Council of the
European Union

Brussels, 14 March 2019
(OR. en)

7510/19
ADD 2

TRANS 199
DELACT 68

COVER NOTE

From:	Secretary-General of the European Commission, signed by Mr Jordi AYET PUIGARNAU, Director
date of receipt:	13 March 2019
To:	Mr Jeppe TRANHOLM-MIKKELSEN, Secretary-General of the Council of the European Union
No. Cion doc.:	C(2019) 1789 final - Annex 2
Subject:	ANNEX to the Commission Delegated Regulation supplementing Directive 2010/40/EU of the European Parliament and of the Council with regard to the deployment and operational use of cooperative intelligent transport systems

Delegations will find attached document C(2019) 1789 final - Annex 2.

Encl.: C(2019) 1789 final - Annex 2

EUROPEAN
COMMISSION

Brussels, 13.3.2019
C(2019) 1789 final

ANNEX 2

ANNEX

to the

Commission Delegated Regulation

supplementing Directive 2010/40/EU of the European Parliament and of the Council with regard to the deployment and operational use of cooperative intelligent transport systems

{SEC(2019) 100 final} - {SWD(2019) 95 final} - {SWD(2019) 96 final}

ANNEX II

1. INTRODUCTION

1.1. References

The following references are used in this Annex:

EN 302 636-4-1	ETSI EN 302 636-4-1, *Intelligent Transport Systems (ITS); Vehicular Communication; Geonetworking; Part 4: Geographical addressing and forwarding for point-to-point and point-to-multipoint communications; Sub-part 1: Media-Independent Functionality*. V1.3.1 (2017-08)
TS 102 894-2	ETSI TS 102 894-2, *Intelligent Transport Systems (ITS); Users and applications requirements; Part 2: Applications and facilities layer common data dictionary*, V1.3.1 (2018-08)
ISO/TS 19091	ISO/TS 19091, *Intelligent transport systems – Cooperative ITS – Using V2I and I2V communications for applications related to signalized intersections,* (2017-03)
EN 302 663	ETSI EN 302 663, *Intelligent Transport Systems (ITS); Access layer specification for Intelligent Transport Systems operating in the 5 GHz frequency band*, V1.2.1 (2013-07)
TS 102 687	ETSI TS 102 687, *Intelligent Transport Systems (ITS); Decentralized Congestion Control Mechanisms for Intelligent Transport Systems operating in the 5 GHz range; Access layer part,* V1.2.1 (2018-04)
TS 102 792	ETSI TS 102 792, *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*, V1.2.1 (2015-06)
EN 302 637-2	ETSI EN 302 637-2, *Intelligent Transport Systems (ITS); Vehicular Communications; Basic Set of Applications; Part 2: Specification of Cooperative Awareness Basic Service*, V1.4.0 (2018-08); this reference shall be read as the reference to version 1.4.1 from the date of the publication of that version.
TS 102 724	ETSI TS 102 724, Intelligent Transport Systems (ITS); Harmonized *Channel Specifications for Intelligent Transport Systems operating in the 5 GHz frequency band*, V1.1.1 (2012-10)
EN 302 636-5-1	ETSI EN 302 636-5-1, *Intelligent Transport Systems (ITS); Vehicular Communications; GeoNetworking;*

	Part 5: Transport Protocols; Sub-part 1: Basic Transport Protocol, V2.1.1 (2017-08)
TS 103 248	ETSI TS 103 248, *Intelligent Transport Systems (ITS); GeoNetworking; Port Numbers for the Basic Transport Protocol (BTP)*, V1.2.1 (2018-08)
EN 302 931	ETSI EN 302 931, *Vehicular Communications; Geographical Area Definition*, V1.1.1 (2011-7)
EN 302 637-3	ETSI EN 302 637-3, *Intelligent Transport Systems (ITS); Vehicular Communications; Basic Set of Applications; Part 3: Specifications of Decentralized Environmental Notification Basic Service*, V1.3.0 (2018-08); this reference shall be read as the reference to version 1.3.1 from the date of the publication of that version.
TS 102 636-4-2	ETSI TS 102 636-4-2, *Intelligent Transport Systems (ITS); Vehicular Communications; GeoNetworking; Part 4: Geographical addressing and forwarding for point-to-point and point-to-multipoint communications; Sub-part 2: Media-dependent functionalities for ITS-G5*, V1.1.1 (2013-10)
SAE J2945/1	SAE J2945/1, *On-board System Requirements for V2V Safety Communications*, (2016-03)
TS 103 097	ETSI TS 103 097, *Intelligent Transport Systems (ITS); Security; Security Header and Certificate Formats*, V1.3.1 (2017-10)
ISO 8855	ISO 8855, *Road vehicles — Vehicle dynamics and road-holding ability — Vocabulary*, (2011-12)
TS 103 301	ETSI TS 103 301, *Intelligent Transport Systems (ITS)*; *Vehicular Communications; Basic Set of Applications; Facilities layer protocols and communication requirements for infrastructure services*, V1.2.1 (2018-08)
TS 103 175	ETSI TS 103 175, *Intelligent Transport Systems (ITS); Cross Layer DCC Management Entity for operation in the ITS G5A and ITS G5B medium*, V1.1.1 (2015-06)
ISO/TS 19321	ISO/TS 19321, *Intelligent transport systems — Cooperative ITS — Dictionary of in-vehicle information (IVI) data structures*, (2015-04-15)
ISO 3166-1	ISO 3166-1:2013, *Codes for the representation of names of countries and their subdivisions -- Part 1: Country codes*
ISO 14816	ISO 14816:2005, *Road transport and traffic telematics; Automatic vehicle and equipment identification; Numbering and data structure*

ISO/TS 14823	ISO/TS 14823:2017, *Intelligent transport systems – Graphic data dictionary*
IEEE 802.11	IEEE 802.11-2016, IEEE Standard for Information technology — Telecommunications and information exchange between systems, local and metropolitan area networks — Specific requirements, Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications, (2016-12-14)

1.2. Notations and abbreviations

The following notations and abbreviated terms are used in this Annex.

AT	Authorization Ticket
BTP	Basic Transport Protocol
CA	Cooperative Awareness
CAM	Cooperative Awareness Message
CBR	Channel Busy Ratio
CCH	Control Channel
CDD	Common Data Dictionary
CEN-DSRC	European Committee for Standardisation (CEN)-Dedicated Short Range Communication
C-ITS	Cooperative Intelligent Transport Systems
DCC	Decentralized Congestion Control
DEN	Decentralized Environmental Notification
DENM	Decentralized Environmental Notification Message
DP	Decentralized Congestion Control Profile
ETSI	European Telecommunications Standards Institute
GBC	GeoBroadcast
GN	GeoNetworking
GNSS	Global Navigation Satellite System
IEEE	Institute of Electrical and Electronics Engineers
IVI	Infrastructure to Vehicle Information
IVIM	Infrastructure to Vehicle Information Message
MAP	Topology information for the intersection
MAPEM	MAP Extended Message
NH	Next Header
NTP	Network Time Protocol
PAI	Position Accuracy Indicator
PoTi	Position and Time

QPSK	Quadrature Phase-Shift Keying
RLT	Road Lane Topology
RSU	Road-side Unit
SCF	Store Carry Forward
SHB	Single Hop Broadcast
SPATEM	Signal Phase and Timing Extended Message
SREM	Signal Request Extended Message
SSEM	Signal Request Status Extended Message
TAI	International Atomic Time
TAL	Trust Assurance Level
TLM	Traffic Light Manoeuvre
TC	Traffic Class
UTC	Coordinated Universal Time
WGS84	World Geodetic System 84

1.3. Definitions

The following definitions are used in this Annex:

(a) 'C-ITS time' or 'time base' means the number of elapsed International Atomic Time (TAI) milliseconds since 2004-01-01 00:00:00.000 Coordinated Universal Time (UTC)+0 as defined in [ETSI EN 302 636-4-1]. Timestamps as defined in [ETSI TS 102 894-2] follow this time format.

Note: 'TAI milliseconds' denote the true number of milliseconds counted and not altered by leap seconds after 1 January 2004.

(b) 'station clock' means a clock representing Cooperative Intelligent Transport Systems (C-ITS) time in a C-ITS station.

2. REQUIREMENTS FOR VEHICLE C-ITS STATIONS DESIGNED FOR SHORT-RANGE COMMUNICATION

This system profile specifies a minimum set of standards and fills the missing gaps as necessary for the realisation of an interoperable vehicle C-ITS station on the transmitting side. The profile includes interoperability requirements only, leaving open any additional requirements. It therefore does not describe the full functionality of the vehicle C-ITS station.

This system profile enables the deployment of the priority (in particular, V2V) services. It may support other services, but these may require additional system specifications.

The profile provides descriptions, definitions and rules for the layers (Applications, Facilities, Networking & Transport and Access) of the ETSI ITS station reference architecture/ITS-S host.

2.1. Definitions

The following definitions are used in this part of the Annex:

(a) ‘vehicle states’ comprise absolute position, heading and velocity at a certain point in time;

(b) information provided with a ‘confidence level’ of 95 % means that the true value is inside the range specified by the estimated value plus/minus the confidence interval in 95 % of the data points in a given statistical base;

(c) ‘sky obstruction’ means the fraction of half-hemisphere values that are obstructed for Galileo or other Global Navigation Satellite Systems (GNSS) satellites due to mountains, buildings, trees, etc.

(d) ‘CEN-DSRC’ (Comité Européen de Normalisation - Dedicated Short Range Communication) is a microwave technology used for electronic toll systems to finance road infrastructure costs or to collect road usage fees. For the purpose of this Annex, ‘CEN-DSRC’ covers all 5.8 GHZ microwave technologies as referred to in Directive 2004/52/EC of the European parliament and of the Council and in Commission Decision 2009/750/EC.

2.2. Parameter settings

The parameter settings in Table 1 are used in this part of the Annex.

