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Foreword

This Technical Specification (TS) has been produced by ETSI Technical Committee Intelligent Transport Systems (ITS).

Modal verbs terminology

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Introduction

The present document specifies the Collective Perception Service (CPS) and how a transmitting ITS station (ITS-S) can inform other ITS-Ss about the kinematic and attitude dynamics and other attributes of objects (e.g. vehicles, pedestrians, animals and others) detected by sensors such as radars, lidars and cameras to which the transmitting ITS-S has access. The CPS increases awareness among ITS-Ss by sharing information about perceived objects in the local environment.

The Collective Perception Message (CPM) enables the interoperable sharing of basic information about the disseminating ITS-S (required for the interpretation of the transmitted data), its sensory capabilities, perceived objects and road-related perception regions. CPMs are generated quasi-periodically as determined by CPM generation events.

1 Scope

The present document specifies the CPS. Conceptually, Collective Perception involves sharing safety-relevant information about the current context of the ITS-S's environment. This includes the definition of the syntax and semantics of the CPM and the specification of the data and message handling of the CPM to increase the awareness of the environment in a cooperative manner.

2 References

2.1 Normative references

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the referenced document (including any amendments) applies.

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The following referenced documents are necessary for the application of the present document.

[1] ETSI TS 103 097: "Intelligent Transport Systems (ITS); Security; Security header and certificate formats; Release 2".

[2] Recommendation ITU-T X.691 (2021-02): "Information technology - ASN.1 encoding rules: Specification of Packed Encoding Rules (PER)".

[3] ETSI TS 102 894-2 (V2.1.1): "Intelligent Transport Systems (ITS); Users and applications requirements; Part 2: Applications and facilities layer common data dictionary; Release 2".

[4] ETSI EN 302 890-2: "Intelligent Transport Systems (ITS); Facilities Layer function; Part 2: Position and Time management (PoTi); Release 2".

[5] ETSI TS 103 836-4-1: "Intelligent Transport Systems (ITS); Vehicular Communications; GeoNetworking; Part 4: Geographical addressing and forwarding for point-to-point and point-to-multipoint communications; Sub-part 1: Media-Independent Functionality; Release 2".

[6] ETSI TS 103 836-5-1: "Intelligent Transport Systems (ITS); Vehicular Communications; GeoNetworking; Part 5: Transport Protocols; Sub-part 1: Basic Transport Protocol; Release 2".

[7] ETSI TS 103 141: "Intelligent Transport Systems (ITS); Facilities layer function; Multi-Channel Operation (MCO) for Cooperative ITS (C-ITS); Release 2".

2.2 Informative references

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the referenced document (including any amendments) applies.

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The following referenced documents are not necessary for the application of the present document, but they assist the user with regard to a particular subject area.

[i.1] ETSI TR 103 562: "Intelligent Transport Systems (ITS); Vehicular Communications; Basic Set of Applications; Analysis of the Collective Perception Service (CPS); Release 2".

[i.2] ETSI TS 103 898: "Intelligent Transport Systems (ITS); Communications Architecture; Release 2".

[i.3] ETSI EN 302 895: "Intelligent Transport Systems (ITS); Vehicular Communications; Basic Set of Applications; Local Dynamic Map (LDM)".

[i.4] Car 2 Car Communication Consortium: "Technical Report on CPM Object Quality".

[i.5] ISO EN 17419: "Intelligent Transport Systems -- Cooperative Systems -- Classification and management of ITS applications in a global context" Definition of terms, symbols and abbreviations".

[i.6] ETSI TS 103 836-3: "Intelligent Transport Systems (ITS); Vehicular Communications; GeoNetworking; Part 3: Network Architecture; Release 2".

[i.7] ETSI TS 102 723-5: "Intelligent Transport Systems (ITS); OSI cross-layer topics; Part 5: Interface between management entity and facilities layer; Release 2".

[i.8] ETSI TR 102 965: "Intelligent Transport Systems (ITS); Application Object Identifier (ITS-AID); Registration list".

[i.9] ETSI TS 102 940: "Intelligent Transport Systems (ITS); Security; ITS communications security architecture and security management; Release 2".

[i.10] ETSI TR 103 460: "Intelligent Transport Systems (ITS); Security; Pre-standardization study on Misbehavior Detection; Release 2".

