment Day Cat.	Already Deployed	Safety Class (Informative, Active, Integral)	Expected Type communication (Standard, Advanced, Ad-Hoc)	Message Type's when applicable	Possible (RED) current (BLACK) technologies	Safety Critical (ASIL, QM, A-D, No)	Communication Requirements							Type of application when Safety/Efficiency related	Spectrum Band (road safety or not)	Security (road safety or not)
										Communication Latency (ms)	Area of relevance (m)	Message behaviour Size (bytes)	Message behaviour Size dynamics	Message behaviour type	Communication Protocol	Service Spectrum needs (<xMHz than)			
Awareness	Cooperative Awareness	1	1	Y	Active	Ad-Hoc	CAM	ITS-G5	application determines functional safety requirement	5	urban/suburban 150m, highway 500m	250-800, average 400	higly	1-10Hz	Mulitcast	see C2C-CC position paper on "Road Safety and Road Efficiency Spectrum Needs in the 5.9 GHz for C-ITS and Cooperative Automated Driving"	Safety Awareness	5.9 GHz	EU ITS Security Policies
Awareness	Decentralized Environmental Notification	1	1	Y	Active	Ad-Hoc	DENM	ITS-G5/4G Standard		5	urban/suburban 150m, highway 500m	1000	higly	1-10Hz	Mulitcast		Safety Awareness	5.9 GHz	EU ITS Security Policies
Awareness	Collective Perception (Vehicles)	2	2	N	Active	Ad-Hoc	CPM	ITS-G5		5	urban/suburban 150m, highway 500m	1000-1900 (containing vehicles and VRU)	higly	1-10Hz	Mulitcast		Safety Awareness	5.9 GHz	EU ITS Security Policies
Awareness	Collective Perception (VRU)	3	2	N	Active	Ad-Hoc	CPM	ITS-G5		5	urban/suburban 150m, highway 500m		higly	1-10Hz	Mulitcast		Safety Awareness	5.9 GHz	EU ITS Security Policies
Automation	Manouuvre Management	4	2-3	N	Active	Ad-Hoc	MCM	ITS-G5		5	urban/suburban 150m, highway 500m	1000-1300	higly	1-10Hz	Mulitcast		Safety Awareness	5.9 GHz	EU ITS Security Policies
Automation	Platooning	5	2	N	Active/Integral	Ad-Hoc	PAM	ITS-G5		5	urban/suburban 150m, highway 500m	200-300	Quite Low	1-20Hz	Mulitcast		Safety Awareness	5.9 GHz	EU ITS Security Policies
							PCM	ITS-G5		5	urban/suburban 150m, highway 500m	400	Low	1-50 Hz	Unicast		Control Safety	5.9 GHz	Extended ITS
Infrastructure Safety	Several	6	1	Y	Active	Ad-Hoc	SPAT/MAP/DENM/IVIM	ITS-G5/4G Standard		5	urban/suburban 150m, highway 500m	1200	Low	1-10Hz	Mulitcast		Safety Awareness	5.9 GHz	EU ITS Security Policies
Prioritized traffic (Emergancy/Public Transport	Several	7	2	N	Active	Ad-Hoc	CAM/DENM/MCM/SPAY/MAP	ITS-G5		5	urban/suburban 150m, highway 500m	same size according to message type	higly	1-10Hz	Mulitcast		Efficiency Awareness	5.9 GHz	EU ITS Security Policies
Environmental Polution	Several	8	2	N	Active	Ad-Hoc	CAM/DENM/IVIM	ITS-G5			urban/suburban 150m, highway 500m	same size according to message type	higly	1-2Hz/event	Mulitcast		Efficiency Environmental	5.9 GHz	EU ITS Security Policies
Safety system	Service Announcement	9	2	N	Active	Ad-Hoc	SAM	ITS-G5			urban/suburban 150m, highway 500m	200-2000	Low	1-2Hz	Mulitcast		Safety Awareness	5.9 GHz	EU ITS Security Policies
Safety system	Service Security	10	2	Y/N	Active	Ad-Hoc	SAM	ITS-G5			urban/suburban 150m, highway 500m	400-2000	Low	1-2Hz	Mulitcast		Safety Awareness	5.9 GHz	EU ITS Security Policies
Safety system	Position Augmentation	11	2	N	Active	Ad-Hoc	PM/GCM/RRS	ITS-G5			urban/suburban 150m, highway 500m	32-1100	Regular	1-12Hz	Multicast/Unicast		Efficiency Environmental	5.9 GHz	EU ITS Security Policies

Table 12: Overview showing overall spectrum requirement.

6 Annex A – Message Priorities

In Release 1 there are references made to the TS 102 724 [ER-73] and TS 102 636-4-2 [ER-74] where only 4 priorities used and which are directly correlated with the physical layer 4 priority queues. More levels are not used as this was not needed for Release-1. The way it is defined is not open and not layer independently specified and needs to be updated. As for the rest there is no reference to the TS 102 724 this is not further used. As the operation is only specified this for the transmitting side there is no technical backward compatibility issue when we take a different approach. When additional priority levels need to be defined this may have some effect on the functional behaviour but does not need to have effect on the interoperability between Release-1 and later Releases.
As we see a large number of new use cases, applications and services upcoming an extended prioritisation scheme needs to be developed as part of the MCO concept. As this depends on the way MCO deals with the channel assignment and usage a simple approach as provided in the Table below can only be seen as an indication of the needs and suggestion in which direction to look. IT however needs to be clear that we need to keep definitions layer specific and not cross layer dependent.