Table 1: Parameter settings

Parameter	Value	Unit	Description
pAlDataRateCch	6	Mbit/s	Default data rate for Control Channel (CCH)
pAlDataRateCchHigh	12	Mbit/s	Optional higher data rate for CCH than the default one
pAlDataRateCchLow	3	Mbit/s	Optional lower data rate for CCH than the default one
pBtpCamPort	2001	n/a	Well-known destination port for CAMs
pBtpDenmPort	2002	n/a	Well-known destination port for DENMs
pBtpDestPortInfo	0	n/a	Value for the destination port information
pCamGenNumber	3	n/a	Number of consecutive generated CAMs without time restrictions
pCamTraceMaxLength	500	m	Maximal length of a trace in CAMs
pCamTraceMinLength	200	m	Minimal length of a trace in CAMs
pCamTrafficClass	2	n/a	Traffic class (TC) value with which CAMs are sent
pDccCcaThresh	-85	dBm	Minimum sensitivity of the channel
pDccMeasuringInterval	100	ms	Value for the interval in which the channel load is provided
pDccMinSensitivity	-88	dBm	Value for minimum receiver sensitivity

pDccProbingDuration	8	µs	Value for the probing sample duration
pDccPToll	10	dBm	Value for transmission power inside protected zones
pDCCSensitivityMargin	3	dB	Value for margin of parameter pDccMinSensitivity
pDenmTraceMaxLength	1000	m	Maximum length of a trace in DENMs
pDenmTraceMinLength	600	m	Minimum length of a trace in DENMs
pGnAddrConfMode	ANONYMOUS (2)	n/a	Configuration method for GeoNetworking (GN) address
pGnBtpNh	2	n/a	Value for the Next Header (NH) field of GN common header
pGnChannelOffLoad	0	n/a	Value for the channel offload field
pGnEtherType	0x8947	--	Value for the EtherType to use
pGnGbcHtField	4	n/a	Value for the HeaderType field in cases of GeoBroadcast (GBC)
pGnGbcScf	1	n/a	Value for the store-carry-forward field in cases of GBC
pGnInterfaceType	ITS-G5 (1)	n/a	Interface type to be used by GN
pGnIsMobile	1	n/a	Defines whether C-ITS station is mobile or not
pGnMaxAreaSize	80	km²	Supported area to cover
pGnSecurity	ENABLED (1)	n/a	Defines use of GN security headers
pGnShbHstField	0	n/a	Value for the HeaderSubType field in cases of Single Hop Broadcast (SHB)
pGnShbHtField	5	n/a	Value for the HeaderType field in cases of SHB
pGnShbLifeTimeBase	1	n/a	Value for the LifeTimeBase field in case of SHB.
pGnShbLifeTimeMultiplier	1	n/a	Value for the LifeTimeMultiplier field in cases of SHB
pPotiMaxTimeDiff	20	ms	Maximum time difference between station clock and time base
pPotiWindowTime	120	s	Size of Position and Time (PoTi) sliding window in seconds

pPotiUpdateRate	10	Hz	Update rate for position and time information
pSecCamToleranceTime	2	s	Maximum time deviation between time in the security header of the Cooperative Awareness Message (CAM) and station clock to accept the CAM
pSecGnScc	0	n/a	Value for the SCC field of the GN address
pSecGnSourceAddressType	0	n/a	Value for the M field of the GN address (configuration type of the address)
pSecMaxAcceptDistance	6	km	Maximum distance between sender and receiver to accept messages
pSecMessageToleranceTime	10	min	Maximum time deviation between time in security header of message (other than CAM) and station clock to accept the message
pSecRestartDelay	1	min	Grace period for AT change after turning on ignition terminal
pTraceAllowableError	0.47	m	Parameter for calculation of path history; see Appendix A.5 of [SAE J2945/1] for further details.
pTraceDeltaPhi	1	°	Parameter for calculation of path history; see Appendix A.5 of [SAE J2945/1] for further details.
pTraceEarthMeridian	6,378.137	km	Earth mean radius (according to International Union of Geodesy and Geophysics (IUGG). Used for calculation of traces; see Appendix A.5 of [SAE J2945/1] for further details.
pTraceMaxDeltaDistance	22.5	m	Parameter for calculation of traces; see Appendix A.5 of [SAE J2945/1] for further details.

2.3. Security

(1) A vehicle C-ITS station shall be securely linked to one specific vehicle. Where the vehicle C-ITS station is powered, it shall verify that it is operating in the vehicle with which it has been securely linked. If such correct functioning condition cannot be verified, the C-ITS station shall be deactivated, preventing it from sending messages (i.e. deactivate at least the radio transmission level of the C-ITS station).

(2) The vehicle C-ITS station shall check the timestamp in the security header against the reception time and accept only CAMs in the last time of *pSecCamToleranceTime* and other messages within the last time of *pSecMessageToleranceTime*.

(3) The vehicle C-ITS station shall check the distance from the sender position — in the security header, if available — and forward only messages with a distance from the sender of *pSecMaxAcceptDistance* or less.

(4) The verification of a message shall comprise at least cryptographic verification of the message's signature.

(5) The vehicle C-ITS station shall forward only verified messages.

(6) The vehicle C-ITS station shall use one end-to-end security header and signature per message in accordance with [TS 103 097] and [EN 302 636-4-1].

(7) The signature shall be generated using a private key corresponding to a valid AT in accordance with clause 7.2.1 in [TS 103 097].

(8) All addresses and identifiers transmitted through short-range communication shall be changed when the AT is changed.

2.4. Positioning and timing

(9) The vehicle states shall be consistent. Therefore, heading and velocity shall refer to the same time as the absolute position (e.g. GenerationDeltaTime in CAMs).

Note: Any inaccuracies that might result from time-related effects should be taken into account in the accuracies of the state variables.

(10) The vehicle C-ITS station shall use World Geodetic System 84 (WGS84) as its reference coordinate system, as specified in [TS 102 894-2].

Note: Based on the drift of the European Terrestrial Reference System (ETRS89), which is fixed to the continental plate of Europe, of 2.5 cm/year in WGS84 it needs to be noted that Vehicle C-ITS stations need to be aware what referencing system is used. When an enhanced referencing system such as a Real-time Kinematics enhanced system is used for high-precision location referencing, this shift may need to be compensated.

(11) Altitude information shall be interpreted as height above WGS84 Ellipsoid.

Note: Alternative altitude interpretations using Geoid definitions (e.g. relative to mean sea level) shall not be used.

(12) For horizontal position, a confidence area is used instead of a single confidence interval. The confidence area is described as ellipse specified via a major axis, minor axis and orientation of the major axis relative to the north direction, as defined in point (10).

(13) The vehicle C-ITS station shall interpret 'heading' as the direction of the horizontal velocity vector. The starting point of the velocity vector shall be the ITS vehicle reference point, as defined in B.19 'referencePosition' in [EN 302 637-2].

Note: Alternative heading interpretations referring to the vehicle body orientation shall not be used.

Note: This definition implies that straight backward driving results in 180 ° difference between heading and vehicle body orientation.

(14) C-ITS time shall be the basis for all timestamps in all messages transmitted by the vehicle C-ITS station in all EU Member States.

(15) When active, C-ITS stations shall update the vehicle states with a frequency of at least the *pPotiUpdateRate*.

(16) Timestamps in messages shall be based on the station clock.

(17) The difference between the station clock and C-ITS time shall be estimated. If the absolute difference |Station clock time - C-ITS time | >= *pPotiMaxTimeDiff*, the vehicle C-ITS station shall not be active.

Note: A precise timestamp is not only needed for time synchronisation, but also implies that system states are valid at precisely that point in time, i.e. that the vehicle states stay consistent.

(18) When coming to a standstill, the system shall report the last known heading value (vehicle direction of motion). The value shall be unlatched when returning to motion.

2.5. System behaviour

(19) The vehicle C-ITS station shall operate the Cooperative Awareness Basic Service when it is on public roads and under regular driving dynamics.

Note: Operation of the cooperative awareness basic service includes the transmission of CAMs if all conditions for CAM generation are fulfilled.

(20) Traces and path history data shall be generated only when position confidence information is available and the station clock adheres to point (90)(91).

(21) A vehicle occupant shall be enabled to deactivate the vehicle C-ITS station easily at any time.

(22) The vehicle C-ITS station shall handle CAM transmissions so that no outdated messages are transmitted even if congestion control is applied.

2.6. Access layer

(23) The vehicle C-ITS station shall use the control channel G5-CCH as specified in Table 3 in [EN 302 663] to send messages to support the Cooperative Awareness Basic Service and the priority C-ITS services specified in Annex I of this Regulation.

(24) The vehicle C-ITS station's access layer shall be compliant with [EN 302 663], with the exception of emission limits and with the exception of clauses 4.2.1, 4.5 and 6.

(25) The vehicle C-ITS station shall use a default transfer rate of *pAlDataRateCch* on the control channel.

(26) The vehicle C-ITS station shall also support *pAlDataRateCchLow* and *pAlDataRateCchHigh* transfer rates on the control channel.

(27) The vehicle C-ITS station's access layer shall be compliant with [TS 102 724].

(28) The vehicle C-ITS station shall support the following Decentralised Congestion Control profiles (DPs) defined in [TS 102 724]: DP0, DP1, DP2 and DP3.

These DCC profiles shall use the following DCC-profile identification values:

- DP0, used only for DENMs with TC = 0;
- DP1, used for DENMs with TC = 1;

- DP2, used for CAMs with TC = *pCamTrafficClass*;
- DP3, used for forwarded DENMs and other low priority messages.

(29) The vehicle C-ITS station's DCC mechanism shall comply with [TS 102 687].

(30) The settings of Table A.2 in [TS 102 687] shall be used if the reactive DCC algorithm outlined in clause 5.3 of [TS 102 687] is implemented.

