C-ITS Infrastructure Functions and Specifications

C-ROADS Platform

Working Group 2 Technical Aspects

Taskforce 3 Infrastructure Communication

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List of Tables

Acronyms

AG	Amsterdam Group
CA	Cooperative Awareness
CAM	Cooperative Awareness Message
CCH	Channel with 5900 MHz carrier centre frequency
CITSC	C-ITS Corridor
C-ITS	Cooperative ITS
C-ITS-S	Central ITS Station
CRW	Collision Risk Warning
CT	Container
DE	Data Element
DEN	Decentralized Environmental Notification
DENM	Decentralized Environmental Notification Message
DF	Data Frame
DSRC	Dedicated Short Range Communication
F	Facilities Layer
FLS	Facilities Layer Service
GN	Geo Network Layer
GNSS	Global Navigation Satellite System
HF	Header Field
ITS-G5	ITS-G5 is a European standard for ad-hoc short-range communication of vehicles among each other (V2V) and with Road ITS Stations (V2I). ITS-G5 refers to the approved amendment of the IEEE 802.11 (standard IEEE 802.11p). This technology (possibly others) uses the 5.9 GHz frequency band to support safety- and non-safety ITS applications. In this document ITS-G5 stands for IEEE802.11p/ETSI ITS-G5.
ITS	Intelligent Transport Systems
ITS-S	ITS Station
ITSS-VG	Road Operator On Board Unit
IVI	In-Vehicle Information
IVIM	Infrastructure to Vehicle Information Message
IVI service	Infrastructure to Vehicle Information (IVI) service
IVS	In-Vehicle Signage
km	kilometre
m	metre
MAPEM	MAP (topology) Extended Message
ms	millisecond
MS	Member State
OBU	On Board Unit

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HLN	Hazardous Location Notifications
OSI	Open Systems Interconnection model
PDU	Protocol Data Unit
R-ITS-S	Roadside ITS Station (the so-called RSU)
RSP	ITS-G5 Roadside System Profile (abbreviated as Roadside System Profile or Infrastructure Profile)
RWW	Roadworks Warning
s	seconds
SAP	Service Access Point
SCT	Sub-Container
SDU	Service Data Unit
SP	Service Primitive
SPATEM	Signal Phase And Timing Extended Message
SREM	Signal Request Extended Message
SSEM	Signal request Status Extended Message
TCC	Traffic Control Centre

N/A	*Not Applicable*

Glossary

ITS-S application	Uses one or more FLSs with different parameters, depending on the situation, to provide an ITS service to the user. ETSI TR 102 638 [1] e.g. is RWW, IVS and CRW.
Use Case Scenario	Denotes a more specific way to execute an ITS-S application, e.g. the stand-alone mode of Roadworks Warning in case of safety trailers failing to connect to the centre. As another example, in the C-ITS Corridor terminology, “TCC-triggered RWW” denotes a use case scenario to implement RWW application based on TCC data only.
Facilities Layer Service (FLS)	In this document, the term service is derived from the term ITS-S service as defined in ETSI EN 302 665 [2]. It describes a communication functionality offered by an ITS-S to an ITS-S application.

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Introduction

Being a part of Intelligent Transport Systems, cooperative ITS (**C-ITS** or cooperative systems) encompass a group of technologies and applications that allow effective data exchange through wireless communication technologies between components and actors of the transport system, very often between vehicles (vehicle-to-vehicle or V2V) or between vehicles and infrastructure (vehicle-to-infrastructure or V2I).

The deployment of C-ITS is an evolutionary process that will start with the less complex ITS-S applications. These are referred to as “Day-1-services”, encompassing messages about for example traffic jams, hazardous locations, road-works, as well as weather information and speed advises to harmonise traffic. C-ITS facilities layer services (FLS) are meant to exchange information to vehicles in a way that allows drivers to get informed but not distracted.

C-ROADS is a platform of Member States working on the deployment of harmonised and interoperable C-ITS FLS in Europe. The C-ROADS Platform will pursue cooperation among Member States for issues related to the deployment of C-ITS, such as sharing experiences and knowledge or user acceptance.

This document defines the common base for the ITS-G5 functional and technical specifications. The specification targets the communication between **roadside units and vehicles**. The communication directions derived from this are also known as **I2V** (Infrastructure-to-Vehicle) and V2I (Vehicle-to-Infrastructure) communication. This selection has been taken based on maturity consideration, i.e. only specifications that have been implemented and tested in the field can be considered for this document.

Thus, note that the interfaces between the following units are not included in the current release of this specification:

- Roadside and centres (R2C and C2R)
- Roadside and web services (R2W and W2R)
- Vehicles and vehicles (V2V)

Since this document focuses more on the technical specifications of supported C-ROADS FLS (day-1 services) according to the list of the final C-ITS Platform [3] report [2], another document (Roadside ITS-G5 System Profile) [3] defines the requirements of the Infrastructure Roadside System Profile (RSP). The Infrastructure Roadside System profile references to this document frequently.

This document is structured into three sections:

- Section 1 defines verbal forms and provisions
- Section 2 lists the functional description of supported system FLS and ITS-S applications
- Section 3 provides the technical specifications of the supported FLSs, including triggering conditions.

Section 3 will include also the security and management entity related specifications. Nevertheless, these will not be handled fully in this document.

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1 Provisions

1.1 Verbal forms for the expression of provisions

In this document, the following verbal forms are used to indicate requirements:

Shall / Shall not

Recommendations shall be indicated by the verbal forms:

Should / Should not

Permissions shall be indicated by the verbal forms:

May / May not

Possibility and capability shall be indicated by the verbal forms:

Can / Cannot

Inevitability used to describe behaviour of systems beyond of the scope of this deliverable shall be indicated by:

Will / Will not

Facts shall be indicated by the verbal forms:

Is / Is not

1.2 Provisions from referenced documents

Normative requirements included in the referenced documents supporting the required functionality of the ITS system shall apply. The verbal forms for the definition of provisions of referenced documents are defined either inside the particular document or generally by the respective SDO (= standards developing organization) or the organization providing them.

1.3 Multiplicity and Usage

The multiplicity of elements is denoted with mandatory or optional

The usage contains information on the use of the Data Elements/Data Frames (DE/DF) in the scope of the ITS-G5 Roadside System profile. This may contain restrictions regarding value / lexical space in case of DEs (e.g. if only a subset of possible values in used). The usage may contain definitions of DE/DF in accordance with corresponding standards. Table 1, Table 3, Table 10, Table 12, Table 13, Table 14 and Table 15 provide general usage information of message sets, while Table 2, Table 6, Table 8 and Table 11 provide details of ITS-S application specific's usage information.

1.4 Principles of location referencing of infrastructure-based messages

The following principles apply to location referencing.

- Infrastructure is working with map projections.
- Map projections provide equidistant points at the middle of the carriageway.
- There is no rule for the exact number and distance of points, this will be specific to the situation on the road and deviate from message to message.
- Maximum deviation between reality and map projection should not be more than one quarter of the width of the carriageway.

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2 System Facilities Layer Services (System FLSs)

2.1 5.8 GHz DSRC / 5.9 GHz C-ITS Coexistence System FLS

2.1.1 Introduction

The Coexistence FLS ensures that ITS stations can operate without interfering CEN DSRC based tolling equipment in accordance with EN 302 571 [5]. In order to avoid harmful interference to CEN DSRC tolling systems operating at 5.8 GHz, ITS stations need to implement mitigation techniques as defined in ETSI TS 102 792 [6]. These mitigation techniques need to be applied in a Protected Zone, which is a circular area around tolling equipment.

According to ETSI TS 102 792 [6], there are three ways that mobile and personal ITS stations become aware of a protected zone:

1. Announcement of Protected Zones via Protected Zone Database.
2. Announcement of Protected zones via CAMs broadcasted from ITS-G5 roadside stations.
3. Direct detection of the tolling signal by a detector in a vehicle (see [6] Clause 5.2.5 for details).

Fixed ITS stations (i.e. roadside installations in a fixed location) may be configured at installation time to meet the coexistence requirements of its local environment ([6], Clause 5.5.2).

Road operators can announce Protected Zones according to (1.) and (2.) above. Road operators shall ensure that their ITS stations (fixed roadside installations as well as VMS/roadworks trailers) operate according to requirements for interference mitigation for CEN DSRC and HDR DSRC in EN 302 571 [5].

Protected zone specification based on ETSI TS 102 792 [6]
As a basis for the coexistence ITS-S application, Protected Zones identify the area in which an ITS station has to ensure not to interfere with CEN DSRC equipment.

2.1.2 Announcement of Protected Zones via Protected Zone Database

To ensure that CEN-DSRC tolling stations are protected against harmful interference by ITS stations, toll chargers and road operators can provide their protected zone data to a European Protected Zone Database. Only permanent tolling installations shall be entered into the database, but not temporary toll stations and tolling enforcement vehicles.

2.1.3 Announcement of Protected zones via CAMs broadcasted from ITS-G5 roadside stations

As the manufacturers of mobile ITS stations are not required to update the equipment-internal list of Protected Zones after the equipment was built, toll chargers and road operators may announce Protected Zones also by means of the transmission of a Cooperative Awareness Message (CAM) in which the locations of CEN-DSRC tolling stations are given.

2.1.3.1 Message format

A CAM for the Coexistence ITS-S application identifies at least one single Protected Zone but may identify a list of Protected Communication Zones within the data frame *ProtectedCommunicationZonesRSU*. This list may contain as much as 16 single data elements of type *ProtectedCommunicationZone*. A protected communication zone is defined at least by the type (permanent or temporary tolling) as well as latitude and longitude of the center position. An optional radius can be specified, if the radius deviates from the default radius, as specified in ETSI EN 302 637-2 [7]. The expiry time shall be specified if the end of tolling operation is known. Table 2 provides detailing of the elements used.

Table 1 Structure of a CAM with Protected Zone elements

Date element / data frame	Data type (No. in CDD [9])
CAM	
header	ItsPduHeader (114)
cam	CoopAwareness
generationDeltaTime	GenerationDeltaTime

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camParameters	CamParameters
basicContainer	BasicContainer
highFrequencyContainer	HighFrequencyContainer
rsuContainerHighFrequency	RSUContainerHighFrequency
protectedCommunicationZonesRSU	ProtectedCommunicationZonesRSU (122)
ProtectedCommunicationZone	ProtectedCommunicationZone (121)
protectedZoneType	ProtectedZoneType (58)
expiryTime	TimestampIts (82)
protectedZoneLatitude	Latitude (41)
protectedZoneLongitude	Longitude (44)
protectedZoneRadius	ProtectedZoneRadius (57)
protectedZoneID	ProtectedZoneID (56)

Table 2 CAM elements specific to the Coexistence ITS-S application

Data element / data frame	M/O*	Usage	Comment
highFrequencyContainer	M	(as specified in [7])	
rsuContainerHighFrequency	M	Note: Mandatory for R-ITS-S	
ProtectedCommunicationZonesRSU	O	Mandatory for Coexistence.	
ProtectedCommunicationZone	M	(as specified in [9])	
protectedZoneType	M	Type of protected zone, ETSI TS 102 792 [6] distinguishes between permanent CEN DSRC tolling (type "0") and temporary CEN DSRC tolling (type "1").	
expiryTime	O	(as specified in [9]) The expiry time shall be specified if the end of tolling operation is known.	
protectedZoneLatitude	M	(as specified in [9])	
protectedZoneLongitude	M	(as specified in [9])	
protectedZoneRadius	O	(as specified in [9]) Note: If the radius data element is omitted, the default radius of 55m applies (ETSI TS 102 792 [6]).	
protectedZoneID	O	Identifier of the protected zone. If the same zone is defined in the European Protected Zone database, the same ID shall be used as protectedZoneID. Otherwise, an ID greater then 67108863, which is not used in the database, shall be used.	
*M/O: Mandatory/Optional according to ETSI TS 102 894-2 [9]			

2.1.3.2 Operational specifications

The Coexistence FLS can be used by road operators and toll chargers that intend to protect their tolling equipment. It is a prerequisite to the Coexistence FLS that Protected Zone data is made available to the roadside ITS stations (R-ITS-S) that are intended to disseminate these data via CAMs. Protected Zone data may be placed directly in the R-ITS-S or sent to the R-ITS-S from any other infrastructure component.

EXAMPLE: In AT the Protected Zone data is provided by the TCC to the C-ITS-S; then the C-ITS-S distributes it to selected R-ITS-S which broadcast it via CAMs.

Furthermore, it needs to be ensured that the Protection Zone CAMs can be received and processed by mobile ITS stations in time by appropriate selection of the dissemination area and the CAM transmission rate.

2.2 Other system FLSs

There are currently no other system FLSs.

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3 Functional FLSs

3.1 Introduction

This chapter defines technical and operational specifications of the infrastructure FLSs, in line with their functional description in C_ROADS_WG2_TF2_Service Descriptions [10]. For the current release, those definitions and rules have been considered that have been specified and tested in the context of the C-ITS Corridor (NL, DE, AT), the French Scoop@F project or the InterCor project (BE(Fla), FR, NL, UK).