[i.11] ETSI TS 102 890-1: "Intelligent Transport Systems (ITS); Facilities layer function; Part 1: Services Announcement (SA) specification".

[i.12] ETSI TS 103 300-3: "Intelligent Transport Systems (ITS); Vulnerable Road Users (VRU) awareness; Part 3: Specification of VRU awareness basic service; Release 2".

[i.13] ETSI TS 103 301: "Intelligent Transport Systems (ITS); Vehicular Communications; Basic Set of Applications; Facilities layer protocols and communication requirements for infrastructure services; Release 2".

3 Definition of terms, symbols and abbreviations

3.1 Terms

For the purposes of the present document, the following terms apply:

central ITS-S: ITS-S in a backend, e.g. traffic control centre, traffic management centre, or cloud system from road authorities, ITS application suppliers or automotive OEMs

classification confidence level: measure related to the certainty, generally a probability, with which a perceived object can be linked to a specific object class or type (e.g. with X % probability the object is of type A)

NOTE: The sum of the object classification confidence levels for each perceived object may not exceed 100 % (e.g. in the example above, the classification confidence for an object to be of type B will not exceed (100-X) %).

Collective Perception (CP): concept involving sharing of information (generated by sensor systems) about the perceived environment of an ITS-S

Collective Perception Message (CPM): message generated by the CPS

Collective Perception Message (CPM) data: some or all data included in a CPM

Collective Perception Service (CPS): functionality in the ITS-S facilities layer to support ITS-S applications, CPM management and CPM dissemination

Collective Perception Service (CPS) protocol: ITS facilities layer protocol for CPM dissemination and reception

confidence level: probability with which the estimate of a statistical parameter (e.g. an arithmetic mean) in a sample survey is also true for the entire population from which the samples were taken

confidence value: estimated absolute accuracy (i.e. closeness of a measured value to a standard or known value) of a measured value of a parameter with a specified confidence level (generally 95 % in the present document)

ITS station (ITS-S): functional entity specified by the ITS station (ITS-S) reference architecture

object: material thing that can be seen and touched and therefore detected and with which parameters can be associated that can be measured and/or estimated

object list: collection of objects

object perception quality: quantification of the estimated likelihood that a detected object exists, i.e. has been detected previously and has continuously been detected by a sensor

perception region confidence: quantification of the estimated likelihood that objects or unoccupied regions may be detected within a perception region

roadside ITS-S: ITS-S operating in the context of roadside ITS equipment

state space representation: mathematical description of a detected object consisting of state variables such as position, velocity, attitude, angular rate, etc.

Vehicle-to-Everything (V2X): type of communication that includes Vehicle-to-Vehicle (V2V), Vehicle-to-Infrastructure (V2I), Infrastructure-to-Vehicle (I2V), or Vehicle-to-Network (V2N), and Network-to-Vehicle (N2V) communications

Vehicle ITS-S: ITS-S operating in the context of vehicular ITS equipment

3.2 Symbols

For the purposes of the present document, the following symbols apply:

IF.CPS	Interface between CPS and LDM or ITS applications
IF.APP	Interface between CPS and ITS applications
IF.FAC	Interface between CPS and other facilities layer entities
IF.MCO	Interface between CPS and the MCO facility layer entity
IF.Mng	Interface between CPS and ITS management entity
IF.N&T	Interface between CPS and ITS network & transport layer
IF.SEC	Interface between CPS and ITS security entity

3.3 Abbreviations

For the purposes of the present document, the following abbreviations apply:

API	Application Programming Interface
ASN.1	Abstract Syntax Notation One
CAM	Cooperative Awareness Message
CP	Collective Perception
CPM	Collective Perception Message
CPS	Collective Perception Service
DCC	Decentralized Congestion Control
DDP	Device Data Provider
DE	Data Element
DF	Data Frame
FoV	Field of View
I2V	Infrastructure to Vehicle
ITS	Intelligent Transport Systems
ITS-S	Intelligent Transport Systems Station
LDM	Local Dynamic Map

MCI	MCO Control Information
MCO	Multi Channel Operations
MIB	Management Information Base
MTU	Maximum Transmission Unit
PCI	Protocol Control Information
R-ITS-S	Roadside ITS Station
SA	Service Announcement
SCH	Service Channel
SCO	Single Channel Operations
UPER	Unaligned Packed Encoding Rule
V2I	Vehicle-to-Infrastructure
V2V	Vehicle-to-Vehicle
VAM	VRU Awareness Message
VoI	Value of Information
VRU	Vulnerable Road User