Note: Table A.2 in [TS 102 687] is based on CAM and Decentralised Environmental Notification Message (DENM) dissemination for priority C-ITS services with an average T_{on} of 500 μs.

(31) The following smoothing function of Channel Busy Ratio (CBR) values shall be performed if the vehicle C-ITS station uses the reactive DCC algorithm outlined in clause 5.3 of [TS 102 687]: CBR_now = (CBR(n)+CBR(n-1))/2 (

Note: Where 'n' and 'n-1' are the current and previous CBR sampling periods respectively).

(32) The vehicle C-ITS station shall, at a minimum, be able to generate and transmit the number of messages determined by the value of the highest CAM generation rate (i.e. 10 Hz) and, if detection algorithms are used, it shall be increased by the minimum required DENM generation rate derived from those triggering conditions.

(33) The vehicle C-ITS station shall abide by the following maximum message rates if it uses the reactive DCC algorithm outlined in clause 5.3 of [TS 102 687]:

- for the relaxed state: the sum of all messages sent on DP1, DP2 and DP3 shall not surpass $R_{max\_relaxed}$ = 16.7 messages per second. Message bursts are allowed for DP0 with R_{Burst} = 20 messages per second, with a maximum duration of T_{Burst} = 1 second, and may take place only every $T_{BurstPeriod}$ = 10 seconds. Thus, adding DP0 messages, the maximum message rate amounts to $R_{max\_relaxed}$ = 36.7 messages per second;
- for active states: the maximum message rate for each state is given in Table A.2 in [TS 102 687];
- for the restrictive state: the maximum message rate per vehicle C-ITS station is set to 2.2 messages per second, i.e. the inverse of T_{TX_MAX} = 460 ms.

(34) The vehicle C-ITS station shall support per-packet transmission power control.

Note: P_{Tx} may depend on the current DCC state (i.e. relaxed, active or restrictive) and on the DCC profile (i.e. DP0, DP1, etc.).

(35) The vehicle C-ITS station shall reduce its transmission power to P_{Toll} = *pDccPToll* as soon as the protected zone is entered and without changing any other DCC transmission parameters as per Table A.2 in [TS 102 687]. DP0 messages are excluded from this restriction.

(36) Where the vehicle C-ITS station is not equipped with a CEN-DSRC radio detector as described in clause 5.2.5 of [TS 102 792], it shall maintain a list of protected zone positions as described in clause 5.5.1 of [TS 102 792]. This list shall be composed of:

- a set of protection zones as listed in the 'latest version' (available when the vehicle is developed) of the protected zone database. The vehicle C-ITS station may include update mechanisms of the database;
- a set of protected zones as identified by the reception of CEN-DSRC mitigation CAMs as described in clauses 5.2.5 and 5.2.2.3 of [TS 102 792];
- a temporarily protected zone as identified by the reception of CEN-DSRC mitigation CAMs as described in clause 5.2.2.2 of [TS 102 792].

(37) Where the vehicle C-ITS station is equipped with a CEN-DSRC radio detector, mitigation shall be applied as described in clause 5.2.5 of [TS 102 792] and the vehicle C-ITS station shall generate CAMs in accordance with clause 5.5.1 of [TS 102 792].

(38) Where the vehicle C-ITS station is not equipped with a CEN-DSRC radio detector, mitigation shall be applied in accordance with [TS 102 792] on the basis of the list defined in point (36) and received CAMs from other road users which have implemented point (37).

Note: Clarification of clause 5.2.5 of [TS 102 792]: A mobile ITS station should mitigate each time to the nearest tolling station centre position. Where several positions are given in the same area, the mobile ITS station should respond to each centre position, possibly in a sequence. Protected zones with identical protectedZone ID may be seen as a single station. Where the protected zone database and the CEN-DSRC mitigation CAMs contain a valid protected zone with the identical protectedZone ID, mitigation shall be based only on the CEN-DSRC mitigation CAM content.

2.7. Networking and transport layer

(39) The vehicle C-ITS station's media-independent part of GeoNetworking (GN) shall be compliant with [EN 302 636-4-1].

(40) All default constants and parameters of the vehicle C-ITS station profile not defined or overwritten in this Regulation shall be set as specified in Annex H to [EN 302 636-4-1].

(41) GN shall be used with itsGnSecurity set to *pGnSecurity*.

(42) GN shall be used with itsGnLocalAddrConfMethod set to *pGnAddrConfMode*.

(43) GN parameter itsGnMaxGeoAreaSize shall be set to *pGnMaxAreaSize*.

(44) Packet repetition shall not be performed by GN in a vehicle C-ITS station and the corresponding steps for repetition in the packet-handling procedures described in clause 10.3 of [EN 302 636-4-1] shall not be executed.

The 'maximum repetition time' parameter of the service primitive GN-DATA.request and the GN protocol constant itsGnMinPacketRepetitionInterval do not apply to a vehicle C-ITS station.

(45) GN shall be used with its GnIfType set to *pGnInterfaceType.*

(46) The Vehicle C-ITS station shall use Single Hop Broadcast (SHB) headers as defined in [EN 302 636-4-1] on all CAM packets it sends.

Consequently, the GN common header shall use a value of *pGnShbHtField* for the HT field and a value of *pGnShbHstField* for the HST field when transmitting SHB packets.

The vehicle C-ITS station shall use GBC headers as defined in [EN 302 636-4-1] on all DENM packets it sends.

Consequently, the GN common header shall use a value of *pGnGbcHtField* for the HT field when transmitting DENM packets.

For the HST field one of the following values shall be used:

- 0 for circular areas;
- 1 for rectangular areas;
- 2 for ellipsoidal areas.

Note: This profile covers the handling of SHB and GBC packets. As it does not cover the handling of other GN packet types defined in [EN 302 636-4-1], it does not prevent their implementation.

(47) The vehicle C-ITS station shall set the LifeTime field of all SHB packets in the following manner:

- set the sub-field multiplier to *pGnShbLifeTimeMultiplier* and the sub-field base to *pGnShbLifeTimeBase*.

(48) The vehicle C-ITS station shall set the LifeTime field of all GBC packets to the minimum value of ValidityDuration and RepetitionInterval, where ValidityDuration and RepetitionInterval are defined in the relevant service profile. The value of the LifeTime field shall not exceed the itsGnMaxPacketLifetime, as specified in Annex H to [EN 302 636-4-1].

(49) The vehicle C-ITS station shall buffer GBC packets where no neighbours are available (store-carry-forward). Consequently, the Store Carry Forward (SCF) bit of the TC field of GBC packets shall be set to *pGnGbcScf*.

(50) The vehicle C-ITS station is not required to offload packets to another channel. Consequently, the channel offload bit of the TC field should be set to *pGnChannelOffLoad.*

(51) The vehicle C-ITS station shall use the DCC profiles specified in point (28). Consequently, the DCC Profile ID bits of the TC field shall use the DCC-profile identification values defined in point (28).

(52) The vehicle C-ITS station shall set the itsGnIsMobile bit of the Flags field to *pGnIsMobile*.

(53) The vehicle C-ITS station shall support multi-hop operation mode. It shall implement the forwarding algorithm specified in Annexes D, E.3 and F.3 to [EN 302 636-4-1].

(54) When forwarding packets, the vehicle C-ITS station shall use the DCC profile DP3 as defined in [TS 102 724] and referred to in point (28).

(55) The vehicle C-ITS station shall use duplicate packet detection on the networking and transport layer. Consequently, the algorithm specified in Annex A.2 to [EN 302 636-4-1] shall be used for detecting duplicate packets.

(56) All GN frames sent by the vehicle C-ITS station shall use the EtherType value *pGnEtherType* as listed by the Institute of Electrical and Electronics Engineers (IEEE) Registration Authority at http://standards.ieee.org/develop/regauth/ethertype/eth.txt.

(57) The vehicle C-ITS station's Basic Transport Protocol (BTP) shall be compliant with [EN 302 636-5-1].

(58) The vehicle C-ITS station shall employ BTP-B headers. Consequently, the GN common header shall use a value of *pGnBtpNh* for the NH field.

(59) The vehicle C-ITS station shall set the destination port info field to the value *pBtpDestPortInfo.*

(60) In the BTP-B header, the vehicle C-ITS station shall set the destination port to the value *pBtpCamPort* for CAMs.

(61) In the BTP-B header, the vehicle C-ITS station shall set the destination port to the value *pBtpDenmPort* for DENMs.

(62) The vehicle C-ITS station shall support circular, rectangular and ellipsoidal geographical areas as defined in [EN 302 931]. Each use case defined in the relevant service profile must specify one of the above geographical area types indicated through the GN header as specified in [EN 302 636-4-1].

(63) Where a vehicle C-ITS station calculates the distance between two positions using Galileo or other GNSS coordinates (e.g. for PathDeltaPoints or in cases of circular relevance area), the great circle or a more accurately performing method shall be used.

2.8. Facility layer

(64) The vehicle C-ITS station's Cooperative Awareness (CA) basic service shall be compliant with [EN 302 637-2].

(65) The path history field in the CAM low-frequency container shall be generated according to the method specified in point (86) and shall contain a PathHistory data element covering a minimum distance of *pCamTraceMinLength* (K_PHDISTANCE_M parameter, as defined in Appendix A.5 to [SAE J2945/1]).

An exception to the minimum covered distance by PathHistory shall be made only if:

- the vehicle has not yet physically covered the distance with its current AT (e.g. after vehicle startup or right after AT change when driving); or
- the maximum number of PathPoints is used, but the overall length covered by the PathHistory still does not reach *pCamTraceMinLength.*

  Note: This may happen if the road topology contains tight curves and the distance between consecutive PathPoints is reduced.

Only in the above cases may the vehicle send PathHistory information covering a distance below *pCamTraceMinLength*.