This chapter is structured into four subsections:

- Subsection 3.2 is based on following facilities layer service definitions based on the ETSI ITS station reference architecture / ITS-S host (ETSI EN 302 665 [2]) and the facilities layer protocols and communication requirements for infrastructure FLS ETSI TS 103 301 [11]:
    - Decentralized Environmental Notification (DEN) basic service (ETSI EN 302 637-3 [12]),
    - Infrastructure to Vehicle Information (IVI) service (ETSI TS 103 301 [11]).
    - Road lane topology (RLT) / traffic light manoeuvre (TLM) service (ETSI TS 103 301 [11]),
    - Traffic light control (TLC) service (ETSI TS 103 301 [11]).

    This section provides the content profiles of the corresponding message sets (DENM, SPATEM, MAPEM, IVIM, SREM and SSEM). If necessary, the description is divided into a general part and variations received from different countries. Besides the profiles of data elements and data frames used from the respective message sets, the tables in this section also include relevant service parameters from the respective facilities layer services. Note that the tables include only the data elements / data frames from the message payload, not the content of the surrounding data structures of the lower layers including the ItsPduHeader. These data elements / data frames are described in the Roadside ITS G5 System Profile [4].
- Subsection 3.3 provides operational specifications of the supported FLSs, including their triggering conditions. Service parameters of the respective facilities layer services are not mentioned in this document have default values regardless of ITS-S application, use case scenario or national implementation (such general parameters are defined in chapter 3 of the Roadside ITS-G5 System Profile [3]). This section also contains choices and parameters of lower layer services (in particular the transport and network layer services and parameters), as far as they are relevant for the ITS-S applications addressed. Wherever the profile indicates ‘not used’ this means: not used for current use cases, kept optional for future use cases, therefore use is not forbidden.
- Subsection 3.3 and subsection 3.4 are reserved for specifications regarding the security and management entities in later revisions.

In the context of a layered communication stack, the message sets handled in this document are Facilities layer PDUs that are exchanged between ITS-Ss. The payload is generated by ITS applications in the transmitting ITS-S or other connected ITS-S (e.g. a C-ITS-S) and passed to the Facilities layer via service access points. Beyond the payload, these service access points may include further parameters to control the handling and transmission of the payload (service parameters). At the receiving ITS-S, the messages are forwarded to applications or connected ITS-S by forwarding mechanisms.
Once message transmission is triggered, the FLSs may be configured to repeat the transmission, until the applications request its termination or trigger another request to generate an updated message.

3.2 Service definition and message content

3.2.1 DEN Basic Service (DEN Basic FLS)

“The DEN basic service uses the services provided by the protocol entities of the ITS networking & transport layer to disseminate DENM” (ETSI EN 302 637-3 [12]).

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"A DENM contains information related to an event that has a potential impact on road safety or traffic condition. An event is characterised by an event type, an event position, a detection time and a time duration. These attributes may change over space and over time" (ETSI EN 302 637-3 [12]). The DENM transmission may be independent from the originating ITS-S in some situations.

Four types of DENMs are generated by the DEN basic FLS:

- **new** DENM,
- **update** DENM,
- **cancellation** DENM and
- **negation** DENM.

New and **update** DENM are being used by all national specifications; the **cancellation** DENM is not always used. **Negation** DENM is never used. A common mechanism of terminating an event is sending a **cancellation** DENM by the originating ITS-S. The type of the DENM to be generated depends on the type of the application request.

The header of DENM shall be as specified in the data dictionary ETSI TS 102 894-2 [9]. Detailed data presentation rules of the ITS PDU header in the context of DENM shall be as specified in clause B.1 of ETSI TS 102 894-2 [9].

3.2.1.1 DENM general elements

DENM data elements, DENM data frames and service parameters shall be used according to the definitions in Table 3.

Table 3 DENM elements in general

Name	M/O	Usage	Comment
Management Container	Mandatory		
actionID	Mandatory	**Content**: The actionID is the unique identifier of a DENM and consists of the data elements originatingStationID and sequenceNumber. originatingStationID is the unique identifier of the ITS-S whose facility layer created the message, which may be either the C-ITS-S or the R-ITS-S. If not set by the C-ITS-S, messages whose content is generated centrally but who are broadcasted from different R-ITS-Ss will have different originatingStationIDs, resulting in different actionIDs. If the originatingstationID and sequenceNumber is given by the C-ITSs in case of centrally generated content that is (potentially) sent out via multiple R-ITS-S, then the system provides the same actionID for all messages relating to the same event, regardless which R-ITS-S is sending out the message. Once the actionID is set, it will not change for messages relating to the same event, even if they are frequently updated. **Value**: not pre-defined, set by system (consistent with standard)	*AT* The sequenceNumber itself is derived out of the source DATEX II from the TCC, thus making an event traceable from the Source DATEX II to the destination DENM.
detectionTime	Mandatory	Initially this DE shall be set to the time the event was detected. The time shall come from a local time source in the R-ITS-S in case of stand-alone use case scenarios. In case of use case scenarios with connection to the C-ITS-S, the detectionTime shall initially be set to the time that the application, that creates the DENM, receives the relevant information, i.e. the moment a roadwork or a	*AT* **Moving and Stationary Standalone RWW**: detectionTime will come from local time source of R-ITS-S, set upon system activation.

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Table 3 DENM elements in general

Name	M/O	Usage	Comment
		hazardous location starts / is detected at a functional level. **Value:** detectionTime is initially set at the start time of the event (new DENM) then reset for each DENM update. For the DENM termination, this DE shall be the time at which the termination of the event is detected	**Augmented and TCC Triggered RWW, HLN:** detectionTime will be set based on C-ITS-S system time when it receives the event information from the TCC. Will be updated using the DENM update mechanism whenever the event changes according to the TCC.
reference Time	Mandatory	**Content:** Following the DENM standard, the referenceTime shall be set to the time the DENM message is generated or updated. **Value:** Set automatically	*AT* referenceTime is set by the C-ITS-S or R-ITS-S depending on the use case scenario, for example by the R-ITS-S for Standalone RWW and by the C-ITS for other RWW and HLN use case scenarios.
termination	Optional	See 3.3.1.1 (RWW) and 3.3.1.2 (HLN)	
eventPosition	Mandatory	In the I2V use case scenario, the DF eventPosition is used to locate lane or carriageway blockings or hazardous locations. It represents the position where the physical blockage on the lane (including hard shoulder) or the carriageway or the hazardous location starts. The accuracy should be on the level of a lane, but shall at least be on the accuracy level of the carriageway. Altitude and confidence DEs can be used or set to the values corresponding with 'unavailable'. In case of blockages by trailers, it depends on the Member State (MS) whether the blockage is the trailer or a cone.	See ITS-S application specific parts in the following subsections.
relevance Distance	Optional		See ITS-S application specific parts in the following subsections.
relevance TrafficDirection	Mandatory	**Content:** Fixed value. For highways this value is set to upstream traffic. This DF indicates for which traffic direction the message is relevant (from the perspective of the eventPosition). **Value:** Set to upStreamTraffic (1).	See also ITS-S application specific parts in the following subsections.
validityDuration	Mandatory	Events are represented by DEN messages. The duration of a singular DENM is based on the (configurable) value of "validityDuration". As long as an event is valid for the road operator, it will be continuously sent out (using DENM repetition) and updated (using DENM update, renewing "validityDuration", "detectionTime" and "referenceTime" in the process). Message update will be triggered by "validityDuration" falling below a certain (also configurable) threshold. If the event is no longer	See also ITS-S application specific parts in the following subsections. *AT, DE* AT is only using DENM repetition and DENM update. DENM update is triggered after half of "validityDuration" has passed. Events no longer valid

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Table 3 DENM elements in general

Name	M/O	Usage	Comment
		valid, it is either timing out or being actively cancelled (DENM cancellation). **Content:** The DE validityDuration is set to a fixed value. **Value:** Set by application.	are no longer updated and therefore timing out. DENM cancellation or negation are not used. Default values for "validityDuration" are 20s for Standalone RWW and 720s for all other RWW use case scenarios and HLN. Details in 3.3.1.1 (RWW) and 3.3.1.2 (HLN). *BE(Fla), FR, NL, UK* See section 3.3.1.1 (RWW) and 3.3.1.2 (HLN)
TransmissionInterval	Optional	Not used	
stationType	Mandatory	**Content:** Fixed value, set to 15 (roadSideUnit). This is true for both fixed R-ITS-S and portable R-ITS-S. Can be 9 for static trailers. For road operator vehicles (static and moving), and towed trainers, 10 (specialVehicles) shall be used. For public Transport 6 (bus) or 11 (tram) shall be used. **Value:** Set to 9 or 10 or 15.	r
Situation Container	Mandatory		
informationQuality	Mandatory	Information quality is the likelihood of occurrence. Values: Risk of (2), Probable (4), Certain (6) If (0) is received it should be rejected and if (7) is received it should be considered as Certain.	
eventType	Mandatory	Combination of DE causeCode and DE subCauseCode. See ITS-S application specific parts in the following subsections.	
linkedCause	Optional	Possibility to link the current message to a set of causeCode / subCauseCode (similar to eventType) to provide further information	*AT* linkedCause is used for HLN. linkedCause is not used for the RWW ITS-S application because messages belonging together are linked with the more detailed "referenceDenm" data frame from the roadworks container. *DE, BE(Fla), NL, UK* Not used *FR*

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Table 3 DENM elements in general

Name	M/O	Usage	Comment
			Used for RWW
eventHistory	Optional	**Content:** This profile optionally uses this DE when the endpoint of the physical blockage can be determined. If so, it describes the start of a blockage to the end of the blockage, or to the start of a new blockage (another DENM). Note that in this context, the eventPoint values are provided without corresponding eventDeltaTime, since the points describe a geospatial extent and not a trajectory. The DE informationQuality inside the eventHistory will be set to the same value as the above specified informationQuality of the whole DENM. The principles of location referencing, defined in 1.4 apply.	*AT* eventHistory in AT is a full history of the event (using equidistant points) from the eventPosition to the end of event. Default point distance is 50m but can increase if events are longer than 1150m due to the restriction of maximum 23 points in the eventHistory. Points are placed in the middle of the carriageway" **Standalone & Augmented RWW, HLN (point events)** Not used. **TCC Triggered RWW, HLN (events with extension)** Used. *DE* Not used for Day 1 *BE(Fla), FR, NL, UK* see InterCor M03 Upgraded Specifications ITS G5 [25]
Location Container	Optional		
eventSpeed	Optional	This DF will not be provided in case of a static event and be provided, when the event is moving, if available.	
eventPositionHeading	Optional	Heading information will only be provided for moving events via eventPositionHeading. Stationary DENM based events will not use this DF	
traces	Mandatory	The first trace point in the message is the point closest to the event position. This point is positioned in the middle of the lane or carriageway upstream from the event position, considering the curvature of the road. This point is coded as an offset delta position about the event position. Additional trace points are defined as offsets or delta positions with respect to their previous trace points. The trace points will be listed in upstream order, thus also defining the event heading. Up to seven traces can be present The principles of location referencing, defined in 1.4 apply.	*DE* RWW: Always set by the R-ITS-S on the roadworks trailer. *AT* **TCC Triggered RWW, HLN:** Generated in the TCC via precise map matching of event location information (potentially originating from a trailer) and provided to the C-ITS-S. The data frame shall consist of at least 10 data elements of type pathPoint with a steady distance of 50m.

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Table 3 DENM elements in general

Name		M/O	Usage	Comment
				Augmented RWW Based on uplink information from R-ITS-S **Standalone RWW** Generated in R-ITS-S or trailer (without any manual interaction; GNSS required). *BE(Fla), FR, NL, UK* **Content:** The last trace point is preferably at least 1.5 km upstream of the event position. Additional trace points are also positioned in the middle of the lane or the carriageway. **Value:** Set by application
roadType		Optional		
Alacarte Container		Optional		
lanePosition		Optional		See ITS-S application specific parts in the following subsections.
impactReduction		Optional	Not used	
externalTemperature		Optional	Not used	
lightBarSirenInUse		Optional	Not used	
roadWorks	closedLanes	Optional		See ITS-S application specific parts in the following subsections.
	restriction	Optional	Not used.	
	speedLimit	Optional	Optional	See ITS-S application specific parts in the following subsections.
	incidentIndication	Optional	Not used.	
	recomme	Optional		See ITS-S application specific part in the following subsections.