4 CPS introduction

Collective Perception Messages (CPMs) are transmitted by ITS-Ss in order to share information about perceived objects (such as vehicles, pedestrians, animals and other collision relevant objects) and perception regions (road regions that allow receiving ITS-Ss to determine unoccupied regions) in the local environment. This enhances the environmental perception of CPS-enabled ITS-Ss by providing information about non-V2X-equipped road users, other collision relevant objects, unoccupied regions and also increases the number of information sources for V2X-equipped road users. The availability of multiple sources of information associated with an object or an unoccupied region allows ITS-Ss to perform data fusion which generally leads to lower uncertainty in both the classification of objects and in their properties such as their sizes and their kinematic and attitude states. Even if data manipulated or corrupted at the source are received, a sufficient number of independent sources that maintain integrity may allow identification of such data.

A CPM contains a set of perceived objects and regions, along with their observed status and attributes. The content may vary depending on the type of the road user or object and the detection capabilities of the originating ITS-S. For perceived objects, the status information is expected to include at least the detection time, position, and optionally other elements of the kinematic and attitude state. To support the CPM interpretation at any receiving ITS-S, a sender can also include information about its sensors, such as sensor types and fields of view.

On reception of a CPM, receiving ITS-Ss become aware of the presence, type, and status of a recognized road user, object or region that was detected by the transmitting ITS-S. The received information can then be used by the receiving ITS-S to support ITS applications that increase safety and improve traffic efficiency thereby generally decreasing travel time. For example, by monitoring the status of a detected road user or object, a receiving ITS-S can estimate the collision risk with that road user or object and can inform the user via the HMI of the receiving ITS-S or take corrective actions automatically. Data distributed by the CPS is clearly useful for a large number of ITS safety and efficiency-related applications making the CPS an essential component of any ITS deployment, especially where any form of autonomous activity is anticipated.

ETSI TR 103 562 [i.1] provides an analysis of the Collective Perception Service with further information and simulation results.

5 CPS functional specification

5.1 CPS in the ITS architecture

The CPS is a facilities layer entity in the ITS-S architecture as defined in ETSI TS 103 898 [i.2]. It may interface with other entities of the Facilities layer and with ITS applications to collect relevant information for CPM generation and for forwarding received CPM content for further processing. Figure 1 depicts the CPS within the ITS-S architecture along with the logical interfaces to other layers and entities within the Facilities layer.

The entities for the collection of data to generate a CPM may be the Device Data Provider (DDP), the Position and Time management (POTI) and the Local Dynamic Map (LDM). For vehicle ITS-Ss, the DDP may be connected to the in-vehicle network to provide the vehicle state information. For roadside ITS-Ss and central ITS-S, the DDP may be connected to sensors mounted on the roadside infrastructure such as poles or gantries. The POTI entity provides estimates of the kinematic state of the ITS-S and time information as specified in ETSI EN 302 890-2 [4]. An LDM as outlined in ETSI EN 302 895 [i.3] is a database in an ITS-S, which in addition to on-board sensor data may be updated with received CAM and CPM data. ITS applications may retrieve information from the LDM for further processing. The CPS may also interface with the Service Announcement (SA) Service [i.11] to indicate an ITS-S's ability to generate CPMs and to provide details about the communication technology used.

Figure 1 presents the CPS in the ITS-S architecture as well as its logical interfaces with other entities and layers.

NOTE: The CPS may exchange information with additional facilities layer entities for the purpose of generation, transmission, forwarding and reception of CPM. For simplicity reason, these interfaces are not illustrated in Figure 1.

The functionalities of the CPS are defined in clause 5.2 and the interfaces are defined in clause 5.3.