(66) The PathHistory in CAMs shall cover at most *pCamTraceMaxLength.*

(67) The PathHistory in CAMs shall include PathDeltaTime in every PathPoint. It shall describe a list of actually travelled geographical locations leading to the

current vehicle position, sorted by the time the positions were reached by the vehicle, with the first point being the closest in time to the current time.

(68) Where the vehicle C-ITS station does not move, i.e. PathPoint position information does not change, the PathDeltaTime of the first PathPoint shall still be updated with every CAM.

(69) Where the vehicle C-ITS station does not move, i.e. PathPoint position information does not change, for a duration longer than the maximum value of PathDeltaTime (specified in [TS 102 894-2]) the PathDeltaTime of the first PathPoint in the CAM shall be fixed to the maximum value.

(70) The CA basic service shall be active as long as the vehicle is on public roads and under regular driving dynamics. As long as the CA basic service is active, CAMs shall be generated in accordance with the generation rules in [EN 302 637-2].

(71) A vehicle C-ITS station shall transmit CAM messages where position confidence information is available and the station clock adheres to point (91).

(72) The TC value for CAM messages shall be set to *pCamTrafficClass.*

(73) The parameter T_GenCam_Dcc (see [EN 302 637-2]) shall be set to the value of the minimum time between two transmissions, T_{off}, as given by Table A.2 (DCC mechanisms) in [TS 102 687].

(74) The adjustable N_GenCam parameter (see [EN 302 637-2]) specified in the CAM generation frequency management shall be set to *pCamGenNumber* for the vehicle C-ITS station.

(75) The vehicle C-ITS station's Decentralised Environmental Notification (DEN) basic service shall be compliant with [EN 302 637-3].

(76) The DENM repetition shall be done by the DEN basic service as specified in [EN 302 637-3].

(77) The path history field in the DEN messages shall be generated according to the method specified in point (86) and shall contain trace-data elements covering a minimum distance of *pDenmTraceMinLength* (K_PHDISTANCE_M parameter defined in Appendix A.5 to [SAE J2945/1]).

An exception to the minimum covered distance by traces shall be made only if:

- the vehicle has not yet physically covered the distance with its current AT. (e.g. after vehicle startup or right after AT change when driving); or
- the maximum number of PathPoints is used, but the overall length covered by the PathHistory still does not reach *pDenmTraceMinLength*.

  Note: This may happen if the road topology contains tight curves and the distance between consecutive PathPoints is reduced.

Only in the above two cases may the vehicle send trace information covering a distance below *pDenmTraceMinLength*.

(78) The traces in the DENMs shall cover at most *pDenmTraceMaxLength*.

(79) A vehicle C-ITS station shall use the DENM traces as follows:

- the first trace element shall describe a time-ordered list of actually travelled geographical locations leading to the event position, as specified in point (67).

(80) The PathDeltaTime data elements of the PathPoints in the first DENM traces element shall be updated only if the DENM is updated.

(81) Where the event-detecting vehicle does not move, i.e. PathPoint position information does not change, the PathDeltaTime of the first PathPoint of the first DENM traces element shall still be updated with every DEN_Update.

Note: This is only the case for stationary events where the detecting vehicle is identical to the event, e.g. a stationary vehicle warning. For dynamic events, e.g. dangerous situations or events that are not identical to the vehicle (adverse weather warnings, etc.), this is not the case.

(82) Where the vehicle C-ITS station does not move, i.e. PathPoint position information does not change, for a duration longer than the maximum value of PathDeltaTime (specified in [TS 102 894-2]), the PathDeltaTime of the first PathPoint in the first DENM trace element shall be fixed to the maximum value.

(83) Additional PathHistory elements may be present in the DENM traces. However, unlike the first element, these shall describe alternative routes to the event location. These routes may or may not be available at the time of detecting the event. In the alternative routes, the PathPoints shall be position-ordered (i.e. shortest-path routes) and shall not include the PathDeltaTime.

(84) For the priority services, the vehicle C-ITS station shall generate only DENMs as described in the relevant service profile.

(85) The data elements that constitute the content of the CAM and DENM shall be compliant with [TS 102 894-2] and use the coordinate system specified in points (87), (10) and (11).

(86) The traces and path histories used by the vehicle C-ITS station shall be generated using Design Method One, as specified in Appendix A.5 to [SAE J2945/1]. The vehicle C-ITS Station shall use this generation method with the following settings:

- K_PHALLOWABLEERROR_M = *pTraceAllowableError*, where PH_ActualError < K_PHALLOWABLEERROR_M;
- maximum distance between concise path points, K_PH_CHORDLENGTHTHRESHOLD = *pTraceMaxDeltaDistance*;
- K_PH_MAXESTIMATEDRADIUS = REarthMeridian;
- K_PHSMALLDELTAPHI_R = *pTraceDeltaPhi*;
- REarthMeridian = *pTraceEarthMeridian* (according to the IUGG), used for great-circle or orthodromic distance calculation:

  PH_ActualChordLength = $REarthMeridian*\cos^{-1}[\cos(lat_1)\cos(lat_2)\cos(long_1-long_2)+\sin(lat_1)\sin(lat_2)]$

(87) The vehicle C-ITS station shall use a coordinate system compliant with section 2.13 of [ISO 8855].

Note: This means that the X and Y axes are parallel to the ground plane, the Z axis is aligned vertically upwards, the Y axis points to the left of the vehicle's forward direction and the X axis points towards the vehicle's forward driving direction.

2.9. Hardware-related requirements

(88) The 95 % confidence value (see points 2.1 (b) and (12)) shall be valid in each scenario listed in point (92). This implies that in a confidence value assessment test (which can be offline) a statistic averaging over all states and scenarios is not appropriate.

Instead, a sliding window containing the vehicle states (see point 2.1 (a)) of the last *pPotiWindowTime* seconds shall be used as the statistical base.

Note: The proposed confidence validation mechanism using the sliding window is typically performed offline, as post-processing of collected test data. It is not required that the vehicle C-ITS station performs confidence validation online, i.e. while in public roads and under regular driving dynamics.

Note: The sliding window approach has the following advantages over separate statistics for each scenario:

- transitions between scenarios are included;
- confidence is valid 'now' instead of 'over lifetime'. 'Error bursts' (many invalid confidence values in a short timeframe) are not allowed, thus:
  - enhancing the usefulness of the confidence value for applications;
  - requiring fast detection of accuracy degradation inside POTI;
- the precise definition of test data has no effect on confidence validation parameters. However, the test data shall contain all scenarios listed in point (92);
- no further statistical calculations are needed; the scenarios cover all relevant states;
- the interval length is similar to typical (environment and driving condition) scenario lengths (e.g. city tunnel, standing at traffic light, driving manoeuvres);
- 5 % of the interval is similar to typical short-term effects (e.g. driving under a bridge).

(89) A vehicle is considered to be under regular driving dynamics when:

- it has passed its initial startup phase;
- it is being used as envisaged by the manufacturer;
- normal control of the vehicle is possible (e.g. it is not directly involved in an accident, road surface allows normal tyre grip);
- all the following conditions (values) apply for passenger cars:
  - vehicle lateral acceleration is < 1.9 m/s^2;
  - vehicle longitudinal acceleration is > -2.4 m/s^2 (deceleration);
  - vehicle longitudinal acceleration is < 2.5 m/s^2;

- vehicle speed is ≤ minimum of (130 km/h, Vmax).

(90) Under optimal GNSS conditions and regular driving dynamics, as defined in point (89), the confidence values shall be equal to or lower than the following values in at least 95 % of 3D position data points in a dataset:

- horizontal position confidence of 5 m;
- vertical position confidence of 20 m.

In other scenarios, the requirement degradations in point (92) apply. This requirement ensures the usefulness of information sent in all C-ITS messages.

(91) The station clock shall be within *pPotiMaxTimeDiff* of C-ITS time, i.e. Delta t = |station clock time - C-ITS time| < *pPotiMaxTimeDiff*.

(92) A vehicle C-ITS station shall be able to provide useful vehicle state estimates even in challenging scenarios. To account for inevitable degradations, required confidence values are defined for different scenarios in Table 2.

'C' is the maximum of semiMajorConfidence and semiMinorConfidence. The condition for 'C' shall be fulfilled in 95 % of data points in the dataset of the given scenario.

Note: The criteria shall be met under the following slope dynamics for the analysed trace fraction: average slope <= 4 % and maximum slope <= 15 %

Note: As a precondition, each scenario shall be started with one minute of driving under open sky and regular driving dynamics.

Note: No C values indicate that the scenario shall be tested to ensure that the reported confidence interval is valid, but no limit is given.

Table 2: Scenarios

ID	Scenario	Definition	Acceptance
Environment under regular driving dynamics			
S1	Open sky	Sky is less than 20 % obstructed, with vehicle moving with normal driving dynamics, normal road conditions	C <= 5 m
S2	Tunnel	No GNSS satellite is visible for at least 30 s and 250 m (v_{min}=30 km/h); GNSS signal reflection at entrance and end of tunnel	C < 15 m
S3	Parking Structure	No direct visible GNSS satellites, but connection by reflections, T > 60 s, v_{max} < 20 km/h, minimum two 90 ° curves and s > 100 m, two ramps in the entrance and exit area	any value is allowed
S4	Half open sky	Sky is 30-50 % obstructed (obstruction concentrated on one side of the car) for more than 30 s; driving conditions as S1	C < 7 m
S5	Forest	Sky is 30-50 % obstructed by objects, including trees higher than the antenna, for more than 30 s.	C < 10 m
S6	Mountains (valley)	Sky is 40-60 % obstructed by high mountain(s); driving conditions as S1	C < 10 m

S7	City	In a 300 s drive, the sky was 30-50 % obstructed (short periods of less than 30-50 % obstructions allowed), frequent GNSS signal reflection off buildings, including short losses of GNSS signal (i.e. fewer than four satellites); driving conditions as S1	C < 14 m
S8	Mild urban	Sky is 20-40 % obstructed, t > 60 s, s > 400 m. Driving conditions as S1, with stops, trees and/or buildings, as well as alleys	C < 10 m
Driving conditions under open sky			
S9	Dynamic driving	Test drive with longitudinal accelerations of more than -6 m/s² and lateral accelerations of > (±) 5 m/s²	C < 7 m
S10	Static	Vehicle standing still for 30 min	C < 5 m
S11	Rough road	Test drive on dirt road with pot holes, v= 20-50 km/h	C < 10 m
S12	Icy road	Test drive with longitudinal accelerations of more than -0.5 m/s² and lateral accelerations of > (±) 0.5 m/s², $\mu < 0.15$	C < 7 m
S13	High speed	V= minimum of (130 km/h, Vmax) on dry road for 30 s	C < 5 m

(93) Under optimal GNSS conditions and regular driving dynamics as defined in point (89), the speed confidence values shall be equal to or lower than the following values in at least 95 % of data points in a dataset:

- 0.6 m/s for speeds between 1.4 m/s and 12.5 m/s;
- 0.3 m/s for speeds greater than 12.5 m/s.