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Table 3 DENM elements in general

Name	M/O	Usage	Comment
nded Path			
startingPointSpeedLimit	Optional		See ITS-S application specific part in the following subsections.
trafficFlowRule	Optional		See ITS-S application specific part in the following subsections.
referenceDenms	Optional		See ITS-S application specific part in the following subsections.
positioningSolution	Optional	Not used for I2V, but may be used for V2V by road operator vehicles.	
stationaryVehicle	Optional	Not used in Day 1. (Might be used for equipped pre-warners in future)	

Table 4 Service Parameters associated with DEN Basic FLS

Service Parameters			
Name	**Type**	**Layer**	**Value**
repetitionDuration	P	F	Equal to the value of data element ValidityDuration. Note: Shall be discussed with other stakeholders.
repetitionInterval	P	F	See ITS-S application specific part in the following subsections. Note: Shall be discussed with other stakeholders.
itGnLocalAddrConMethod	P	GN	ITS-S application and country specific.
LifeTime	HF	GN	ITS-S application and country specific.
Flags	HF	GN	ITS-S application and country specific.
Country Code	HF	GN	ITS-S application and country specific.
Other parameters	-	All	See the Roadside ITS-G5 System Profile [3].

Legend: P = Parameter, HF = Header Field, F = Facility Layer, GN = Geo Networking

3.2.1.2 Roadworks Warning (RWW)

This section provides an overview of short-term Roadworks Warning ITS-S applications supported by C-ROADS countries. ITS-S applications, which require the application of multiple message types, e.g. IVIM, MAPEM and DENM for complex RWW, are currently not covered.

Table 5 RWW and use case scenarios

ITS-S application	Use Case Scenarios	Austria [AT]	Germany [DE]	France [FR]	Netherlands [NL]	Spain [ESP]

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Closure of part of a lane, whole lane or several lanes	TCC Triggered	Yes	No	Yes	Yes	Yes
	Standalone	Yes	Yes	Yes	No	No
	Augmented	Yes	Yes	No	No	No
Alert planned closure of road or a carriageway	TCC Triggered	Yes	No	Yes	Yes	Yes
	Standalone	Yes	Yes	No	No	No
	Augmented	Yes	Yes	No	No	No
Alert planned road works – mobile	TCC triggered	No	No	Yes	Yes	Yes
	Standalone	Yes	Yes	Yes	No	No
	Augmented	No	Yes	No	No	No

The RWW specific usage of DENM data elements and DENM data frames is defined in Table 6.

Table 6 DENM elements specific to RWW

Name	M/O	Usage	Comment
	M	**Management Container**	
eventPosition	Mandatory		*AT* **Standalone and Augmented RWW:** The position of the trailer. The position of the trailer. **TCC Triggered RWW** The position of the cone. *DE:* The position of the trailer.
relevanceDistance	Optional		*AT* A default value of lessThan5km (5) is used. *DE* The fields relevanceDistance and ValidityDuration contain fixed values for the trailers. Nevertheless, they shall be set by the C-ITS-S in order to enable the values to be changed during trial operation. *NL,* Used. *BE(Fla), FR, UK:* Not used.
relevanceTrafficDirection	Mandatory	*Winter maintenance* allTrafficDirection *Road operator vehicle in intervention* upstreamTraffic on dual carriage way roads and allTrafficDirection for all other roads	
Situation Container	**Mandatory**		

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Table 6 DENM elements specific to RWW

Name	M/O	Usage	Comment
causeCode	Mandatory	**Content:** The causeCode is set to 3 (road works). **Winter maintenance** 26 (slow vehicle) in case of salting (sCC 8) or snow plough (sCC 6) Alternatively, 3 and sCC 6 (winter service) can be used. **Road operator vehicle in intervention** 15 (rescue and recovery work in progress) **Road operator vehicle in intervention** 95 (emergency vehicle approaching) **Value:** Set to 3, 15, 26 or 95	In case of snow ploughing and salting, the major event (snow ploughing) shall be alerted.

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Table 6 DENM elements specific to RWW

Name	M/O	Usage	Comment
subCauseCode	Mandatory	0 is used for unknown **Alert planned road works – mobile:** 3 **Closure of part of a lane, whole lane or several lanes:** 0,1,2,4,5 **Alert planned closure of road or a carriageway:** 1,4 **Alert salting (cC 26):** 6 **Alert snow ploughing (cC 26):** 8 **Alert winter service in general (cC 3):** 6 **Road operator vehicle in intervention** 0 (unavailable)	*AT* **Alert planned road works – mobile:** • Stand-alone RWW: 3 (or 0 if the R-ITS-S has difficulties identifying the movement) **Closure of part of a lane, whole lane or several lanes:** • TCC Triggered RWW: 0,1,2,4,5 • Augmented RWW: 4 (or 0 if the R-ITS-S has difficulties identifying stationary use) • Stand-alone RWW: 4 (or 0 if the R-ITS-S has difficulties identifying stationary use) **Alert planned closure of road or a carriageway:** • Stand-alone, Augmented and TCC triggered RWW: 1 *DE* Stand-alone for every ITS-S application: 0 **Alert planned road works – mobile:** • Augmented: 3 **Closure of part of a lane, whole lane or several lanes:** • Augmented: 4 **Alert planned closure of road or a carriageway** • Augmented: 4 *FR* **Alert planned road works – mobile:** • Stand-alone RWW: 3 **Closure of part of a lane, whole lane or several lanes:** • TCC Triggered RWW: 0 **Alert planned closure of road or a carriageway** • 1

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Table 6 DENM elements specific to RWW

Name	M/O	Usage	Comment
Alacarte Container	**Optional**		
lanePosition	Optional		*AT* **Augmented RWW** Only used if upstream information from R-ITS-S is available. **Moving and Stationary Standalone RWW** Used for optional inclusion of pre-warner; to be set hardShoulder (0) to indicate, that the pre-warner is located on the hard shoulder (default value in Day 1). *DE* Not used *BE(Fla), FR, NL, UK* **Status:** Optional **Content:** Position of the eventPosition on lanes. **Value:** Set by application.
closedLanes	Optional	The lanes are counted from inside border of the road excluding the hard shoulder. This DF consists of drivingLaneStatus and hardShoulderStatus.	*AT, DE* Optional. Its usage depends on the particular use case scenario: **Standalone RWW** Not used. **Augmented (AT: and TCC Triggered) RWW** provided by the TCC as precise as possible if the information is available. *BE(Fla), FR, NL, UK* **Status:** Optional **Content:** In case of a 'plusstrook', an extra narrow lane on the left side, that lane is always included with the correct status set (0=open or 1=closed) in drivingLaneStatus. In case of a hard shoulder temporarily used as a normal lane (also known as 'hard shoulder running'), the hard shoulder shall be included as a regular lane in drivingLaneStatus if it is in use. If this lane is in use, hardShoulderStatus shall, since the hard shoulder as such no longer exists, not be used. If available, it is valid only at the eventPosition.

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Table 6 DENM elements specific to RWW

Name	M/O	Usage	Comment
speedLimit	Optional		*AT* **Moving and Stationary Standalone RWW** Not used. **Augmented and TCC Triggered RWW** Used if the information is available. *DE* Not used *BE(Fla), FR, NL, UK* **Status:** Optional **Content:** It is the lowest speedLimit at the point defined by startingPointSpeedLimit. **Value:** Set by application.
recommendedPath	Optional		*FR* Optional *AT, BE(Fla), DE, NL, UK* Not used
startingPointSpeedLimit	Optional		*AT* **Moving and Stationary Standalone RWW** Not used. **Augmented and TCC Triggered RWW** Used if the information is available. *BE(Fla), FR, NL, UK* **Status:** Optional **Content:** This point is on the accuracy level of a carriageway. It is only used when the starting point is different than the eventPosition. **Value:** Set by application.

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Table 6 DENM elements specific to RWW

Name	M/O	Usage	Comment
trafficFlowRule	Optional		*AT* **Standalone RWW** noPassing (0), noPassingForTrucks(1) are not supported in this use case scenario **Augmented RWW** The C-ITS-S shall set that information, if available from uplink information from R-ITS-S. *DE* noPassing (0), noPassingForTrucks(1), passToRight (2) or passToLeft (3) This DE will always be set by the R-ITS-S. *BE(Fla), FR, NL, UK* **Content:** Values 0 and 1 indicating passage rules are not used.
referenceDenms	Optional	RWW DENMs belonging to the same roadwork situation will be linked in the C-ITS-S by listing all actionIDs belonging together in the referenceDenms data element of each message	*AT* **Moving and Stationary Standalone RWW** Not used. **Augmented and TCC Triggered RWW** Used if the information is available. *BE(Fla), FR, NL, UK* Optional

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Table 7 Service parameters associated with RWW with national choices

Service Parameters						
Name	**Type**	**Layer**	**AT**	**DE**	**NL**	**FR**
repetitionInterval	P	A or F	*Standalone RWW* 500 milliseconds. *Augmented and TCC Triggered RWW* 1000 milliseconds	200 milliseconds	Between 250 and 1000 milliseconds.	Between 250 and 500 milliseconds
repetitionDuration	P	A or F	-	Not mentioned in the German specification	Equal to validityDuration	Equal to validityDuration
Life Time	HF	GN	-	Not mentioned in the German specification -	-	-
itsGnMaxGeoAreaSize	P	GN	-	Not mentioned in the German specification	Managed (1)	-
Flags	HF	GN	*Standalone RWW* Mobile (1) *Augmented and TCC Triggered RWW* Stationary (0)	Not mentioned in the German specification -	This parameter is Stationary (0) for R-ITS-S.	-
Country Code	HF	GN	232	Not mentioned in the German specification -	-	-

3.2.1.3 Hazardous Location Notifications (HLN)

The specific usage of DENM data elements and DENM data frames is defined in Table 8. Service parameters are specified in Table 9.

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Table 8 DENM elements specific to Hazardous Location Notifications (HLN)

Name	M/O	Usage	Comment
Management-Container	**Mandatory**		
relevanceDistance	Optional		*AT* lessThan5km (5) *FR, NL* Not Used
validityDuration	Mandatory	*HLN-RLX (Railway level crossing)* Less than 10s	
Situation Container	**Mandatory**		
eventType	Mandatory	• causeCode 1 subCauseCode 0 (traffic condition) • causeCode 2 subCauseCode 0-5, 7 (accident) • causeCode 6 subCauseCode 0-9 (adhesion) • causeCode 9 subCauseCode 0, 1, 4, 5, 7 (surface condition) • causeCode 10 subCauseCode 0-5 (obstacle on the road) • causeCode 11 subCauseCode 0, 2, 4 (animal on the road) • causeCode 12 subCauseCode 0-2 (human presence on the road) • causeCode 14 subCauseCode 2 (wrong way driving) • causeCode 15 subCauseCode 0 (rescue and recovery work in progress) • causeCode 17 subCauseCode 1, 2, 4 (extreme weather condition) • causeCode 18 subCauseCode 0-6 (visibility) • causeCode 19 subCauseCode 0, 1 (Precipitation) • causeCode 26 subCauseCode 3 (slow vehicle) • causeCode 27 subCauseCode 0 (Dangerous end of queue)	*AT* • causeCode 1 subCauseCode 0 (Traffic condition) • causeCode 2 subCauseCode 0,1,3,4,5 (Accident) • causeCode 6 subCauseCode 4-6 (Adverse weather condition - adhesion) • causeCode 9 subCauseCode 0 (Hazardous location - Surface condition) • causeCode 10 subCauseCode 1,4 (Hazardous location - Obstacle on the road) • causeCode 11-12 subCauseCode 0 (Animal or human presence on the road) • causeCode 13 subCauseCode 0 (Wrong way driving) • causeCode 15 subCauseCode 0 (Rescue and recovery work in progress) • causeCode 17 subCauseCode 1-2 (Adverse weather condition – extreme weather condition) • causeCode 18 subCauseCode 1 (Adverse weather condition - visibility) • causeCode 19 subCauseCode 1 (Adverse weather condition - precipitation) • causeCode 26 subCauseCode 3 (Slow vehicle) • causeCode 94 subCauseCode 2 (Stationary vehicle) • causeCode 99 subCauseCode 0 (Dangerous situation) *ESP* • causeCode 1 subCauseCode 0 (Traffic jam)

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Table 8 DENM elements specific to Hazardous Location Notifications (HLN)

Name	M/O	Usage	Comment
		• causeCode 94 subCauseCode 0, 2, 4 (Stationary vehicle) • causeCode 95 subCauseCode 0 (Emergency vehicle approach) • causeCode 97 subCauseCode 1 (collision risk) • causeCode 99 subCauseCode 0, 1 (dangerous situation)	• causeCode 2 subCauseCode 0, 7 (Accident) • causeCode 6 subCauseCode 0-8 (Adhesion) • causeCode 9 subCauseCode 0, 1, 5 (Surface Condition) • causeCode 10 subCauseCode 0-5 (Obstacle) • causeCode 11 subCauseCode 0, 2, 4 (Animal) • causeCode 12 subCauseCode 0-2 (Human presence) • causeCode 17 subCauseCode 1 (Extreme weather condition) • causeCode 18 subCauseCode 0-6 (Visibility) • causeCode 19 subCauseCode 1 (Precipitation) • causeCode 94 subCauseCode 0, 2 (Stationary vehicle) • causeCode 95 subCauseCode 0 (Emergency vehicle approach) • causeCode 99 subCauseCode 1 (Dangerous situation) *FR* • causeCode 2 subCauseCode 0-5, 7 (Unprotected accident area) • causeCode 6 subCauseCode 0-9 (Temporarily slippery road) • causeCode 9 subCauseCode 0, 1, 4, 5, 7 (Unmanaged blockage of a road) • causeCode 10 subCauseCode 4 (Obstacle on the road) • causeCode 11-12 subCauseCode 0 (Animal or person on the road) • causeCode 14 subCauseCode 2 (Wrong way driving) • causeCode 17 subCauseCode 1, 4 or causeCode 19 subCauseCode 1 (Exceptional weather conditions) • causeCode 18 subCauseCode 0, 5 (Reduced visibility) • causeCode 27 subCauseCode 0 (End of queue) • causeCode 94 subCauseCode 0, 2 (Breakdown vehicles) *NL* causeCode set to 97 subCauseCode set to 1
Other DFs / DEs		All other DFs and DEs are the same as specified in the general table (Table 3).	