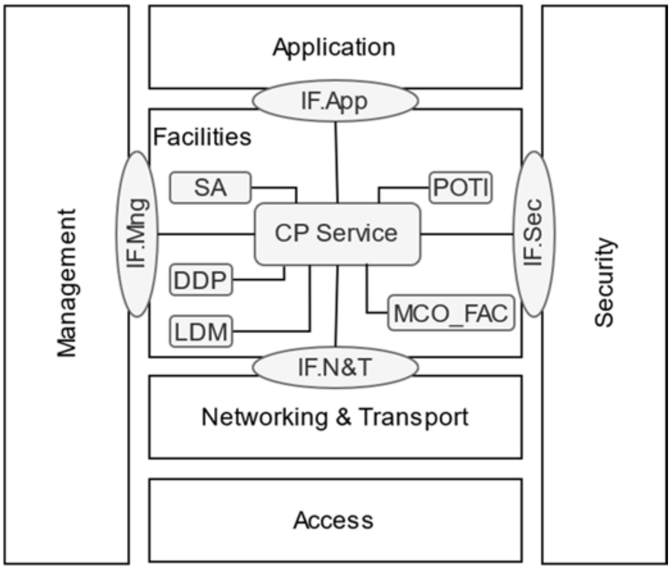

Figure 1: CPS within the ITS-S architecture

NOTE: IF.App in Figure 1 can be implemented as IF.CPS as shown in Figure 2.

5.2 CPS functional architecture

For sending and receiving CPMs, the CPS shall provide the following sub-functions:

- **Encode CPM:** This sub-function shall construct the CPM according to the format specified in Annex A. The most recent abstract CP object information, sensor information and perception region information data shall be included in the CPM.
- **Decode CPM:** This sub-function shall decode the received CPM.
- **CPM transmission management:** This sub-function implements the protocol of the originating ITS-S including:
  - Activation and termination of CPM transmission operation.
  - Determination of the CPM generation event frequency.
  - Triggering the generation of the CPM.
- **CPM reception management:** This sub-function implements the protocol in the receiving ITS-S including:
  - Triggering the decoding of the CPM upon receiving an incoming CPM.

- Provisioning of the decoded CPM to the LDM and/or ITS applications of the receiving ITS-S.
- Optionally, checking the validity of the information of received CPMs.

NOTE: Details for checking the validity of received CPM information is provided in ETSI TR 103 460 [i.10].

Figure 2 shows the functional block diagram of the CPS and interfaces to other facilities and layers (clause 5.3).

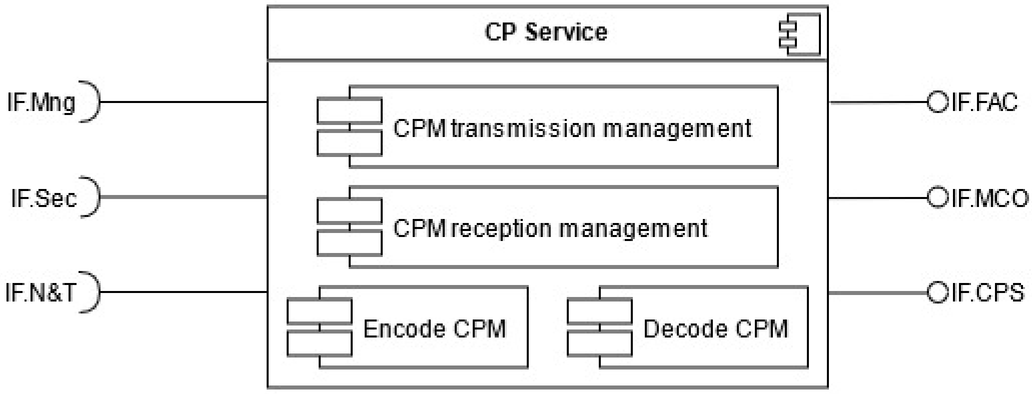

Figure 2: Functional block diagram of the CPS

5.3 Interfaces of the CPS

5.3.1 Interface to ITS applications

An ITS application is an application layer functionality that implements the logic for fulfilling one or more ITS use cases.

For the provision of received data, the CPS provides the interface IF.CPS to LDM or ITS application as illustrated in Figure 2.

5.3.2 Interface to data provisioning facilities

For the generation of CPMs, the CPS interacts with other Facilities layer entities to obtain the required data. This set of other facilities is referred to as data provisioning facilities, e.g. the ITS-S's POTI, DDP or LDM. Data is exchanged between the data provisioning facilities and the CP basic service via the interface IF.FAC.

NOTE: Specifications of the interface to the data provisioning facilities and the corresponding protocols are out of scope of the present document.