(94) Under optimal GNSS conditions and regular driving dynamics as defined in point (89), the heading confidence values shall be equal to or lower than the following values in at least 95 % of data points in a dataset:

- 3° for speeds between 1.4 m/s and 12.5 m/s;
- 2° for speeds greater than 12.5 m/s.

3. REQUIREMENTS FOR ROADSIDE C-ITS STATIONS DESIGNED FOR SHORT-RANGE COMMUNICATION

This system profile specifies a minimum set of standards and fills the missing gaps as necessary for the realisation of an interoperable roadside C-ITS station on the transmitting side. The profile includes interoperability requirements only, leaving open any additional requirements. It therefore does not describe the full functionality of the roadside C-ITS station.

This system profile enables the deployment of the priority (in particular, I2V) services. It may support other services, but these may require additional system specifications.

The profile provides descriptions, definitions and rules for the layers (Applications, Facilities, Networking & Transport and Access) and management of the ETSI ITS station reference architecture/ITS-S host.

3.1. Positioning and timing

(95) The C-ITS time of a static roadside C-ITS station shall be the basis for all timestamps in all transmitted messages and GN beacons.

Note: This means that timestamps in GN header must use the same clock and time base as timestamps in CAM/DENM/IVIM payloads. For SPATEM and MAPEM, the timestamp used should be as specified in [ISO TS 19091].

(96) The position of static roadside C-ITS stations shall be accurately measured and set permanently.

The confidence values shall be equal to or lower than the following values in at least 95 % of datasets:

- horizontal (latitude, longitude) position confidence of 5 m;
- altitude position confidence of 20 m.

Note: This avoids GNSS jitter in position accuracy and raises confidence to nearly 100 %.

(97) The difference between station clock and time base shall be estimated. The absolute difference |station clock time — time base| should not exceed 20 ms, but must in any case be less than 200 ms. The roadside C-ITS station shall not transmit messages if the station clock time differs by more than 200 ms.

Note: A precise timestamp is not only needed for time synchronisation, but also means that system states are valid at precisely that point in time, i.e. that the system states stay consistent.

Note: The information for time synchronisation can be obtained from a Galileo or other GNSS receiver or from a Network Time Protocol (NTP) service.

3.2. System behaviour

(98) All roadside C-ITS stations shall be able to transmit the infrastructure messages (e.g. DENM, CAM, Infrastructure to Vehicle Information Message (IVIM), Signal Phase and Timing Extended Message (SPATEM), MAP Extended Message (MAPEM) and Signal Request Status Extended Message (SSEM).

(99) Roadside C-ITS stations shall be able to receive DENM, CAM and Signal Request Extended Message (SREM) messages as defined in section 3.6.

3.3. Access layer

The access layer comprises the two lowest layers in the protocol stack, i.e. physical (PHY) and data-link layers, where the latter is further subdivided into medium-access control (MAC) and logical-link control (LLC).

(100) Roadside C-ITS stations shall use the optional enhanced receiver performance requirements as defined in Tables 17-19 in IEEE 802.11.

(101) Roadside C-ITS stations shall use the control channel G5-CCH as specified in Table 3 in [EN 302 663] to send messages to support the priority C-ITS services specified in Annex 3, using a default transfer rate of 6 Mbit/s (Quadrature Phase-Shift Keying (QPSK) 1/2).

(102) Roadside C-ITS stations' access layer shall be compliant with [EN 302 663], with the exception of emission limits and with the exception of clauses 4.2.1, 4.5 and 6.

(103) Roadside C-ITS stations shall be compliant with [TS 102 687].

(104) Roadside C-ITS stations should manage the limited hardware and software resources at their disposal and may perform traffic shaping or selective forwarding in line with the 'best effort' principle.

Note: Traffic shaping is especially relevant for relayed DENM messages, as it is anticipated that in some situations (such as severe traffic congestion or other extreme vehicular network scenarios) the DENM load might increase abruptly. In such cases, roadside C-ITS stations are explicitly allowed to forego the forwarding of foreign DENM messages.

(105) A roadside C-ITS station shall, at a minimum, be able to generate and transmit the number of messages as determined by the value of the highest CAM generation rate (i.e. 10 Hz) and, if detection algorithms are used, increased by the minimum required DENM generation rate derived from those triggering conditions.

(106) A roadside C-ITS station shall support the broadcast mode defined in [EN 302 663].

(107) A protected zone shall be defined as follows:

- where a tolling location consists of a single CEN-DSRC Road-side Unit (RSU), a protected zone with a default radius of 55 m shall be defined, with the location of the CEN-DSRC RSU as centre position;
- where there are multiple CEN-DSRC RSUs nearby, overlaps of protected zones should be avoided as far as possible through a combined protected zone. A combined Protected Zone shall use the geographical centre (circumcentre) of all DSRC RSUs concerned as a centre position; the radius shall be given by the circumradius + 55 m. In any case, a maximum radius of 255 m shall not be exceeded.

Note: Due to the maximum radius of 255 m, overlaps cannot always be avoided.

(108) Where a roadside C-ITS station is located close to CEN-DSRC-based tolling equipment (at least inside the protected zone), it shall apply mitigation techniques as defined in [TS 102 792].

(109) Mobile roadside C-ITS stations shall apply mitigation methods on the basis of tolling zone announcement messages.

(110) Where the roadside C-ITS station is used to indicate the presence of a tolling station, it shall transmit CAMs including protected zones in line with the technique defined in [TS 102 792] and with the CA message format as specified in [EN 302 637-2]. It shall transmit these CAMs on the control channel, before a vehicle C-ITS station enters the protected zone.

(111) Roadside C-ITS stations' access layer shall be compliant with [TS 102 724].

(112) Roadside C-ITS stations shall apply DCC techniques in accordance with [TS 102 687].

3.4. Network and transport layer

(113) Roadside C-ITS stations shall apply GN as networking protocol in accordance with [EN 302 636-4-1].

(114) All default constants and parameters of the infrastructure roadside profile not specified in this Annex shall be set as specified in Annex H to [EN 302 636-4-1].

(115) Packet repetition shall not be performed by GN and the corresponding steps in the packet-handling procedures defined in clause 10.3 of [EN 302 636-4-1] shall not be executed. The 'maximum repetition time' parameter of the service primitive GN-DATA.request and the GN protocol constant itsGnMinPacketRepetitionInterval do not apply.

(116) Roadside C-ITS stations may choose 'anonymous address' for GN address configuration (itsGnLocalAddrConfMethod set to ANONYMOUS(2)).

(117) Roadside C-ITS stations shall use GN with itsGnIfType set to ITS-G5(1).

(118) Where GN packet repetition is disabled, itsGnMinPacketRepetitionInterval is not applicable.

(119) The LifeTime field of all SHB packets shall be set to one second.

(120) The LifeTime field of all GBC packets shall be set to the minimum of ValidityDuration and RepetitionInterval, but shall not exceed the itsGnMaxPacketLifetime parameter, specified in Annex H to [EN 302 636-4-1].

(121) Where 'store-carry-forward' is enabled, the SCF bit in the TC field shall be set to one.

Note: As a result, packets can be buffered if no neighbours are available.

(122) A roadside C-ITS station is not required to offload packets to another channel. Consequently, the channel offload bit of the TC field should be set to 0 for all message types.

(123) A stationary roadside C-ITS station shall set the itsGnIsMobile bit of the Flags field to 0. A mobile roadside C-ITS station shall set the itsGnIsMobile bit of the Flags field to 1.

(124) Roadside C-ITS stations shall support the multi-hop operation mode by using the algorithms specified in Annexes E.3 and F.3, based on the selection principles outlined in Annex D, to [EN 302 636-4-1].

(125) Roadside C-ITS stations shall use duplicate packet detection on the networking and transport layer. For the detection of duplicated packets, the algorithm specified in Annex A.2 to [EN 302 636-4-1] shall be used.

(126) Roadside C-ITS stations may send only GN beacons with the Position Accuracy Indicator (PAI) set to 1.

(127) GN frames sent by the roadside C-ITS station shall use the EtherType value 0x8947 as listed by the IEEE Registration Authority at http://standards.ieee.org/develop/regauth/ethertype/eth.txt.

(128) Roadside C-ITS stations shall implement the BTP in accordance with [EN 302 636-5-1].

(129) Roadside C-ITS stations shall use BTP-B headers. Consequently, the GN common header shall use a value of 2 for the NH field.

(130) Roadside C-ITS stations shall set the destination port info field to the value 0.

(131) Roadside C-ITS stations shall set the destination port depending on the message set as specified in [TS 103 248].

(132) Geographical areas shall be applied in accordance with [EN 302 931].