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Table 9 Service parameters associated with HLN with national choices

Service Parameters					
Name	**Type**	**Layer**	**AT**	**NL**	**FR**
repetitionInterval	P	A or F	1000 milliseconds	Between 250 and 1000 milliseconds.	Between 250 and 500 milliseconds
repetitionDuration	P	A or F	-	Equal to validityDuration	Equal to validityDuration
Life Time	HF	GN	-	-	-
itsGnMaxGeoAreaSize	P	GN	-	Managed (1)	-
Flags	HF	GN	Stationary (0)	This parameter is Stationary (0) for R-ITS-S.	-
Country Code	HF	GN	232	-	-

3.2.2 Infrastructure to Vehicle Information (IVI) Service (IVI FLS)

“IVI service is one instantiation of the infrastructure services to manage the generation, transmission and reception of the IVIM messages. An IVIM supports mandatory and advisory road signage such as contextual speeds and road works warnings. IVIM either provides information of physical road signs such as static or variable road signs, virtual signs or road works” (ETSI TS 103 301 [11]).

The IVI FLS instantiated in an ITS-Station shall provide either the transmission or the reception service.

Four types of IVIMs are generated by the IVI FLS:

- **new** IVIM
- **update** IVIM
- **cancellation** IVIM and
- **negation** IVIM.

“The type of the IVI to be generated upon an application request" (ETSI TS 103 301 [11]).

The header of IVIM shall be as specified in the data dictionary ETSI TS 102 894-2 [9].

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The data elements of the IVIM message payload are defined in CEN ISO/TS 19321 [15].

Data elements, data frames and service parameters shall be used according to the definitions in tables Table ***10*** and Table ***11***.

3.2.2.1 IVIM general elements

Table 10 IVIM elements in general

Name	M/O	Usage	Comment
IVI ManagementContainer	Mandatory		
serviceProviderId	Mandatory	serviceProviderID consists of data elements "countryCode" and "providerIdentifier". countryCode is a bitstring according to ISO 3166-1 [16]. For Austria, for example, the bitstring stands for "AT" (Bitstring Code: A (11000) and T (00001) 1100000001 according to ISO 14816 [17]). Together with iviIdentificationNumber, this is the unique identifier for messages for the receiving V-ITS-S.	
iviIdentificationNumber	Mandatory	This DE is the identifier of the IVI Structure, as assigned by the Service Provider. This component serves as the ID of the message per serviceProvider and can be used by other related messages as a reference.	
timestamp	Mandatory	This DE is the timestamp representing the time at which the IVI message is generated or when the last content change of the messages had occurred.	
validFrom	Optional	This component may hold the start time of the validity period of the message. If start time is not relevant or unknown to the system, validFrom is not present or equal to timestamp.	
validTo	Mandatory	This DE shall always be used to determine the validity. An update shall be sent before the message times out. Value: set by application Default validity period is defined by road operator.	
connectedIviStructures (1..8)	Optional	Not used.	
iviStatus	Mandatory	This component holds the status of the IVI Structure. This can be set to; new (0), update (1), cancellation (2) or negation (3). Is used for message handling.	
Geographic Location Container	Mandatory		
referencePosition	Mandatory	This DE is used as a reference point for all zones within GLC (Geographical Location Container). The Reference point for IVI is defined at the middle of the carriageway, at a gantry, and is the first point of zone definitions for Relevance Zone(s) and Detection Zone(s).	

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Table 10 IVIM elements in general

Name	M/O	Usage	Comment
		The Altitude may be set to unavailable if unknown. If the altitude is provided, it is the altitude of the road. Value: set by application	
referencePosition Time	Optional	Not used.	
referencePosition Heading	Optional	Not used	
referencePosition Speed	Optional	Not used.	
GlcPart	Mandatory	parts (1..16). Up to 16 parts can be defined in one Geographic Location Container. The GLC contains at least two zones, one for relevance and one for detection. Value: set by application	
zoneId	Mandatory	At least one detection zone and one relevance zone shall be provided for each message.	
laneNumber	Optional	Mandatory if single lanes are described in this location container. Default is absent (no lane information).	*FR* Not used
zoneExtension	Optional	Not used.	
zoneHeading	Mandatory		*NL* Effective direction of applicability of the sign at the Reference Position, indicating the traffic direction *FR* FR will always provide this element for determining message relevance in case the detectionZone is not matching: as long as the approach angle is only deviating +/- 30 degrees maximum from the message heading, the message should be considered valid for the vehicle.
zone	Mandatory	Definition of a zone using the DF zone consisting of the choice DF segment, DF polygonalLine or DF computedSegment. The Segment option shall be used with polygonalLine as a line (constructed with deltaPosition as for DENM traces) and with laneWidth optionally (only used when a single lane is referenced within the zone).	
IVI Application Container	Mandatory		
detectionZoneIds	Mandatory	List of Identifier(s) of the definition(s) of the Detection Zone(s), using the DE Zid (1..8)	
its-Rrid	Optional	Not used.	

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relevanceZoneIds	Mandatory	List of Identifier(s) of the definition(s) of the Relevance Zone(s), to which the IVI Container applies, using the DE Zid (1..8)	
direction	Mandatory	Direction of Relevance in relation to the direction (implicitly) defined by the zone using the DE direction. Always set to sameDirection(0).	
driverAwarnessZoneIds	Optional	Not used.	
minimumAwarenessTime	Optional	Not used.	
applicableLanes (1..8)	Optional	List of identifiers of the lane(s) to which the IVS Container applies using the DE LanePosition (1..8).	
iviType	Mandatory	Provides the type of IVI (e.g. immediate danger message, regulatory message, traffic information message) to allow for classification and prioritization of IVI at the receiving ITS-S.	
iviPurpose	Optional	Not used.	
laneStatus	Optional	Indicates the lane status (e.g. open, closed, mergeR) of the applicableLanes.	
completeVehicleCharacteristics	Optional	CompleteVehicleCharacteristics shall contain the definition of the characteristics of the vehicles to which an Application Container is applicable. The component "train", if present shall contain the characteristics applicable to the entire vehicle train.	
driverVehicleCharacteristics	Optional	Not used.	
layoutId	Optional	Not used.	
preStoredLayoutId	Optional	Not used.	
roadSignCodes	Mandatory	It shall contain the definition of the road sign code. It allows different options pointing to different pictogram catalogues. This component specifies which road signs are applicable for a Relevance Zone. Road sign codes are dependent on the referenced classification scheme. Additional attributes to the road sign code can be added as provided by the options. List of 1..4 of RSCode	
RSCode	Mandatory	It contains layoutComponentId and a code.	
layoutComponentId	Optional	This data frame can be used to associate RSCode to the layout component of referenced layout.	
code	Mandatory	For signcoding the ISO/TS 14823 [18] shall be used.	
ISO14823Code	Mandatory	For signcoding the ISO/TS 14823 [18] shall be used. This data frame includes several DFs and DEs. It includes: ○ pictogramCode (countryCode, serviceCategorycode and pictogramCategoryCode)	

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		○ The attributes SET (Section) and NOL (Number of Lane) are not supported because these attributes are providing duplicated information already supported in the Application Container.	
extraText ((1..4),...)	Optional	List of text lines associated to the ordered list of road sign codes. Each piece contains language code plus extra, limited-size text in the selected language using the DF text. Note: This DF can be safely overloaded to include more lines of text.	

3.2.2.2 In-Vehicle Signage (IVS)

The In-Vehicle Signage (IVS) ITS-S application is implemented using In-Vehicle Information (IVI) messages according to (ISO 19321) [15].

IVI messages are used for the IVS ITS-S application in Austria (ECo-AT_SWP2.1_InVehicleInformation [19]), for the IVS ITS-S application in case of Road Works (DUTCH C-ITS Corridor Profile [21]) and it is specified in Scoop@F project. A harmonized specification is made between FR, NL, GB, B for IVS in the InterCor project.

Since all implementations are making use of the IVI standard (ISO 19321) [15], Table 11 describes how respective data elements and data frames are applied.

Table 11 IVIM elements specific to IVS

Name	M/O	Usage	Comment
IVI Management Container	Mandatory		
serviceProviderId	Mandatory	Numbers shall be assigned on national basis. See ISO 3166-1 [16] for registration.	*AT* providerIdentifier will be set to "1" for all AT (ASFINAG) based IVI messages according to http://www.tc278.eu/files/Registries/14816/CS1registerAT.pdf. *BE(Fla), FR, NL, UK* providerIdentifier: A value between 0 and 16383
iviStatus	Mandatory	New, Update, Cancellation: used. Negation: not used Value: set by application	*AT* Supported iviStatus: new, update. iviStatus cancellation or negation will not be used
Geographic Location Cont.	Mandatory		
GlcPart			
IVI Application Container	Mandatory		
applicableLanes (1..8)	Optional	If applicable to all lanes on a carriageway this DE may be absent. Otherwise used if lane specific. Value: set by application	*AT* All lanes to which the iviStatus and/or laneStatus applies.
extraText ((1..4),...)	Optional	Can be used to send a message for clarification or additional information.	*FR*

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Table 11 IVIM elements specific to IVS

Name	M/O	Usage	Comment
		Due to an error in the currently published version of (ISO/TS 19321) [15], the layoutComponentId data element is mandatory at the moment, even if no layoutContainer (lac) is present. It will be statically set to "1" until an update of (ISO/TS 19321) [15] which rectifies this error is available. The language data element uses a bitstring representing the language according to ISO 639-1 [22], e.g. German text is encoded as "DE" (D (10010) and E (10000) 1001010000 according to ISO 14816 [17]). The actual text can be found in the textContent data element. Value: set by application	Coding of sub-roadsign panel is coded between "//" (example : //25km//) in the first container of extraText. If well interpreted, it will be displayed properly on HMI. If not, users may understand it well enough. So that it is a solution respecting standard constraints, without any interoperability issue generated.
Other DFs / DEs		All other DFs and DEs in the IVI standard are not used.	

3.2.3 Traffic Light Manoeuvre (TLM) and Road and Lane Topology (RLT) Service (TLS FLS and RLT FLS)

Traffic Light Manoeuvre (TLM)

The TLM FLS is one instantiation of the infrastructure services to manage the generation, transmission and reception of SPATEM messages. The TLM FLS includes safety-related information for supporting traffic participants (vehicles, pedestrians, etc.) to execute safe manoeuvres in an intersection area. The goal is to enter and exit an intersection "conflict area" in a controlled way. The TLM FLS informs in real-time about the operational states of the traffic light controller, the current signal state, the residual time of the state before changing to the next state, the allowed maneuvers and aids with crossing. Additionally, the TLM FLS foresees the inclusion of detailed green way advisory information and the status for public transport prioritization.

Road and Lane Topology (RLT)

The RLT FLS is one instantiation of the infrastructure services to manage the generation, transmission and reception of a digital topological map, which defines the topology of an infrastructure area. It includes the lane topology for e.g. vehicles, bicycles, parking, public transportation and the paths for pedestrian crossings and the allowed maneuvers within an intersection area or a road segment. In future enhancements, the digital map will include additional topology-descriptions like traffic roundabouts.

Operational parameters and relevant standards

The TLM and RLT FLSs including operational parameters are defined in ETSI TS 103 301 [11], which refers to ISO TS 19091 [26], which in turn refers to SAE J2735 [27]. Data elements, data frames and service parameters shall be used according to the definitions in Table 12 to 12.6 and Table 13 to 13.5. Wherever the profile indicates 'not used' this means: not used for current ITS-S application, kept optional for future ITS-S application, therefore use is not forbidden. The header of MAPEM/SPATEM shall be as specified in the data dictionary ETSI TS 102 894-2 [9].

The relationships of the tables of MAPEM are depicted in Figure 1 and in Figure 2 for the relationship of the SPATEM tables.