5.3.3 Interface to MCO_FAC

If the ITS-S supports MCO, the CPS shall exchange information with the MCO_FAC via the interface IF.MCO specified in ETSI TS 103 141 [7] and depicted in Figure 2. This interface can be used to configure the default MCO settings for the generated CPMs and can also be used to configure the MCO parameters on a per message basis.

If the ITS-S supports MCO, the CPS shall provide the CPM embedded in a Facility-layer Service Data Unit (FL-SDU) together with protocol control information (PCI) to the MCO_FAC. In addition, it can also provide MCO Control Information (MCI) following ETSI TS 103 141 [7] to configure the MCO parameters of the CPM being provided. At the receiving ITS-S, the MCO_FAC shall pass the received CPM to the CPS.

The data set that is passed between CPS and the MCO_FAC for the originating and receiving ITS-S is specified in Table 1.

Table 1: Data exchanged between the CPS and the MCO_FAC

Category	Data	Data requirement	Mandatory/Conditional /Optional
Data passed from the CPS to the MCO_FAC	CPM	*{cpm}* as specified in Annex A	Mandatory
	PCI	Depending on the protocol stack applied in the networking and transport layer as specified in Table 2	Optional
	MCI	MCO parameters configuration. Needed if the default MCO parameters have not been configured or want to be overwritten for a specific CPM	Conditional
Data passed from the MCO_FAC to the CPS	Received CPM	*{cpm}* as specified in Annex A	Mandatory

If the GeoNetworking/BTP stack is used and GeoNetworking is used as the network layer protocol, the PCI being passed from CPS to the GeoNetworking/BTP stack shall comply with Table 2.

Table 2: PCI from CPS to GeoNetworking/BTP at the originating ITS-S

Category	Data	Data requirement	Mandatory/Conditional /Optional
Data passed from the CPS to GeoNetworking/BTP	BTP type	BTP header type B ETSI TS 103 836-5-1 [6], (clause 7.2.2)	Conditional The data shall be passed if the value is not provided by the ITS-S configuration, e.g. defined in a Management Information Base (MIB) or if the value is different from the default value as set in the MIB.
	Destination port	As specified in ETSI TS 103 836-5-1 [6] (see note)	Conditional The data shall be passed if the value is not provided by the ITS-S configuration, e.g. defined in a Management Information Base (MIB) or if the value is different from the default value as set in the MIB.
	Destination port info	As specified in ETSI TS 103 836-5-1 [6]	Conditional The data shall be passed if the value is not provided by the ITS-S configuration, e.g. defined in a Management Information Base (MIB) or if the value is different from the default value as set in the MIB.
	GN Packet transport type	GeoNetworking SHB	Conditional The data shall be passed if the value is not provided by the ITS-S configuration, e.g. defined in a Management Information Base (MIB) or if the value is different from the default value as set in the MIB.
	GN Communication profile	Unspecified, ITS-G5 or LTE-V2X	Conditional The data shall be passed if the value is not provided by the ITS-S configuration, e.g. defined in a Management Information Base (MIB) or if the value is different from the default value as set in the MIB.
	GN Security profile	SECURED or UNSECURED	Conditional The data shall be passed if the value is not provided by the ITS-S configuration, e.g. defined in a Management Information Base (MIB) or if the value is different from the default value as set in the MIB.
	GN Traffic Class	As defined in ETSI TS 103 836-4-1 [5]	Mandatory

Category	Data	Data requirement	Mandatory/Conditional /Optional
	GN Maximum packet lifetime	Shall not exceed 1 000 ms	Mandatory
	Length	Length of the CPM	Mandatory
NOTE: When a global registration authority for ITS application as specified in ISO EN 17419 [i.5] is operational, the BTP destination port registered with this authority shall be used.			

5.3.4 Interface to the Networking & Transport layer

If the ITS-S does not support MCO, the CPS exchanges information with the ITS Networking & Transport Layer via the interface IF.N&T, as depicted in Figure 2.

At the originating ITS-S, the CPS shall provide the CPM embedded in a Facility-layer Service Data Unit (FL-SDU) together with protocol control information (PCI) to the ITS Networking & Transport Layer. At the receiving ITS-S, the ITS Networking & Transport Layer passes the received CPM to the CPS, if available.

The data set that shall be passed between CPS and the ITS Networking & Transport Layer for the originating and receiving ITS-S is specified in Table 3.