(133) Roadside C-ITS stations shall support at least circular, rectangular and ellipsoidal geographical areas as defined in [EN 302 931]. Each C-ITS service shall specify one of the above geographical area types, indicated through the GN header as specified in [EN 302 636-4-1].

(134) Where the roadside C-ITS station calculates the distance between two positions using Galileo or other GNSS coordinates (e.g. for PathDeltaPoints or in cases of circular relevance area), it is recommended that the great circle or a more accurately performing method shall be used. Care shall be taken (e.g. by using the haversine formula) to avoid large rounding errors on low-precision floating point systems.

Where the relevance area is an ellipse or a rectangle, the Cartesian coordinates of the area centre and of the current position must be calculated as specified in [EN 302 931], for assessing whether to hop the packet. For this purpose, the 'local tangent plane' method is recommended, or another method delivering the same accuracy.

3.5. Facility layer

(135) Roadside C-ITS stations' DEN basic service shall be compliant with [EN 302 637-3].

(136) Roadside C-ITS station shall implement the DENM repetition as specified in [EN 302 637-3].

(137) The cases in which DENM updates are triggered are specified in the relevant service profile in Annex I.

(138) Where a roadside C-ITS station sends a DENM, the traces shall be described as a list of geographical locations leading from the event position back to the first path point.

(139) Where a mobile roadside C-ITS station becomes stationary, the PathDeltaTime of the first PathPoint of the first DENM traces element shall be fixed to the maximum value specified in [EN 302 637-3]. Therefore, PathPoints do not 'fall out' of the first DENM traces element. This applies only to trailer-based C-ITS services.

(140) Additional PathHistory elements may be present in the DENM traces. However, unlike the first element, these shall describe alternative routes to the event location. These routes may or may not be available at the time of detecting the event.

(141) For roadside C-ITS stations, the TC value of a message is specific to the based service of the message format or the C-ITS service itself and is therefore specified in the relevant service profile in Annex I. The selected TC value shall comply with the message classifications as specified in [TS 102 636-4-2] and [TS 103 301], except that Infrastructure to Vehicle Information (IVI) messages

related to variable speed limits are low-priority DENM equivalents and therefore may have the same TC value.

(142) The roadside system shall use a coordinate system compliant with section 2.13 of [ISO 8855].

Note: This means that the X and Y axes are parallel to the ground plane, the Z axis is aligned vertically upwards, the Y axis points to the left of the vehicle's forward direction and the X axis points towards the vehicle's forward driving direction.

(143) For the transmission of messages by roadside systems, the facilities layer protocol and communication profile setting CPS_001 shall be used as specified in [TS 103 301].

(144) The protected zone data provided in a CAM sent by a roadside C-ITS station shall not conflict with the protected zone information provided in the protected zone database or an equivalent database. If the same zone is defined in the protected zone database, the same ID shall be used as protectedZoneID. Otherwise, an ID greater than 67108863 that is not used in the database shall be used.

(145) Roadside C-ITS stations intended to disseminate protected zone data shall transmit CAMs on a regular basis containing protected zone data using the message format specified by [EN 302 637-2]. CAM termination is not used.

Note: The specific data elements for the coexistence C-ITS service are located in the highFrequencyContainer and the rsuContainerHighFrequency data frame.

Note: A CAM may contain other data elements not related to the coexistence C-ITS service.

(146) The antenna of a roadside C-ITS station intended to disseminate protected zone data shall be placed so that protection zone CAMs can be received in time before entry into the protected zone.

Note: Arrangements for complying with this requirement must take account of the processing time the road-user's equipment needs to process the information received. A time of 300 ms should be used as a reference.

(147) A roadside C-ITS station intended to disseminate protected zone data shall transmit CAMs containing protected zone data with a transmission frequency that ensures that mobile C-ITS stations are able to identify the presence of protected zones in time.

(148) A roadside C-ITS station intended to disseminate protected zone data shall be installed outside protected zones or configured in accordance with [TS 102 792].

(149) A CAM shall not contain more than one temporary protected zone (i.e. ProtectedCommunicationZone with ProtectedZoneType=1).

Note: This is specific to temporary tolling and enforcement vehicles. Mobile C-ITS stations are required to store only one temporary protected zone in accordance with clause 5.2.2.2 of [TS 102 792], in order to avoid ambiguity.

(150) Where the coexistence (ITS-G5 — CEN-DSRC) Facilities Layer Service is used, it shall be applied in accordance with [EN 302 637-2] and as specified in [TS 102 792].

(151) [ISO/TS 19321] refers to an older version (1.2.1) of the [TS 102 894-2] common data dictionary (CDD) for payload data. All [ISO/TS 19 321] based IVI C-ITS services shall therefore be based on the updated version (1.3.1), until [ISO/TS 19321] is updated accordingly.

(152) The CA basic service shall be active as long as the mobile roadside C-ITS station is participating on public roads under regular driving dynamics. As long as the CA basic service is active, CAMs shall be generated in accordance with the generation rules in [EN 302 637-2].

(153) Roadside C-ITS stations shall transmit CAM messages where position confidence information is available and the station clock adheres to point (97).

(154) The parameter T_GenCam_Dcc shall be set to the value of the minimum time between two transmissions T_{off} as provided by the DCC mechanism specified in point (103).

(155) The adjustable N_GenCam parameter specified in the CAM generation frequency management shall be set to 0 for the roadside C-ITS station, unless it is intended to disseminate protected zone data as defined in point (145).

3.6. Management

Not all specified security services have to be implemented. In addition, for some services, implementation is defined internally by the C-ITS station operator.

(156) Roadside C-ITS stations implementing ITS-G5 functionalities shall implement a management layer including a DCC_CROSS entity as specified in [TS 103 175].

3.7. Service Elements

3.7.1. DEN basic service

The DEN basic service uses the services provided by the protocol entities of the ITS networking and transport layer to disseminate DENMs.

A DENM contains information relating to an event that has a potential impact on road safety or traffic conditions. 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. DENM transmission may be independent from the originating C-ITS station in some situations.

Four types of DENM are generated by the DEN basic service:

- new DENMs;
- update DENMs;
- cancellation DENMs;
- negation DENM.

(157) The DENM header shall be as specified in the data dictionary [TS 102 894-2].

(158) DENM data elements, data frames and service parameters shall be set in accordance with Table 3. In addition, for C-ITS services on roadworks warnings, DENM data frames and service parameters shall be set in accordance with Table 4.

Table 3: DENM elements in general

Name	Use	Usage
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 C-ITS station whose facility layer created the message, which may be either the central or the roadside C-ITS station. If not set by the central C-ITS station, messages of which the content is generated centrally but which are broadcast from different roadside C-ITS stations will have different originatingStationIDs, resulting in different actionIDs If the originatingStationID and sequenceNumber are given by the central C-ITS station where centrally generated content is (potentially) sent out via multiple roadside C-ITS stations, the system provides the same actionID for all messages relating to the same event, regardless of which roadside C-ITS station is sending 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
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 roadside C-ITS station in stand-alone use-case scenarios. In use-case scenarios with connection to the central C-ITS station, 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 hazardous location starts / is detected at a functional level. **Value:** detectionTime is initially set to the start time of the event (new DENM) then reset for each DENM update. For DENM termination, this DE shall be the time at which the termination of the event is detected.
referenceTime	Mandatory	**Content:** The referenceTime shall be set to the time the DENM message is generated or updated. **Value:** Set automatically
termination	Optional	C-ITS service specific
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 at lane level, but must be at least at carriageway level. Altitude and confidence DEs can be used or set to the values

Name	Use	Usage
		corresponding with ‘unavailable’.
relevanceDistance	Optional	Optional
relevanceTrafficDirection	Mandatory	**Content:** Fixed value. For highways this value is set to 1 (upstream traffic). This DF indicates for which traffic direction the message is relevant (from the perspective of the eventPosition).
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 (using DENM repetition) and updated (using DENM update, renewing ‘validityDuration’, ‘detectionTime’ and ‘referenceTime’ in the process). A message update will be triggered by ‘validityDuration’ falling below a certain (also configurable) threshold. If the event is no longer valid, it is either timed out or actively cancelled (DENM cancellation). **Content:** The DE validityDuration is set to a fixed value. **Value:** C-ITS service specific.
TransmissionInterval	Not used	Not used
stationType	Mandatory	**Content:** Fixed value, set to 15 (roadSideUnit). This is true for fixed and mobile roadside C-ITS stations. The value can be 9 (trailer) or 10 (specialVehicles) in the case of road operator vehicles. **Value:** Set to 9, 10 or 15.
Situation container	Mandatory	
informationQuality	Mandatory	Information quality is the likelihood of occurrence, in a range of 0 to 7. Values: risk (2), probable (4), certain (6) If (0) is received, it should be rejected; if (7) is received, it should be considered as certain.
eventType	Mandatory	Combination of DE causeCode and DE subCauseCode. C-ITS service specific.
linkedCause	Optional	Possibility of linking the current message to a set of causeCode / subCauseCode (similar to eventType) to provide further information.
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

Name	Use	Usage
		blockage (another DENM). 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 in the eventHistory will be set to the same value as the above-specified informationQuality of the whole DENM. Where map projections are used, these shall refer to points at the middle of the lane or carriageway. Maximum deviation between reality and map projections shall not exceed a quarter of the width of the carriageway.
Location container	Optional	
eventSpeed	Optional	This DF shall only be provided in case of a moving event, if available. In case of static events it shall not be provided.
eventPositionHeading	Optional	Heading information will be provided only 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 in the middle of the lane or carriageway upstream from the event position, considering the curvature of the road. It is coded as an offset or 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. When map projections are used, these shall refer to points in the middle of the lane or carriageway. Maximum deviation between reality and map projections shall not exceed a quarter of the width of the carriageway.
roadType	Optional	Optional
Alacarte container	Optional	
lanePosition	Optional	C-ITS service specific.
impactReduction	Not used	Not used
externalTemperature	Not used	Not used
lightBarSirenInUse	Not used	Not used

Table 4: DENM elements specific to roadworks warnings

Name	Use	Usage
Alacarte container	Optional	
lanePosition	Optional	optional
closedLanes	Optional	The lanes are counted from the inside border of the road, excluding the hard shoulder. This DF consists of drivingLaneStatus and hardShoulderStatus.
speedLimit	Optional	optional
recommendedPath	Optional	optional
startingPointSpeedLimit	Optional	optional
trafficFlowRule	Optional	optional passToRight(2) or passToLeft(3) are generally supported in all C-ITS service scenarios.
referenceDenms	Optional	Road works warning DENMs belonging to the same roadwork situation will be linked in the central C-ITS station by listing all actionIDs belonging together in the referenceDenms data element of each message.