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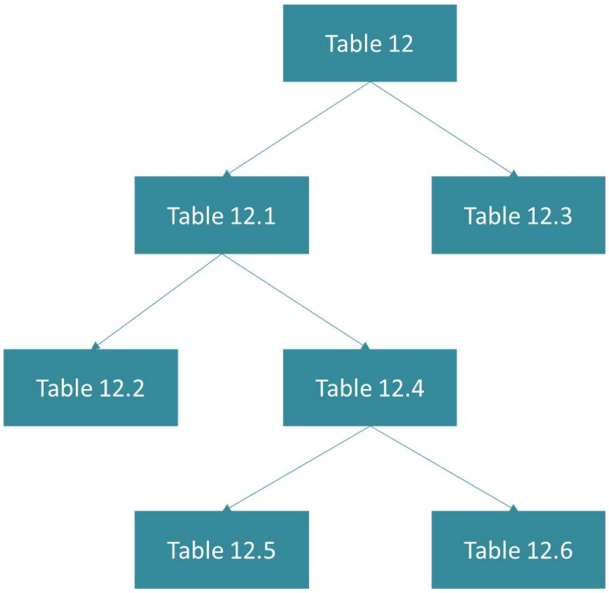

Figure 1 relationship of MAPEM data element tables

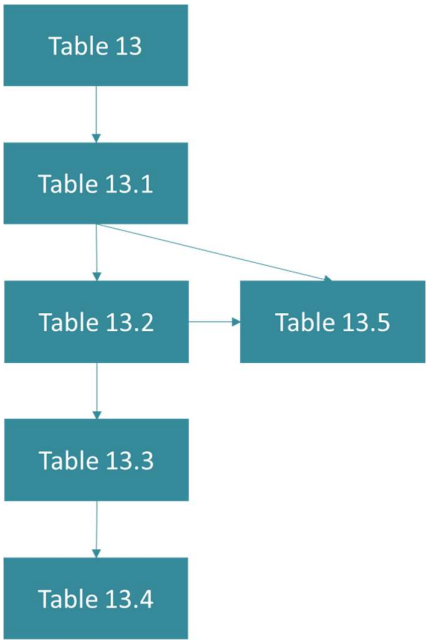

Figure 2 relationship of SPATEM data element tables

3.2.3.1 MAPEM general elements

Table 12 MAPEM data elements

Level	Name	Type	M/O	Usage	Comment
*	mapData	DF	Mandatory		
**	timeStamp	DE	Optional	Not used.	

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Table 12 MAPEM data elements

Level	Name	Type	M/O	Usage	Comment
**	msgIssue Revision	DE	Mandatory	Set to 0. As defined in ISO TS19091.	
**	layerType	DE	Optional	Not used.	
**	layerID	DE	Optional	As defined in ISO TS19091.	
**	intersectio ns (1..32)	DF	Mandatory	IntersectionGeometryList ::= SEQUENCE (SIZE(1..32)) OF IntersectionGeometry (see table 12.1) Mandatory for TLM/RLT ITS-S applications.	
**	roadSegm ents (1..32)	DF	Optional	Not used. Data elements within are not further profiled.	
**	dataPara meters	DF	Optional		*NL* Used, in particular processAgency and lastCheckedData.
***	process Method	DE	Optional	Not used.	
***	process Agency	DE	Optional		*NL* Used.
***	lastChec kedDate	DE	Optional	as: yyyy-mm-dd	*NL* Used.
***	geoidUs ed	DE	Optional	Not used.	
**	restriction List (1..32)	DF	Optional	RestrictionClassList ::= SEQUENCE (SIZE(1..254)) OF RestrictionClassAssi gnment (see table 12.3).	*NL* Used, if applicable.
**	regional	DE	Optional	REGION.Reg-MapData. Not used.	

Table 12.1 IntersectionGeometryList → IntersectionGeometry

Level	Name	Type	M/O	Usage	Comment
*	intersecti onGeome try	DF	Mandatory	Mandatory if 'intersections' is used.	
**	name	DE	Optional	Typically human readable and recognizable by road authority.	*NL* Used.
**	id	DF	Mandatory	(IntersectionReferenceID) Must be the same as in the	

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Table 12.1 IntersectionGeometryList → IntersectionGeometry

Level	Name	Type	M/O	Usage	Comment
				SPATEM. The combination of region and id must be unique within a country.	
***	region	DE	Optional		*NL* Used.
***	id	DE	Mandatory		
**	revision	DE	Mandatory	The revision number must be increased by 1 each time the MapData of this intersection changes. The revision numbers of SPATEM and MAPEM must be the same as an indication that the right MAPEM revision is used. As defined in ISO TS19091.	
**	refPoint	DF	Mandatory		
***	lat	DE	Mandatory		
***	long	DE	Mandatory		
***	elevation	DE	Optional	Not used. Replaced by regional Reg-Position3D.	
***	regional	DF	Optional	REGION.Reg-Position3D. Optional. When given provides altitude.	
****	altitude	DF	Mandatory	Consists of altitudeValue and altitudeConfidence	
*****	altitudeValue	DE	Mandatory		
*****	altitudeConfidence	DE	Optional	Mandatory, when not available set to (15) = unavailable.	
**	laneWidth	DE	Optional		*NL, BE(Fla)* Used.
**	speedLimits (1..9)	DF	Optional	SpeedLimitList ::= SEQUENCE (SIZE(1..9)) OF RegulatorySpeedLimit (see table 12.2).	*NL, BE(Fla), FR* Used.
**	laneSet (1..255)	DF	Mandatory	LaneList ::= SEQUENCE (SIZE(1..255)) OF GenericLane (see table 12.4).	

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Table 12.1 IntersectionGeometryList → IntersectionGeometry

Level	Name	Type	M/O	Usage	Comment
**	preemptPriorityData (1..32)	DF	Optional	Not used. Data elements within are not further profiled.	
**	Regional	DF	Optional	REGION.Reg-IntersectionGeometry). Not used.	

Table 12.2 SpeedLimitList → RegulatorySpeedLimit

Level	Name	Type	M/O	Usage	Comment
*	regulatorySpeedLim it	DF	Mandatory	Mandatory if 'speedLimits' is used.	
**	type	DE	Mandatory		
**	speed	DE	Mandatory		

Table 12.3 ResdtrictionClassList → RestrictionClassAssignment

Level	Name	Type	M/O	Usage	Comment
*	restrictionClassAssignment	DF	Mandatory	Mandatory if 'restrictionList is used.	
**	id	DE	Mandatory		
**	users	DF	Mandatory	RestrictionUserTypeList ::= SEQUENCE (SIZE(1..16)) OF RestrictionUserType	
***	restrictionUserType	DF	Mandatory		
****	basicType	DE	Optional	Used.	
****	regional (1..4)	DF	Optional	REGION.Reg-RestrictionUserType-addGrpC. Optional to provide emission restrictions.	
*****	emission	DE	Optional		

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Table 12.4 LaneList → GenericLane

Level	Name	Type	M/O	Usage	Comment
*	genericLane	DF	Mandatory	Mandatory if 'laneSet' is used	
**	laneID	DE	Mandatory		
**	name	DE	Optional		*AT, NL, BE(Fla)* Used.
**	ingressApproach	DE	Optional	If used, ingress and egress approaches of the same arm have the same ApproachID.	*NL* Used.
**	egressApproach	DE	Optional	If used, ingress and egress approaches of the same arm have the same ApproachID.	
**	laneAttributes	DF	Mandatory		
***	directionalUse	DE	Mandatory		
***	sharedWith	DE	Mandatory	With bits as defined: overlappingLaneDescriptionProvided (0) multipleLanesTreatedAsOneLane (1) -- not permitted in profile as all lanes shall be described. otherNonMotorizedTrafficTypes (2) -- e.g. horse drawn individualMotorizedVehicleTraffic (3) -- passenger cars busVehicleTraffic (4) taxiVehicleTraffic (5) pedestriansTraffic (6) cyclistVehicleTraffic (7) trackedVehicleTraffic (8) pedestrianTraffic (9) -- use 6 instead (error)	
***	laneType	DF	Mandatory	Mandatory. Used in this profile: - vehicle - crosswalk - bikeLane - trackedVehicle -- see ISO TS19091 for pedestrian crossing examples.	
****	Vehicle	DE	Optional	(choice)	
****	crosswalk	DE	Optional	(choice)	
****	bikeLane	DE	Optional	(choice)	
****	sidewalk	DE	Optional	Not used.	

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Table 12.4 LaneList → GenericLane

Level	Name	Type	M/O	Usage	Comment
****	median	DE	Optional	Not used.	
****	striping	DE	Optional	Not used.	
****	trackedVehicle	DE	Optional	(choice)	
****	parking	DE	Optional	Not used.	
***	regional	DF	Optional	Reg-laneAttributes. Not used.	
**	maneuvers	DE	Optional	Not used.	
**	nodeList	DF	Mandatory		
***	nodes (2..63)	DF	Mandatory	NodeSetXY ::= SEQUENCE (SIZE(2..63)) OF NodeXY (see table 12.5) Mandatory if 'nodeList' is used. Recommended use for curved lanes is to add an additional node when the centre line of the GenericLane deviates from the actual centre line more than 0.5m.	
***	computed	DF	Optional	Not used.	
**	connectsTo (1..16)	DF	Optional	ConnectsToList ::= SEQUENCE (SIZE(1..16)) OF Connection (see table 12.6). For example for egress lanes or lane which are not managed by a traffic light.	
**	overlays	DF	Optional	Not used.	
**	regional	DF	Optional	REGION-Reg-GenericLane. Not used (until upcoming release of ISO TS19091). To provide ConnectionTrajectory-addGrpC. Relevant for use case scenario safe intersection manoeuvre.	

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Table 12.5 NodeSetXY → NodeXY

Level	Name	Type	M/O	Usage	Comment
*	nodeXY	DF	Mandatory	Mandatory if 'nodes' is used.	
**	delta	DF	Mandatory		
***	node-XY1	DF	Optional	(choice) DF composed with X and Y, both mandatory.	
***	node-XY2	DF	Optional	(choice) DF composed with X and Y, both mandatory.	
***	node-XY3	DF	Optional	(choice) DF composed with X and Y, both mandatory.	
***	node-XY4	DF	Optional	(choice) DF composed with X and Y, both mandatory.	
***	node-XY5	DF	Optional	(choice) DF composed with X and Y, both mandatory.	
***	node-XY6	DF	Optional	(choice) DF composed with X and Y, both mandatory.	
***	node-LatLon	DF	Optional	Not used for intersections. Use for e.g. motorways is acceptable.	
***	regional	DF	Optional	REGION.Reg-NodeOffsetPointXY. Not used.	
**	attributes	DF	Optional	This DE provides any optional attributes which are needed. This includes changes to the current lane width and elevation. All attributes are provided in the order of the nodes (as opposed to the driving direction). Also left/right indications by attributes must be interpreted based on the order of the nodes.	*NL* Used.
***	localNode (1..8)	DF	Optional	NodeAttributeXYList ::= SEQUENCE (SIZE(1..8)) OF NodeAttributeXY Subject to case. Stopline is mandatory when present in the field.	
****	nodeAttributeXY	DE	Mandatory	Mandatory if localNode is used.	
***	disabled (1..8)	DF	Optional	SegmentAttributeXYList ::= SEQUENCE (SIZE(1..8)) OF SegmentAttributeXY	

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Table 12.5 NodeSetXY → NodeXY

Level	Name	Type	M/O	Usage	Comment
				Optional. Subject to case.	
****	segmentAttributeXY	DE	Mandatory	Mandatory if disabled is used.	
***	enabled (1..8)	DF	Optional	SegmentAttributeXYList ::= SEQUENCE (SIZE(1..8)) OF SegmentAttributeXY Subject to case.	
****	segmentAttributeXY	DE	Mandatory	Mandatory if enabled is used.	
***	data	DF	Optional		*NL* Used, if applicable. Only used to update the speedLimits.
****	pathEndPointAngle	DE	Optional	Not used.	
****	pathEndPointAngle	DE	Optional	Not used.	
****	laneCrownPointCenter	DE	Optional	Not used.	
****	laneCrownPointLeft	DE	Optional	Not used.	
****	laneCrownPointRight	DE	Optional	Not used.	
****	laneAngle	DE	Optional	Not used.	
****	speedLimits (1..9)	DE	Optional	SpeedLimitList ::= SEQUENCE (SIZE(1..9)) OF RegulatorySpeedLimit (see table 12.2). (choice)	*NL* Used, if applicable.
****	regional	DF	Optional	REGION.Reg-LaneDataAttribute. Not used.	
***	dWidth	DE	Optional		*NL* Used when lanes are smaller than 2.75m. Provided at the first node of the lane only to indicate the smallest width along the lane.
***	dElevation	DE	Optional		*NL, Be(Fla)* Used when road gradient compared to previous node is more than 2%.

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Table 12.5 NodeSetXY → NodeXY

Level	Name	Type	M/O	Usage	Comment
***	regional	DF	Optional	REGION.Reg-NodeAttributeSetXY. Not used.	