Priority level	Queue Priority	**Message SETs** In case in same channel	Comment
0	AC_VO	DENM - High Prio	According to DSP
1		PCM	Proposed
2			
3			
4	AC_VI	CAM	According to DSP
5		PAM	Proposed
6			
7			
8	AC_BE	DENM - Low Prio	According to DSP
9		IVI, SPAT/MAP	According to C-ROADS at 8
10			
11			
12	AC_BK	SAM	Proposed
13			
14			
15			

7 Annex B – References

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8 Annex C – ENSEMBLE Functional Safety and safety of the Intended Functionality analyses method

At this moment the ENSEMBLE has not yet identified the communication requirement to realize Safety of the Intended Functionality and Functional Safety. ENSEMBLE has identified an alliterative process to identify relevant requirements for level A platooning according to the process flow as identified in Figure 16.

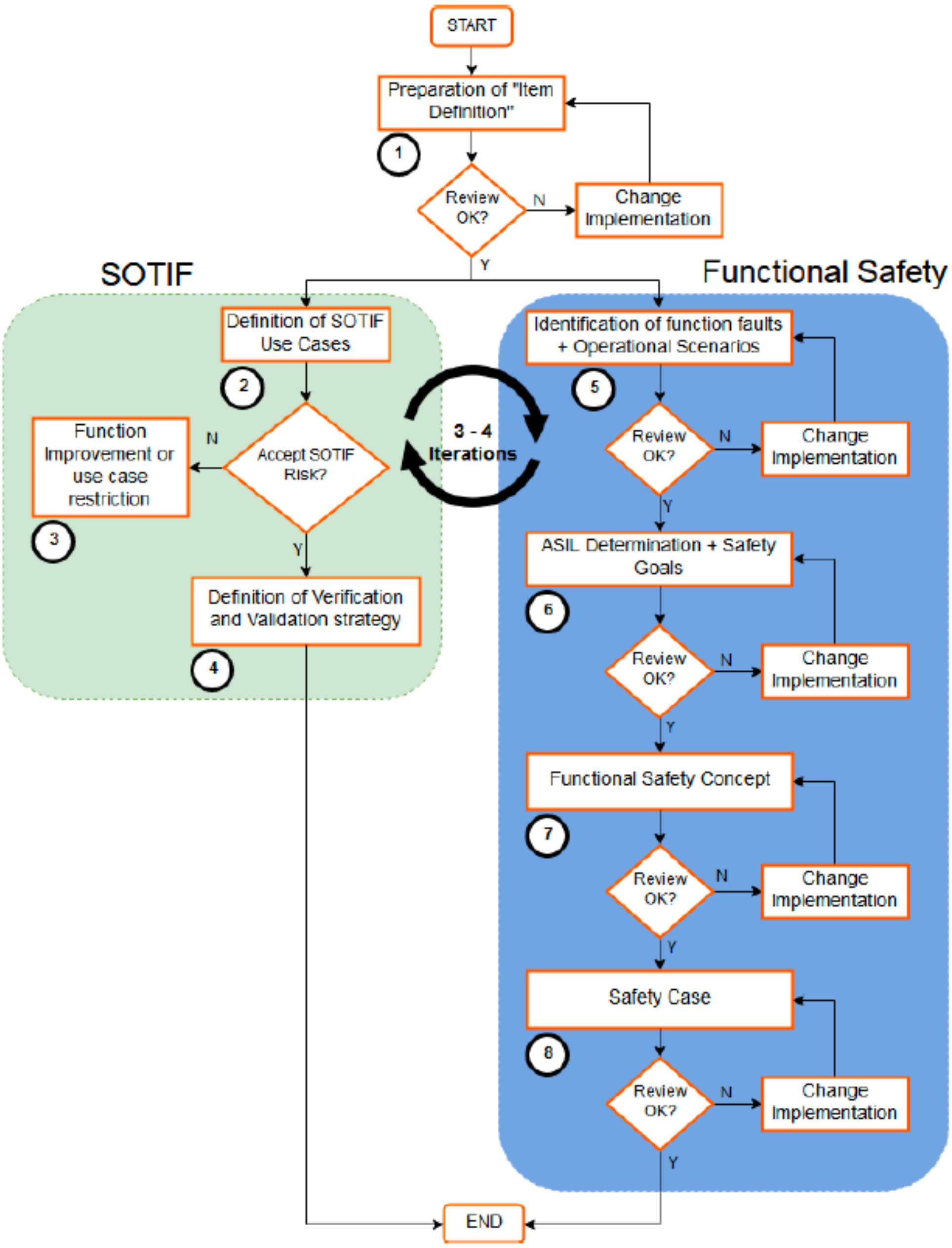

Figure 16 Evaluation process determining the SOFIT and Functional Safety requirements (ENSEMBLE)

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