3.7.2. IVI Service

The IVI service uses the services provided by the protocol entities of the ITS networking and transport layer to disseminate IVIM.

An IVIM supports mandatory and advisory road signage such as contextual speeds and roadworks warnings. IVIM provides information of physical road signs such as static or variable road signs, virtual signs or roadworks.

The IVI service instantiated in a C-ITS station shall provide either the transmission or the reception service.

The IVI service generates four types of IVIM:

- new IVIMs;
- update IVIMs;
- cancellation IVIMs;
- negation IVIMs.

(159) The IVIM header shall be as specified in [TS 102 894-2].

(160) The data elements of the IVIM message payload are defined in [ISO/TS 19321].

(161) IVIM data elements, IVIM data frames and service parameters shall be set in accordance with Table 5.

Table 5

Name	Use	Usage

Name	Use	Usage
IVI management container	Mandatory	
serviceProviderId	Mandatory	serviceProviderID consists of data elements 'countryCode' and 'providerIdentifier'. countryCode is a bitstring in line with [ISO 3166-1]. For Austria, for example, the bitstring stands for 'AT' (bitstring code: A (11000) and T (00001) 1100000001 in line with [ISO 14 816]). Together with iviIdentificationNumber, this is the unique identifier for messages for the receiving vehicle C-ITS station.
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 content of the messages was last changed.
validFrom	Mandatory	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 is 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 the road operator.
connectedIviStructures (1..8)	Not used	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). It is used for message handling.
Geographical location container (GLC)	Mandatory	
referencePosition	Mandatory	This DE is used as a reference point for all zones in the GLC. The reference point for IVI is the middle of the carriageway, at a gantry, and is the first point of zone definitions for relevance zones and detection zones. 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
referencePositionTime	Not used	Not used.
referencePositionHeading	Not used	Not used
referencePositionSpeed	Not used	Not used.

Name	Use	Usage
GlcPart	**Mandatory**	parts (1..16). Up to 16 parts can be defined in each GLC. 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).
zoneExtension	Not used	Not used.
zoneHeading	Mandatory	Mandatory
zone	Mandatory	Definition of a zone using the DF zone consisting of either a chosen 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 (used only where 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	Not used	Not used.
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	Not used	Not used.
minimumAwarenessTime	Not used	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 prioritisation of IVI at the receiving C-ITS station.
iviPurpose	Not used	Not used.
laneStatus	Optional	Indicates the lane status (e.g. open, closed, mergeL, 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)

Name	Use	Usage
		shall contain the characteristics applicable to the entire vehicle train.
driverVehicleCharacteristics	Not used	Not used.
layoutId	Not used	Not used.
preStoredLayoutId	Not used	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	Not used	This data frame can be used to associate RSCode to the layout component of referenced layout.
code	Mandatory	For signcoding [ISO/TS 14 823] shall be used.
ISO 14823Code	Mandatory	For signcoding, [ISO/TS 14 823] shall be used. This data frame includes several DFs and DEs. It includes pictogramCode (countryCode, serviceCategorycode and pictogramCategoryCode). The attributes SET (section) and NOL (number of lane) are not supported, because they duplicate information that is already supported in the application container.
extraText ((1..4),...)	Optional	List of text lines associated with 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.

3.7.3. Road Lane Topology (RLT) service

The RLT service uses the services provided by the protocol entities of the ITS networking & transport layer to disseminate RLT.

It includes the lane topology for vehicles, bicycles, parking, public transport and the paths for pedestrian crossings, for example, and the permissible manoeuvres within an intersection area or a road segment. In future enhancements, the digital map will include additional topology descriptions such as traffic roundabouts.

(162) MAPEM headers shall be as specified in [ETSI TS 102 894-2].

(163) MAPEM data elements, MAPEM data frames and service parameters shall be set in accordance with Table 6.

Table 6: MAPEM data elements

Level	Name	Type	Use	Usage
*	mapData	DF	Mandatory	
**	timeStamp	DE	Not used	Not used.
**	msgIssue Revision	DE	Mandatory	Mandatory and set to 0. As defined in [ISO TS 19091].
**	layerType	DE	Not used	Not used.
**	layerID	DE	Optional	Optional. As defined in [ISO TS 19091].
**	intersections (1..32)	DF	Mandatory	IntersectionGeometryList::= SEQUENCE (SIZE(1..32)) OF IntersectionGeometry (see Table 6.1) Mandatory for Traffic Light Manouvre (TLM)/RLT C-ITS services.
**	roadSegments (1..32)	DF	Not used	Not used. Data elements are not further profiled.
**	dataParameters	DF	Optional	Optional.
***	processMethod	DE	Not used	Not used.
***	processAgency	DE	Optional	Optional.
***	lastCheckedDate	DE	Optional	Optional, as yyyy-mm-dd
***	geoidUsed	DE	Not used	Not used.
**	restriction List (1..32)	DF	Optional	RestrictionClassList::= SEQUENCE (SIZE(1..254)) OF RestrictionClassAssignment (see Table 6.3). Optional.
**	regional	DE	Not used	REGION.Reg-MapData. Not used.

Table 6.1: IntersectionGeometryList -> Intersection Geometry

Level	Name	Type	Use	Usage
*	intersectionGeometry	DF	Mandatory	Mandatory if 'intersections' is used.
**	name	DE	Optional	Optional. Typically human-readable and recognisable by road authority.
**	id	DF	Mandatory	(IntersectionReferenceID) Mandatory. Must be the same as in the SPATEM. The combination of region and id must be unique within a country.

***	region	DE	Optional	Optional.
***	id	DE	Mandatory	Mandatory.
**	revision	DE	Mandatory	Mandatory. The revision number must be increased by one each time the MapData of this intersection changes. The revision numbers of SPATEM and MAPEM must be the same, to indicate that the right MAPEM revision is used. As defined in [ISO TS 19091].
**	refPoint	DF	Mandatory	Mandatory.
***	lat	DE	Mandatory	Mandatory.
***	long	DE	Mandatory	Mandatory.
***	elevation	DE	Not used	Not used. Replaced by regional Reg-Position3D.
***	regional	DF	Optional	REGION.Reg-Position3D. Optional. When given, provides altitude.
****	altitude	DF	Mandatory	Mandatory. Consists of altitudeValue and altitudeConfidence
*****	altitudeValue	DE	Mandatory	Mandatory.
*****	altitudeConfidence	DE	Optional	Mandatory; when not available set to (15) = unavailable.
**	laneWidth	DE	Optional	Optional.
**	speedLimits (1..9)	DF	Optional	SpeedLimitList::= SEQUENCE (SIZE(1..9)) OF RegulatorySpeedLimit (see Table 6.2). Optional.
**	laneSet (1..255)	DF	Mandatory	LaneList::= SEQUENCE (SIZE(1..255)) OF GenericLane (see Table 6.4). Mandatory.
**	preemptPriorityData (1..32)	DF	Not used	Not used. Data elements are not further profiled.
**	Regional	DF	Not used	REGION.Reg- IntersectionGeometry). Not used.

Table 6.2: SpeedLimitList -> RegulatorySpeedLimit

Level	Name	Type	Use	Usage
*	regulatory SpeedLimit	DF	Mandatory	Mandatory if ‘speedLimits’ is used.
**	type	DE	Mandatory	Mandatory.

**	speed	DE	Mandatory	Mandatory.

Table 6.3: RestrictionClassList -> RestrictionClassAssignment

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

Table 6.4: LaneList -> GenericLane

Level	Name	Type	Use	Usage
*	genericLane	DF	Mandatory	Mandatory if 'laneSet' is used.
**	laneID	DE	Mandatory	Mandatory.
**	name	DE	Optional	Optional.
**	ingressApproach	DE	Optional	Optional. If used, ingress and egress approaches of the same arm have the same ApproachID.
**	egressApproach	DE	Optional	Optional. If used, ingress and egress approaches of the same arm have the same ApproachID.
**	laneAttributes	DF	Mandatory	Mandatory.
***	directional Use	DE	Mandatory	Mandatory.
***	sharedWith	DE	Mandatory	Mandatory. With bits as defined: overlappingLaneDescriptionProvided(0) multipleLanesTreatedAsOneLane(1) -- not permitted in profile, as all lanes must 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 TS 19091] for pedestrian crossing examples.
****	Vehicle	DE	Optional	Optional (choice).
****	crosswalk	DE	Optional	Optional (choice).
****	bikeLane	DE	Optional	Optional (choice).
****	sidewalk	DE	Not used	Not used.
****	median	DE	Not used	Not used.
****	striping	DE	Not used	Not used.
****	trackedVehicle	DE	Optional	Optional (choice).
****	parking	DE	Not used	Not used.
***	regional	DF	Not used	Reg-laneAttributes. Not used.
**	maneuvers	DE	Not used	Not used.
**	nodeList	DF	Mandatory	Mandatory.
***	nodes (2..63)	DF	Mandatory	NodeSetXY::= SEQUENCE (SIZE(2..63)) OF NodeXY (see Table 6.5) Mandatory if 'nodeList' is used. Recommended use for curved lanes is to add an additional node when the centre line of the GenericLane deviates more than 0.5 m from the actual centre line.
***	computed	DF	Not used	Not used.
**	connectsTo (1..16)	DF	Optional	ConnectsToList::= SEQUENCE (SIZE(1..16)) OF Connection (see Table 6.6). Optional. For example for egress lane(s) not managed by a traffic light.
**	overlays	DF	Not used	Not used.
**	regional	DF	Not used	REGION-Reg-GenericLane. Not used (until upcoming release of [ISO TS 19091]). To provide ConnectionTrajectory-

				addGrpC. Relevant for use-case scenario safe intersection manoeuvre.