Table 12.6 ConnectsToList → Connection

Level	Name	Type	M/O	Usage	Comment
*	connection	DF	Optional	Mandatory if 'connectsTo' is used.	
**	connectingLane	DF	Mandatory		
***	lane	DE	Mandatory		
***	maneuver	DE	Optional		*NL, BE(Fla)* Used, if applicable. 0-3 and 8 are most commonly used.
**	remoteIntersection	DF	Optional	Only used if the referenced intersection is part of the same MAPEM.	*NL, BE(Fla)* Used, if applicable.
***	region	DE	Optional		
***	id	DE	Mandatory		
**	signalGroup	DE	Optional	Optional as not all connections may have a signalgroup related to it. However, for connections which are controlled by a traffic light the signalgroup must be set.	
**	userClass	DE	Optional		*NL, BE(Fla)* Used, if applicable.
**	connectionID	DE	Mandatory		

3.2.3.2 SPATEM general elements

Table 13 SPATEM data elements

Level	Name	Type	M/O	Usage	Comment
*	Spat	DF	Mandatory		
**	timeStamp	DE	Optional	Not used	*DE* Used.
**	name	DE	Optional	Not used	*AT* Used.

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Table 13 SPATEM data elements

Level	Name	Type	M/O	Usage	Comment
**	Intersections (1..32)	DF	Mandatory	IntersectionStateList ::= SEQUENCE (SIZE(1..32)) OF IntersectionState (see table 13.1).	
**	regional (1..4)	DF	Optional	REGION.Reg-SPAT. Not used.	

Table 13.1 IntersectionStateList → IntersectionState

Level	Name	Type	M/O	Usage	Comment
*	intersectionS tate	DF	Mandatory		
**	name	DE	Optional	Used, but kept optional Based on a numbering scheme used by the road authority.	*NL, BE(Fla)* Used.
**	id	DF	Mandatory	(IntersectionReferenceID) Must be the same as in the MAPEM. The combination of region and id must be unique within a country.	
***	region	DE	Optional		
***	id	DE	Mandatory		
**	revision	DE	Mandatory	The revision number must be increased by 1 each time the MapData of this intersection changes. The revision numbers of SPATEM and MAPEM must be the same as an indication that the right MAPEM revision is used. As defined in ISO TS19091.	
**	status	DE	Mandatory	Typically used based on EN 12675 are: • manualControlIsEnabled (0), • fixedTimeOperation (5), • trafficDependentOperation (6), • standbyOperation (7), • failureMode (8),	*NL* failureMode (8) is not used, instead failureFlash(2) and off(9) are used.
**	moy	DE	Mandatory	Also used to validate the reference time of the TimeMarks.	
**	timeStamp	DE	Mandatory		
**	enabledLanes	DF	Optional	Mandatory if the revocableLane bit is used in any of the lane descriptions, otherwise not used.	
**	states (1..16)	DF	Mandatory	MovementList ::= SEQUENCE (SIZE(1..255)) OF MovementState (see table 13.2).	
**	maneuverAssistList (1..16)	DF	Optional	ManeuverAssistList ::= SEQUENCE (SIZE(1..16)) OF ConnectionManeuverAssist (see table 13.5).	

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Table 13.1 IntersectionStateList → IntersectionState

Level	Name	Type	M/O	Usage	Comment
				Not used, therefore not further profiled on this level.	
**	Regional (1..4)	DF	Optional	REGION.Reg-IntersectionState. Optional, to ensure interoperability with existing public transport prioritisation systems.	*AT, DE* Used.

Table 13.2 MovementList → MovementState

Level	Name	Type	M/O	Usage	Comment
*	movementState	DF	Mandatory	Mandatory if 'states' is used.	
**	movementName	DE	Optional		*BE(Fla), NL, FR* Used.
**	signalGroup	DE	Mandatory		
**	state-time-speed	DF	Mandatory	MovementEventList ::= SEQUENCE (SIZE(1..16)) OF MovementEvent Mandatory (1-16). (see table 13.3).	*NL* As many state-time-speed are provided until the confidence value < 21%.
**	maneuverAssistList (1..16)	DF	Optional	ManeuverAssistList ::= SEQUENCE (SIZE(1..16)) OF ConnectionManeuverAssist (see table 13.5).	*NL* Used to convey queue length for speed advisory calculation.
**	regional (1..4)	DF	Optional	REGION.Reg-MovementState. Not used.	

Table 13.3 MovementEventList → MovementEvent

Level	Name	Type	M/O	Usage	Comment
*	movementEvent	DF	Mandatory	Mandatory if 'state-time-speed' is used.	

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Table 13.3 MovementEventList → MovementEvent

Level	Name	Type	M/O	Usage	Comment
**	eventState	DE	Mandatory	Defined as follows: (0) unavailable (unknown or error) (1) dark (not used in EU) (2) stop-then-Proceed (e.g. red light combined with road sign with green arrow for turn movement). (3) stop-and-remain (e.g. red light) (4) pre-Movement (e.g. red/amber as used in some EU countries before green signal) (5) permissive-Movement-Allowed (e.g. green "full ball" light, with potential conflicting traffic, especially while turning left or right). (6) protected-Movement-Allowed (e.g. green "arrow" light, with no conflicting traffic or pedestrians while crossing the conflict area). (7) permissive clearance (e.g. amber "full ball" light, prepare to stop. Used after a "green" signal state). (8) protected clearance (e.g. amber "arrow" light, Directional prepare to stop. Used after a "green arrow" signal state). (9) caution-Conflicting-Traffic (e.g. Amber light blinking; Proceed with caution, Conflicting traffic may be present in the intersection conflict area).	
**	timing	DF	Optional	For example timing data may not be available when 'status' is 0, 1 or 9. All TimeMarks are defined as an offset to the UTC full hour (see TS19091) and not for functional safety, but informative related to signal timing. likelyTime with confidence or minEndTime with maxEndTime are both measures for probability which can be used interchangeably subject to availability.	
***	startTime	DE	Optional	Not used.	
***	minEndTime	DE	Mandatory	Pre-configured or calculated value with high probability, but sometimes not available (36001). In case of e.g. fixed time control identical to maxEndTime which indicates high probability.	

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Table 13.3 MovementEventList → MovementEvent

Level	Name	Type	M/O	Usage	Comment
***	maxEndTime	DE	Mandatory	Pre-configured or calculated value with high probability, but sometimes not available (36001). In case of e.g. fixed time control identical to minEndTime which indicates high probability.	
***	likelyTime	DE	Optional		*NL, BE(Fla)* Used.
***	confidence	DE	Optional	Mandatory if likelyTime is provided. The definition of 'confidence' in the base standard is not useable. Instead, confidence is defined by the standard deviation (sigma) of the likelyTime in seconds. The value provided by this data element, between 0 and 15 represents 1 sigma (rounded). 15 = unknown. Hence, the conversion table with probabilities as provided in J2735 is not used. Assuming normal distribution and a standard deviation of 3,6 seconds, the following applies: • The likelyTime is within 26 and 34 seconds (1 sigma) with 68,27% probability. • The likelyTime is within 22 and 38 seconds (2 sigma) with 95,44% probability. • The likelyTime is within 18 and 42 seconds (3 sigma) with 99,73% probability.	
***	nextTime	DE	Optional		
**	speeds (1..16)	DF	Optional	AdvisorySpeedList ::= SEQUENCE (SIZE(1..16)) OF AdvisorySpeed (see table 13.4).	*NL* Used e.g. in case of physical roadside signage displaying dynamic advisory speeds.
**	regional (1..4)	DF	Optional	REGION.Reg-MovementEvent,	*NL* Priority and preemption may have a considerable impact to the timing parameters in the SPAT message (eventState). User acceptance is expected to increase if the reason for sudden changes in timing parameters is communicated to them. Therefore the following extension has been added:

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Table 13.3 MovementEventList → MovementEvent

Level	Name	Type	M/O	Usage	Comment

					stateChangeReason ::= ENUMERATED
					{
					unknown
					publicTransportPriority
					emergencyVehiclePriority
					trainPriority bridgeOpen
					vehicleHeight
					weather
					priority
					trafficJam
					tunnelClosure meteringActive
					truckPriority
					bicyclePlatoonPriority
					vehiclePlatoonPriority
					…
					}

Table 13.4 AdvisorySpeedList → AdvisorySpeed

Level	Name	Type	M/O	Usage	Comment
*	advisorySpeed	DF	Mandatory	Mandatory if 'speeds' is used.	
**	type	DE	Mandatory	greenwave (1) = speed for a sequence of coordinated intersections (repeated at each intersection). ecoDrive (2) = speed for current intersection. transit (3) = restricted to specific vehicle type.	
**	speed	DE	Optional		*NL* Used.
**	confidence	DE	Optional	Not used.	
**	distance	DE	Optional	Not used for greenwave (1). In other cases, distance is specified upstream from the stop bar along the ingressing lane.	*NL* Used.
**	class	DE	Optional		
**	regional (1..4)	DF	Optional	REGION.Reg-AdvisorySpeed . Not used.	

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Table 13.5 ManeuverAssistList → ConnectionManeuverAssist

Level	Name	Type	M/O	Usage	Comment
*	connectionManeuverAssist	DF	Mandatory	Mandatory if 'maneuverAssistList' is used.	
**	connectionID	DE	Mandatory		
**	queueLength	DE	Optional		*NL* Used when available to allow vehicles to improve the speed advisory calculation based on time-to-green information.
**	availableStorageLength	DE	Optional	Not used.	
**	waitOnStop	DE	Optional	Not used.	
**	pedBicycleDetect	DE	Optional	Not used.	
**	regional (1..4)	DF	Optional	REGION.Reg-ConnectionManeuverAssist . Not used.	

3.2.4 Traffic Light Control (TLC) FLS

The Traffic Light Control service is one instantiation of the infrastructure services to manage the generation, transmission of SREM messages and SSEM messages. The TLC service supports prioritization of public transport and public safety vehicles (ambulance, fire brigade, etc.) to traverse a signalized road infrastructure (e.g. intersection) as fast as possible or using a higher priority than ordinary traffic participants. The corresponding SREM is sent by an ITS-S (e.g. vehicle) to the traffic infrastructure environment (e.g. R-ITS-S, TCC). In a signalized environment (e.g. intersection) the SREM is sent for requesting traffic light signal priority (public transport) signal pre-emption (public safety). The service may not only be requested for the approaching signalized environment but also for a sequence of e.g. intersections along a defined traffic route. In response to the request the infrastructure (e.g. R-ITS-S/TLC or TCC) will acknowledge with a SSEM notifying if the request has been granted, cancelled or changed in priority due to a more relevant signal request (e.g. ambulance). (ETSI TS 103 301 [11])

Operational parameters and relevant standards

The TLC FLS including operational parameters is defined in ETSI TS 103 301 [11], which refers to ISO TS19091 [26], which in turn refers to SAE J2735 [27]. Data elements, data frames and service parameters shall be used according to the definitions in Table 14 and Table 15. The header SREM/SSEM shall be as specified in the data dictionary ETSI TS 102 894-2 [9].

The relationships of the tables of SREM are depicted in Figure 3 and in Figure 4 for the relationship of the SSEM tables.

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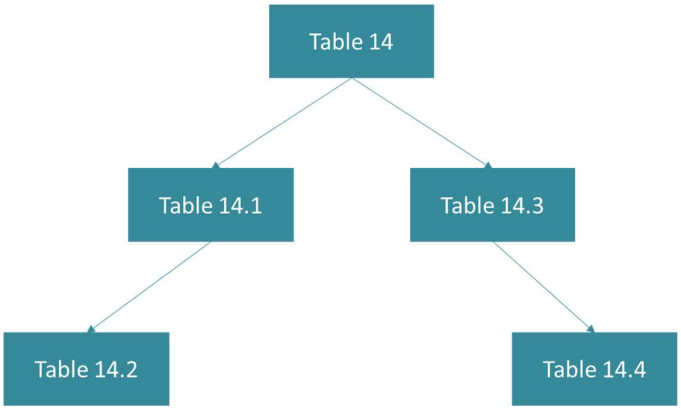

Figure 3 relationship of SREM data element tables

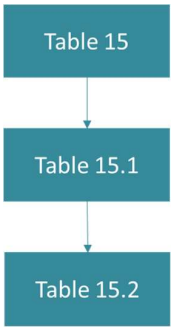

Figure 4 relationship of SSEM data element tables

3.2.4.1 SREM general elements

Table 14 SREM general elements

Level	Name	Type	M/O	Usage	Comment
*	SREM	DF	Mandatory		
**	timeStamp	DE	Mandatory		
**	second	DE	Mandatory		
**	sequenceNumber	DE	Mandatory		
**	requests	DE	Mandatory	SignalRequestList ::= SEQUENCE (SIZE(1..32)) OF SignalRequestPackage (see table 14.1).	
**	requestor	DF	Mandatory	See table 14.3.	
**	regional	DF	Optional	REGION.Reg-SignalRequestMessage Not used.	

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Table 14.1

Level	Name	Type	M/O	Usage	Comment
*	signalRequestPackage	DF	Mandatory	Continues 'requests'	
**	request	DF	Mandatory	See table 14.2.	
**	minute	DE	Optional		
**	second	DE	Optional		
**	duration	DE	Optional	Not used.	
**	regional	DF	Optional	REGION.Reg-SignalRequestPackage	

Table 14.2

Level	Name	Type	M/O	Usage	Comment
*	signalRequest	DF	Mandatory	Continues 'request'	
**	id	DE	Mandatory		
***	region	DE	Optional		
***	id	DE	Mandatory		
**	requestID	DE	Mandatory		
**	requestType	DE	Mandatory		
**	inBoundlane	DF	Mandatory		
***	lane	DE	Optional	(choice)	
***	approach	DE	Optional	(choice)	
***	connection	DE	Optional	(choice)	
**	outBoundLane	DF	Optional		

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Table 14.2

Level	Name	Type	M/O	Usage	Comment
***	lane	DE	Optional	(choice)	
***	approach	DE	Optional	(choice)	
***	connection	DE	Optional	(choice)	
**	regional	DE	Optional	REGION.Reg-SignalRequest Not used.	

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Table 14.3

Level	Name	Type	M/O	Usage	Comment
*	requestorDescription	DF	Mandatory	Continues 'requestor'	
**	id	DF	Mandatory		
***	entityID	DE	Optional	Not used.	
***	stationID	DE	Mandatory	Identical to the stationID of the CAM message and may not change during pending SREM.	
**	type	DF	Optional	See table 14.4	
**	position	DF	Optional	Not used.	
***	position	DE	Optional	Not used as parent DF is not used.	
****	lat	DE	Optional	Not used as parent DF is not used.	
****	long	DE	Optional	Not used as parent DF is not used.	
****	elevation	DE	Optional	Not used as parent DF is not used.	
****	regional	DF	Optional	REGION.Reg-Position3D Not used as parent DF is not used.	
***	heading	DE	Optional	Not used.	
***	speed	DF	Optional	Not used.	
****	transmission	DE	Optional	Not used as parent DF is not used.	
****	speed	DE	Optional	Not used as parent DF is not used.	
**	name	DE	Optional		
**	routeName	DE	Optional		
**	transitStatus	DE	Optional		
**	transitOccupancy	DE	Optional	Not used.	

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**	transitSchedule	DE	Optional		
**	regional	DE	Optional	REGION.Reg-Requestor-Description. Not used.	

Table 14.4

Level	Name	Type	M/O	Usage	Comment
*	requestorType	DF	Mandatory	Continues 'type'	
**	role	DE	Mandatory		
**	subrole	DE	Optional		*NL* Used.
**	request	DE	Optional		
**	iso3833	DE	Optional	Not used.	
**	hpmsType	DE	Optional	Not used.	
**	regional	DE	Optional	REGION.Reg-RequestorType Not used.	

3.2.4.2 SSEM general elements

Table 15 SSEM general elements

Level	Name	Type	M/O	Usage	Comment
*	SSEM	DF	Mandatory		
**	timeStamp	DE	Mandatory		
**	second	DE	Mandatory		
**	status	DF	Mandatory	SignalStatusList ::= SEQUENCE (SIZE(1..32)) OF SignalStatus See table 15.1.	
**	regional	DF	Optional	[REGION.Reg-SignalStatus-Message Not used.	

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Table 15.1

Level	Name	Type	M/O	Usage	Comment
*	signalStatus	DF	Mandatory	Continues 'status'.	
**	sequenceNumber	DE	Mandatory		
**	id	DF	Mandatory		
***	region	DE	Optional		
***	id	DE	Mandatory		
**	sigStatus	DF	Mandatory	SignalStatusPackageList ::= SEQUENCE (SIZE(1..32)) OF SignalStatusPackage See table 15.2.	
**	regional	DF	Optional	REGION.Reg-SignalStatus. Not used.	

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Table 15.2

Level	Name	Type	M/O	Usage	Comment
*	signalStatusPackage	DF	Mandatory	Continues 'sigStatus'	
**	requestor	DF	Mandatory		
***	id	DE	Mandatory		
****	entityID	DE	Optional	Choice: not used.	
****	stationID	DE	Mandatory	Choice	
***	request	DE	Mandatory		
***	sequenceNumber	DE	Mandatory		
***	role	DE	Optional	Not used.	
***	typeData	DE	Mandatory		
****	role	DE	Mandatory		
****	subrole	DE	Optional		
****	request	DE	Optional	Not used.	
****	iso3833	DE	Optional	Not used.	
****	hpmsType	DE	Optional	Not used.	
****	regional	DF	Optional	REGION.Reg-RequestorType Not used.	
**	inBoundlane	DF	Mandatory		
***	lane	DE	Optional	(choice)	
***	approach	DE	Optional	(choice)	
***	connection	DE	Optional	(choice)	
**	outBoundLane	DF	Optional		
***	lane	DE	Optional	(choice)	

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***	approach	DE	Optio nal	(choice)	
***	connection	DE	Optio nal	(choice)	
**	minutes	DE	Mand atory		
**	second	DE	Mand atory		
**	duration	DE	Mand atory		
**	status	DE	Mand atory		
**	regional	DF	Optio nal	REGION.Reg-SignalStatus-Package Not used.	

3.3 Operational Specifications / Triggering Conditions

This section describes the information management of the different message sets. Note, that different triggering conditions do not cause interoperability issues. If the information enclosed in the messages is interoperable, different update or cancellation mechanisms do not cause semantic problems.

3.3.1 The principle of DENM transmission conditions

This paragraph covers the following principles of DENM transmissions of the RWW ITS-S application, the principles are also valid for the ITS-S application of Hazardous Location Notifications.

AT

There are different use case scenarios of the RWW ITS-S application which differ in where the information is created (C-ITS-S or R-ITS-S) and where the basic information is received from (from TCC, from safety trailers at the roadside, or from a fusion of both sources).

In the use case scenario of TCC triggered RWWs, the Central ITS station (C-ITS-S) conveys the RWW messages (on behalf of TCC) to a set of selected, suitable R-ITS-S for transmission. Transmitting the DENMs is triggered by the transmission of the DENMs from C-ITS-S to R-ITS-S.

In the use case scenario of a trailer triggered RWW, an R-ITS-S generates the DENM autonomously; the trailer activation is acting as a trigger.

In both cases a DENM will be updated whenever the event content changes, either according to the TCC or due to changed values from the local systems on the trailer. Note that the latter implies that DENMs for moving roadworks are updated frequently due to trailer movement (changing data elements depending on trailer location).

Even if the event content is not changed, the DENM will be updated after half of the initial validity duration has expired. This is needed to ensure that DENMs received by vehicles have a sufficient remaining lifetime to ensure that the message content is still processed when the vehicle finally reaches the relevant location.

A DENM will be terminated by simply stopping its transmission in the sending station. This occurs automatically at latest when the end of its validity (detectionTime + validityDuration) is reached. The C-ITS can stop the transmission earlier by updating the DENM with a shorter validityDuration.

Note that even if the latter mechanism is used, some vehicles may have received the message with the longer validity but not the update with the shortened validity. Hence, the timing parameters in AT are chosen to strike a good balance between reaction time of the system when ending a RWW and the frequency of DENM updates required.

Also, note that the use of cancellation messages would suffer the same problem and hence would not change the situation. In particular, even when using cancellation messages there is a risk in using long validityDuration values.

Type of messages: **new** DENM and **update** DENM

DE

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A DENM is initially triggered in all use case scenarios by a safety trailer. RWW always starts standalone, where the activation of the trailer is acting as the actual trigger. Note that the system is already capturing its trajectory before in order to allow calculating the traces data frame at the time the transmission is triggered.

If a connection to the TCC is available, the use case scenario can be switched to augmented RWW (German terminology: Basic Modus) in which the C-ITS-S provides additional information based on fusing the trailer generated message with TCC data from a digital map and a roadworks management system, if available.

A DENM will be updated

- whenever the event data from the trailer changes (e.g. direction of arrow sign)
- because of a TCC data fusion or
- after half of the validity duration.

A DENM is terminated by stopping sending it. This occurs when the end of its validity (detectionTime + validityDuration) is reached.

Type of messages: **new** DENM and **update** DENM

FR

There are two use case scenarios; either TCC triggered RWWs or standalone. In the use case scenario of TCC triggered RWWs, the local Scoop@F platform conveys the RWW messages (on behalf of TMC) to a set of suitably selected R-ITS-S (for ITS-G5) for transmission.

In the standalone use case scenario, DENM transmission is triggered by ITSS-VG - passenger car with OBU in operator mode - manually if equipment are not connected or automatic if connected.

A DENM will be updated whenever the event information changes according to the TMC, and maximum validity duration of DENM (less than 24h) may be shorter than the duration of RWW.

Note:

Due to the functional description of the TCC Triggered RWW use case scenario in Scoop@F: Planned roadwork [23], the duration of RWW may last longer than 24h which is an indication for a Long-term RWW.

A DENM can only be terminated by TMC via the local Scoop@F platform if it was centrally triggered. In the standalone use case scenario, DENM is terminated manually by the road operator agent or automatically (i.e. when equipment stops working). The Scoop@F ITS-Ss do not have the right to negate the DENMs transmitted by another ITS station.

Type of messages: **new** DENM, **update** DENM and **cancellation** DENM.

NL

The use case scenario that is adapted in the DUTCH C-ITS profile is TCC Triggered RWWs. In the use case scenario of TCC triggered RWWs, the C-ITS-S (on behalf of the TMC) conveys the RWW messages to a pre-selected R-ITS-S for transmission.

A DENM will be updated whenever an event update is detected or after half of the validity duration. The DE validityDuration is set at a fixed value. Different approaches like setting validityDuration at a high value are also allowed.

By means of a direction termination, a DENM is terminated via the C-ITS-S (on behalf of the TCC). If the originating stationID is the same as the ID of the station that terminates the message, a cancellation message shall be sent. otherwise, the negation option shall be used.

Type of messages: **new** DENM, **update** DENM, **cancellation** DENM, and **negation** DENM.

3.3.1.1 Roadworks Warning (RWW)

A warning message about roadworks is broadcasted as DENM message using Basic Transport Protocol and GeoNetworking.

The specific usage of DENM service primitives is defined in Table 16.

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Table 16 DENM service primitives for RWW

Name	AT	DE	FR	NL
DENM Trigger	*Augmented RWW* The DENM is triggered by the C-ITS-S if all information from the trailer is available. RWW always starts with Standalone RWW. If a connection to TCC is possible and additional information in the TCC exists, the TCC sends the Augmented RWW to the R-ITS-S which stops updating the Standalone RWW and triggers the transmission of the Augmented RWW. *Standalone RWW* The DENM is triggered at the moment the trailer board is activated. *TCC Triggered RWW* The DENM is triggered by the C-ITS-S based on available TCC information. When the TCC signals the end of a roadwork, the C-ITS-S stops updating the DENM and subsequently the	The DENM is triggered at the moment the trailer board reaches the open state. *Standalone RWW* All RWW start as Standalone RWW. *Augmented RWW* If a connection to the TCC is possible and additional information in TCC exist, then the augmented RWW starts when the DENM is augmented.	*Standalone use case scenarios (for mobile roadworks)* Mobile roadworks (causeCode: 3 and subCauseCode: 3) : the DENM is triggered by fulfilling those conditions: Activity of the ITSS-VG is « mobile roadworks" AND ((manual activation) XOR (automatic: light arrow OR another equipment is activated)) *TCC triggered use case scenarios (for closure of a lane, a road, or mobile roadworks)* The DENM is triggered by the R-ITS-S based on available TCC information. When the TCC signals the end of a roadwork, the R-ITS-S stops updating the message. If the roadworks are more than 24 hours, the C-ITS divides the event into 24 hours slots and prepares to send updates of the event every 24 hours accordingly.	*TCC Triggered RWW* The DENM is centrally triggered at the (best estimate for the) moment the physical blockage of the lane due to the roadworks.

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Table 16 DENM service primitives for RWW

Name	AT	DE	FR	NL
	DENM transmission ends.			
DENM Update	*Augmented RWW* The DENM is updated when its content changes or when the age (current system time minus DENM detection time) is greater than or equal to half of its validity time. *Standalone RWW - Mobile* The DENM is updated when its content changes (e.g. change of arrow sign) or when the age (current system time minus DENM detection time) is greater than or equal to half of its validity time. *Standalone RWW - Stationary* The DENM is updated when its content changes or when the age (current system time minus DENM detection time) is greater than or equal to half of its validity time. *TCC Triggered RWW* The DENM is updated when its content	*Augmented RWW & Standalone RWW - Mobile* The DENM is updated when its content changes or when the age (current system time minus DENM detection time) is greater than or equal to half of its validity time. Content changes may be changing location or change of arrow position. *Augmented RWW & Standalone RWW - Stationary* The DENM is updated when its content changes or when the age (current system time minus DENM detection time) is greater than or equal to half of its validity time. *TCC Triggered RWW* Not supported	*Standalone use case scenarios (for mobile roadworks)* The message is updated every 1 second. Field to be updated: trace, eventposition, eventspeed, referenceTime, detectionTime. The time elapsed to validity duration (600s) is reinitialised. *TCC triggered use case scenarios (for closure of a lane, a road, or mobile roadworks)* The DENM is updated when its content changes. If the end of the RWW is unknown, the local Scoop@F platform sets a defined validity duration, and updates the event as long as it is not ended by the TCC. If the end of the RWW is known, the message is only repeated regularly until the end of the RWW).	*TCC Triggered RWW* The DENM is updated when its age (current system time minus DENM detection time) is greater than or equal to half of its validity time.