Table 6.5: NodeSetXY -> NodeXY

Level	Name	Type	Use	Usage
*	nodeXY	DF	Mandatory	Mandatory if 'nodes' is used.
**	delta	DF	Mandatory	Mandatory.
***	node-XY1	DF	Optional	Optional (choice). DF composed with X and Y, both mandatory.
***	node-XY2	DF	Optional	Optional (choice). DF composed with X and Y, both mandatory.
***	node-XY3	DF	Optional	Optional (choice). DF composed with X and Y, both mandatory.
***	node-XY4	DF	Optional	Optional (choice). DF composed with X and Y, both mandatory.
***	node-XY5	DF	Optional	Optional (choice). DF composed with X and Y, both mandatory.
***	node-XY6	DF	Optional	Optional (choice). DF composed with X and Y, both mandatory.
***	node-LatLon	DF	Not used	Not used for intersections. Use for motorways, for example, is acceptable.
***	regional	DF	Not used	REGION.Reg-NodeOffsetPointXY. Not used.
**	attributes	DF	Optional	This DE provides any optional attributes that 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 on the basis of the order of the nodes.
***	localNode	DF	Optional	NodeAttributeXYList::=

	(1..8)			SEQUENCE (SIZE(1..8)) OF NodeAttributeXY Optional. 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 Optional. Subject to case.
****	segmentAttributeXY	DE	Mandatory	Mandatory if disabled is used.
***	enabled (1..8)	DF	Optional	SegmentAttributeXYList::= SEQUENCE (SIZE(1..8)) OF SegmentAttributeXY Optional. Subject to case.
****	segmentAttributeXY	DE	Mandatory	Mandatory if enabled is used.
***	data	DF	Optional	Optional.
****	pathEndPointAngle	DE	Not used	Not used.
****	pathEndPointAngle	DE	Not used	Not used.
****	laneCrownPointCenter	DE	Not used	Not used.
****	laneCrownPointLeft	DE	Not used	Not used.
****	laneCrownPointRight	DE	Not used	Not used.
****	laneAngle	DE	Not used	Not used.
****	speedLimits (1..9)	DE	Optional	SpeedLimitList::= SEQUENCE (SIZE(1..9)) OF RegulatorySpeedLimit (see Table 6.2). Optional (choice).
****	regional	DF	Not used	REGION.Reg-LaneDataAttribute. Not used.
***	dWidth	DE	Optional	Optional.
***	dElevation	DE	Optional	Optional.
***	regional	DF	Not used	REGION.Reg-NodeAttributeSetXY.

				Not used.

Table 6.6: ConnectsToList -> Connection

Level	Name	Type	Use	Usage
*	connection	DF	Optional	Mandatory if 'connectsTo' is used.
**	connectingLane	DF	Mandatory	Mandatory.
***	lane	DE	Mandatory	Mandatory.
***	maneuver	DE	Optional	Optional.
**	remoteIntersection	DF	Optional	Optional. Only used if the referenced intersection is part of the same MAPEM.
***	Region	DE	Optional	Optional.
***	Id	DE	Mandatory	Mandatory.
**	signalGroup	DE	Optional	Optional, as not all connections may have related signalgroups. However, for connections controlled by a traffic light, the signalgroup must be set.
**	userClass	DE	Optional	Optional.
**	connectionID	DE	Mandatory	Mandatory.

3.7.4. TLM service

The TLM service uses the services provided by the protocol entities of the ITS networking & transport layer to disseminate TLM.

It includes safety-related information to help 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 service provides real-time information 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, and permissible manoeuvres, and helps with crossing.

(164) SPATEM headers shall be as specified in [TS 102 894-2].

(165) SPATEM data elements, data frames and service parameters shall be set in accordance with Table 7.

Table 7: SPATEM data elements

Level	Name	Type	Use	Usage
*	Spat	DF	Mandatory	
**	timeStamp	DE	Optional	Not used, but kept optional.
**	name	DE	Optional	Not used, but kept optional.

**	Intersections (1..32)	DF	Mandatory	IntersectionStateList::= SEQUENCE (SIZE(1..32)) OF IntersectionState (see Table 7.1). Mandatory
**	regional (1..4)	DF	Not used	REGION.Reg-SPAT. Not used.

Table 7.1: IntersectionStateList -> IntersectionState

Level	Name	Type	Use	Usage
*	intersectionState	DF	Mandatory	
**	name	DE	Optional	Used, but kept optional. Based on a numbering scheme used by the road authority.
**	id	DF	Mandatory	(IntersectionReferenceID) Mandatory. Must be the same as in the MAPEM. The combination of region and ID must be unique within a country.
***	region	DE	Optional	Optional.
***	id	DE	Mandatory	Mandatory.
**	revision	DE	Mandatory	Mandatory. The revision number must be increased by one each time the MapData of this intersection changes. The revision numbers of SPATEM and MAPEM must be the same, to indicate that the right MAPEM revision is used. As defined in [ISO TS 19091].
**	status	DE	Mandatory	Mandatory. Typically used, on the basis of EN 12675, are: • manualControlIsEnabled(0); • fixedTimeOperation(5); • trafficDependentOperation(6); • standbyOperation(7); • failureMode(8).
**	moy	DE	Mandatory	Mandatory. Also used to validate the reference time of the TimeMarks.
**	timeStamp	DE	Mandatory	Mandatory.
**	enabledLanes	DF	Optional	Mandatory if the revocableLane bit is used in any of the lane descriptions; otherwise not used.
**	states	DF	Mandatory	MovementList::= SEQUENCE (SIZE(1..255)) OF

	(1..16)			MovementState (see Table 7.2). Mandatory.
**	maneuverAssistList (1..16)	DF	Not used	ManeuverAssistList::= SEQUENCE (SIZE(1..16)) OF ConnectionManeuverAssist (see Table 7.5). 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.

Table 7.2: MovementList -> MovementState

Level	Name	Type	Use	Usage
*	movementState	DF	Mandatory	Mandatory if 'states' is used.
**	movementName	DE	Optional	Optional.
**	signalGroup	DE	Mandatory	Mandatory.
**	state-time- speed	DF	Mandatory	MovementEventList::= SEQUENCE (SIZE(1..16)) OF MovementEvent. Mandatory (1-16). (see Table 7.3).
**	maneuverAssistList (1..16)	DF	Optional	ManeuverAssistList::= SEQUENCE (SIZE(1..16)) OF ConnectionManeuverAssist (see Table 7.5). Optional.
**	regional (1..4)	DF	Not used	REGION.Reg-MovementState. Not used.

Table 7.3: MovementEventList -> MovementEvent

Level	Name	Type	Use	Usage
*	movementEvent	DF	Mandatory	Mandatory if 'state-time-speed' is used.
**	eventState	DE	Mandatory	Mandatory and 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 when turning); (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	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 [ISO TS 19091]) and not for functional safety, but informative related to signal timing. likelyTime with confidence or minEndTime with maxEndTime are both measures for probability and can be used interchangeably subject to availability.
***	startTime	DE	Not used	Not used.
***	minEndTime	DE	Mandatory	Mandatory. Pre-configured or calculated value with high probability, but sometimes not available (36001). In cases of fixed time control, for example, identical to maxEndTime, which indicates high probability.
***	maxEndTime	DE	Mandatory	Mandatory. Pre-configured or calculated value with high probability, but sometimes not available (36001). In cases of fixed time control, for example, identical to minEndTime, which indicates high probability.
***	likelyTime	DE	Optional	Optional.
***	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 SAE J2735 is

				not used. Assuming normal distribution and a standard deviation of 3.6 seconds, likelyTime is: • within 26 and 34 seconds (1 sigma), with 68.27 % probability; • within 22 and 38 seconds (2 sigma), with 95.44 % probability; • within 18 and 42 seconds (3 sigma), with 99.73 % probability.
***	nextTime	DE	Optional	Optional.
**	speeds (1..16)	DF	Optional	AdvisorySpeedList::= SEQUENCE (SIZE(1..16)) OF AdvisorySpeed (see Table 7.4). Optional.
**	regional (1..4)	DF	Optional	REGION.Reg-MovementEvent, Optional.

Table 7.4: AdvisorySpeedList -> AdvisorySpeed

Level	Name	Type	Use	Usage
*	advisorySpeed	DF	Mandatory	Mandatory if 'speeds' is used.
**	type	DE	Mandatory	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	Optional.
**	confidence	DE	Not used	Not used.
**	distance	DE	Optional	Optional. Not used for greenwave(1). In other cases, distance is specified upstream from the stop bar along the ingressing lane.
**	class	DE	Optional	Optional.
**	regional (1..4)	DF	Not used	REGION.Reg-AdvisorySpeed. Not used.

Table 7.5: ManeuverAssistList -> ConnectionManeuverAssist

Level	Name	Type	Use	Usage

*	connection ManeuverAssist	DF	Mandatory	Mandatory if ‘maneuverAssistList’ is used.
**	connectionID	DE	Mandatory	Mandatory.
**	queueLength	DE	Optional	Optional.
**	availableStorageLength	DE	Not used	Not used.
**	waitOnStop	DE	Not used	Not used.
**	pedBicycleDetect	DE	Not used	Not used.
**	regional (1..4)	DF	Not used	REGION.Reg-ConnectionManeuverAssist. Not used.