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Table 16 DENM service primitives for RWW

Name	AT	DE	FR	NL
	changes or when the age (current system time minus DENM detection time) is greater than or equal to half of its validity time.			
DENM Termi-nation	Not used	Not used	*Standalone use case scenarios (for mobile roadworks)* Two cases: The extinction of the equipment triggers a termination message if the V-ITSS is connected to the equipment. Manual termination by the agent. *TCC triggered use case scenarios (for closure of a lane, a road, or mobile roadworks)* When RWW is finished by the TCC, a cancel message is sent, lasting as long as the last DENM message was valid for.	Used

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3.3.1.2 Hazardous Location Notifications (HLN)

In general terms, the same principles for DENM transmission apply as described in section 3.3.1. The specific usage of DEN service primitives is defined in Table 17.

Table 17 DENM service primitives for Hazardous Location Notifications

Name	Usage	AT	FR	NL
DENM Trigger	*HLN-RLX* The message is triggered and generated in the ITSS-PT (Public transport vehicle OBU) when the Vpt the area of the public transport stop and its speed is ≤ X (e.g. 5 km/h). The database of the public transport stop area and related pre-prepared warning messages are saved in the vehicle's OBU. *HLN-PTVC* The message is triggered and generated in the ITSS-PT (Public transport vehicle OBU) when PT vehicle enters the trigger area. The database of the trigger area and related pre-prepared warning messages are saved in the vehicle's OBU.	The message is triggered and generated in the C-ITS-S, based on event data received from TCC. The message is then forwarded to relevant R-ITS-S for transmission.	The DENM message is triggered manually in operator vehicles (ITSS-VG). This transmission will have a lower quality level than an automatic transmission. The message can be triggered by the TMC via the local Scoop@F platform and the R-ITS-S (The TMC operator will be able to specify the type of event).	The DENM message is triggered when the traffic inspector activates a button in his vehicle.
DENM Update		TCC event data updates received by the C-ITS-S cause a DENM update whenever the event data changes. Furthermore, the C-ITS will update the DENM after half of validityDuration (≤720s) since the last update has passed.	In the case of ITSS-VG: not used (validity duration is 1200s). In the case of R-ITS-S: updates are generated in the TMC. The time elapsed to validity duration is reinitialized (validity duration is between 3600 and 7200s).	Identical to RWW. The DENM is updated when its age (current system time minus DENM detection time) is greater than or equal to half of its validity time.
DENM Termi-nation		The termination service primitive is not used. The C-ITS-S stops updating the DENM after it has received an information from the TCC that the event is no longer valid.	The termination service primitive is used to transmit cancellation DENMs. In the case of ITSS-VG: manual termination by the agent or ends after validity duration if not cancelled In the case of R-ITS-S: termination at the end of the event determined by the TCC.	The termination service primitive is used to transmit cancellation DENMs when the traffic inspector de-activates the button.

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3.3.2 The principles of IVIM transmission conditions

AT

The current status of all available signs (note: only dynamic signs covered in current release) is sent out to approaching vehicles based on information provided from the TCC to the C-ITS-S. Each transmitted IVIM message has a status (iviStatus) that determines the type of message.

The end of validity duration is determined from C-ITS-S. updated after half the duration of the message $\frac{validTo-times}{2}$.

A new message or any change has a new timestamp.

Type of messages: new IVIM and update IVIM

NL

The trigger of IVIM transmission is the set of a measure e.g. changing a sign from blanc in the signalling system (MTM). Operationally, C-ITS-S sends IVIM message content based on TCC incoming information. Each transmitted IVIM message has a status (iviStatus) that determines the type of message.

The data frame validTo shall always be used to determine the validity. The update is provided only when the content of sign(s) changes (for example, when the maximum speed limit is reduced during rush hour). It is not intended to use iviStatus cancellation or negation.

It can be observed that the update of IVIM message in the Austrian implementation is more frequent than in the Netherlands.

Type of messages: new IVIM and update IVIM

3.3.2.1 In-Vehicle Signage (IVS)

Table 18 IVIM service primitives for IVS

Name	AT	NL
IVIM Trigger	IVIM is not triggered, but generated with timestamp and transmitted by C-ITS-S (based on information incoming from TCC).	There is no such a trigger as each available sign should be sent out to the drivers within. Operationally, C-ITS-S sends IVIM message content based on TCC incoming information. Each transmitted IVIM message has a status (iviStatus) that determines the type of message.
IVIM Update	End time of the validity period of the message. Will be provided by the C-ITS-S as part of the message management of IVI messages. Default validity for the IVI ITS-S application is 20 seconds. validTo will be set 20s ahead of timestamp and updated after half the duration of the message *((validTo – timestamp) / 2)*.	The data frame validTo shall always be used to determine the validity. An update shall be sent when the validity of a part of a sign is changed. For example, when the maximum speed limit is reduced during rush hour or when trucks are allowed to overtake during off-peak hours.
IVIM Termination	It is not intended to use iviStatus cancellation or negation.	Not used.

3.3.3 The principles of MAPEM transmission conditions

The specification doesn't contain any further information on information management for MAPEM.

3.3.4 The principles of SPATEM transmission conditions

The specification doesn't contain any further information on information management for SPATEM.

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3.4 Management Entity

The Management Entity is not relevant for the messages sent from the roadside to vehicle interface. The Management Entity is relevant for configuration of a R-ITS-S and for the split in functionality between R-ITS-S and C-ITS-S. The central to roadside interface is however not in scope of this document.

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3.5 Security Principles

The Security Principles chapter comprises all functions required for secured message generation, i.e. signature generation, key and certificate handling, as well as authentication (verification) of received messages.

To allow continuous operation of these security functions, not only functions and processes on an isolated ITS station have to be considered, but additionally the interface towards the Public Key infrastructure (PKI) must be addressed. This covers communication with Certificate Authorities (CA) for initial enrolment of ITS stations and periodic certificate requests, as well as details related to re-keying and certificate renewal, i.e. cryptographic parameters, validity times and protocols. Several of these aspects are covered by the Certificate Policy issued by the European Commission, which serves as a normative reference for all C-ROADS implementations.

Beyond the “Security Entity” described above, additional measures are required. Only those aspects that are specific to the introduction and operation of C-ITS equipment and FLSs can and will be detailed by Task Force 1 (TF1), other IT security requirements may be mentioned for reference but without any claim for completeness.

Such additional, rather generic “cybersecurity” aspects must be ensured by every road operator for all existing systems independent of cooperative systems. A non-exhaustive list of generic requirements comprises for example tamper-proof infrastructure components with secured interfaces, access restrictions, appropriate documentation and logging, plausibility checks on received data and misbehaviour detection, e.g. theft and access violation. Typically, all of the above is addressed by an ISMS (Information Security Management Systems), e.g. according to ISO/IEC 27001 [24] or other standards available.

Since these aspects are core responsibilities of any operator of IT networks/components, they are not addressed in depth within C-ROADS’ TF1.

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4 References

All normative references within a standard referenced here are automatically included and will not be listed separately. Only if a normative reference is out of date because a newer version of the reference standard is supported, the newer reference is listed and marked accordingly.

Table 19 Table of normative key references

#	Reference
[5]	ETSI EN 302 571 V2.1.1 (2017-02) - Intelligent Transport Systems (ITS); Radiocommunications equipment operating in the 5 855 MHz to 5 925 MHz frequency band; Harmonised Standard covering the essential requirements of article 3.2 of Directive 2014/53/EU
[11]	ETSI TS 103 301 V1.2.1 (2018-08) - Intelligent Transport Systems (ITS); Vehicular Communications; Basic Set of Applications; Facilities layer protocols and communication requirements for infrastructure services

Table 20 Table of additional normative references

#	Reference
[1]	ETSI TR 102 638 V1.1.1 (2009-06) Intelligent Transport Systems (ITS); Vehicular Communications; Basic Set of Applications; Definitions
[2]	ETSI EN 302 665 V1.1.1 (2010-09) Intelligent Transport Systems (ITS); Communications Architecture
[3]	C-ITS Platform Final report, January 2016
[4]	C-ROADS, Roadside ITS G5 System Profile, Release 1 (2017-07)
[6]	ETSI TS 102 792 V1.2.1 (2015-06) Intelligent Transport Systems (ITS); Mitigation techniques to avoid interference between European CEN Dedicated Short Range Communication (CEN DSRC) equipment and Intelligent Transport Systems (ITS) operating in the 5 GHz frequency range
[7]	ETSI EN 302 637-2 V1.3.2 (2014-11) Intelligent Transport Systems (ITS); Vehicular Communications; Basic Set of Applications; Part 2: Specification of Cooperative Awareness Basic Service
[8]	ECo-AT_SWP3.5_Coexistence_v04.60
[9]	ETSI TS 102 894-2 V1.3.1 (2018-08) Intelligent Transport Systems (ITS); Users and applications requirements; Part 2: Applications and Facilities layer common data dictionary

[10]	C_ROADS_WG2_TF2_Service Descriptions v1.3
[12]	ETSI EN 302 637-3 v1.2.2 (2014-11) Intelligent Transport Systems (ITS); Vehicular Communications; Basic Set of Applications; Part 3: Specifications of Decentralized Environmental Notification Basic Service
[13]	ECo-AT_SWP2.1_DENM_Applications_v04.00
[14]	Amsterdam Group – Road Works Warning Functional Description, Version 1.0 Amsterdam Group – Message Set and Triggering Conditions for Road Works Warning Service, Version 2.0 (2016-04)
[15]	ISO/TS 19321:2015 (2015-04-15) - Intelligent transport systems - Cooperative ITS - Dictionary of in-vehicle information (IVI) data structures
[16]	ISO 3166-1:2013 Codes for the representation of names of countries and their subdivisions -- Part 1: Country codes
[17]	ISO 14816:2005 Road transport and traffic telematics; Automatic vehicle and equipment identification; Numbering and data structure.
[18]	ISO/TS 14823:2017. Intelligent transport systems -- Graphic data dictionary
[19]	ECo-AT_SWP2.1_InVehicleInformation_v04.00
[20]	ECo-AT_SWP2.1_IntersectionSafety_v04.00
[21]	DUTCH C-ITS Corridor Profile, Version 3.0
[22]	ISO 639-1 Codes for the representation of names of languages - Part 1: Alpha-2 code
[23]	SCOOP: Planned roadwork
[24]	ISO/IEC 27001:2013 Information technology -- Security techniques -- Information security management systems -- Requirements
[25]	InterCor_M03-Upgraded-Specifications-ITS-G5_v1.1.pdf

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[26]	ISO/TS 19091:2017 Intelligent transport systems — Cooperative ITS — Using V2I and I2V communications for applications related to signalized intersections
[27]	SAE J2735:2016, Dedicated Short Range Communications (DSRC) Message Set Dictionary

5 Informative Annex I

Legacy implementations exist, which implement functionality similar to the TLC FLS by using CAM. They can be used for testing purposes, but need to migrate to the specified solution in 3.2.4 according to the migration path and are not fully supported by C-ROADS. Table 21 Shows the usage of CAM elements for this purpose.

Table 21 CAM elements specific for the TLC functionality

Name	Type	M/O	Usage	Comments
CAM	DF	Mandatory		
generationDeltaTime	DE	Mandatory	Timestamp belonging to the referencePosition.	
Basic Container	DF	Mandatory		
stationType	DE	Mandatory	Type of broadcast source – bus / tram	
referencePosition	DE	Mandatory	Vehicle location	
High Frequency Container	DF	Mandatory		
speed	DE	Mandatory	Vehicle speed	
heading	DE	Mandatory	Vehicle direction	
longitudinalAcceleration	DE	Mandatory	Vehicle acceleration	
driveDirection	DE	Mandatory	Drive direction	
vehicleLenght	DE	Mandatory	Length of the vehicle	
Low Frequency Container	DF	Optional		
vehicleRole	DE	Mandatory	Vehicle role – publicTransport / emergency	
exteriorLights	DE	Mandatory	Activated headlights	
Public Transport Container	DF	Optional		
embarkationStatus	DE	Optional	State of passenger doors	
ptActivation	DF	Optional	Information about PT vehicle (e.g. priority request information, public transport line number)	
Emergency Container	DF	Optional		
emergencyPriority	DE	Optional	Priority request	

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