Table 3: Data passed between the CPS and the ITS Networking & Transport Layer

Category	Data	Data requirement	Mandatory/Conditional /Optional
Data passed from the CPS to the ITS Networking & Transport Layer	CPM	*{cpm}* as specified in Annex A	Mandatory
	PCI	Depending on the protocol stack applied in the networking and transport layer as specified in Table 2	Optional
Data passed from the ITS Networking & Transport Layer to the CPS	Received CPM	*{cpm}* as specified in Annex A	Mandatory

If the GeoNetworking/BTP stack is used and GeoNetworking is used as the network layer protocol, the PCI being passed from CPS to the GeoNetworking/BTP stack shall comply with Table 2.

5.3.5 Interface to the IPv6 stack and the combined IPv6/GeoNetworking stack

The CPS may use the IPv6 stack or the combined IPv6/GeoNetworking stack for CPM dissemination as specified in ETSI TS 103 836-3 [i.6].

NOTE 1: The specifications of the interface between the CPS and the IPv6 stack is out of scope of the present document.

NOTE 2: If IP-based transport is used to transfer the facility layer CPM between interconnected actors, security constraints as outlined in clause 6.2.1 may not be applicable. In this case trust enforcement among the participating actors, e.g. using mutual authentication, and authenticity of information can be based on other standard IT security methods, such as IPSec, DTLS, TLS or other VPN solutions that provide an end-to-end secure communication path between known actors.

NOTE 3: Security methods, sharing methods and other transport related information, such as messaging queuing protocols, transport layer protocol, ports to use, etc. can be agreed among interconnected actors.

When the CPM dissemination makes use of the combined IPv6/GeoNetworking stack, the interface between the CPS and the combined IPv6/GeoNetworking stack may be identical to the interface between the CPS and IPv6 stack.q

5.3.6 Interface to the ITS management entity

The CPS of an originating ITS-S obtains configuration parameters and other control information from the Management Information Base (MIB) located in the management entity via the IF.Mng interface, as depicted in Figure 2.

NOTE 1: A list of primitives exchanged with the management layer are provided in ETSI TS 102 723-5 [i.7].

NOTE 2: Specifications of IF.Mng and the corresponding protocol are out of scope of the present document.

5.3.7 Interface to the security entity

The CPS may exchange primitives with the Security entity of the ITS-S (see Figure 1) using the IF.SEC interface provided by the Security entity, as depicted in Figure 2.

In case the facility layer security is used, for ITS stations that use the trust model according to ETSI TS 102 940 [i.9] and ITS certificates according to ETSI TS 103 097 [1] and that are of type [Itss_WithPrivacy] as defined in ETSI TS 102 940 [i.9], the CPS shall interact with the ID management functionality of the Security entity to set the actual value of the ITS-S ID in the ITS PDU Header of the CPM. When the Security entity is triggering an Authorization Ticket change, the CPS shall change the value of the ITS-ID in the component *ItsPduHeader.stationId* accordingly and shall not send CPM messages with the previous ID anymore.

NOTE 1: Due to priority mechanisms implemented at MCO_FAC or at lower layers, the sending ITS-S may apply reordering of the messages contained in its buffer. Queued messages which are identified with the old ITS-ID are discarded as soon as a message with the new ITS-ID is sent. Implementers should be aware that whether or not messages previously queued prior to an ID change event get transmitted or not is implementation dependent.

NOTE 2: ITS stations of type [Itss_NoPrivacy] as defined in ETSI TS 102 940 [i.9] and ITS stations that do not use the trust model according to ETSI TS 102 940 [i.9] and ITS certificates according to ETSI TS 103 097 [1] do not need to implement functionality that changes ITS-S IDs (pseudonyms).

In order to avoid similarities between successive CPMs, all detected objects shall be reported as newly detected objects in the CPM following a pseudonym change. Additionally, the *SensorInformationContainer* may be omitted for a certain time as described in clause 6.1.2.2.

6 CPM dissemination

6.1 CPM generation

6.1.1 CPM generation management

The functional scheme of the CPM generation management is illustrated in Figure 3. for single channel operation and in Figure 4. for multi-channel operation. Its different entities related to the CPM data inclusion management and the CPM assembly are specified in clause 6.1.2 and clause 6.1.3, respectively. The CPM Generation Frequency and Content Management is specified in Annex D.

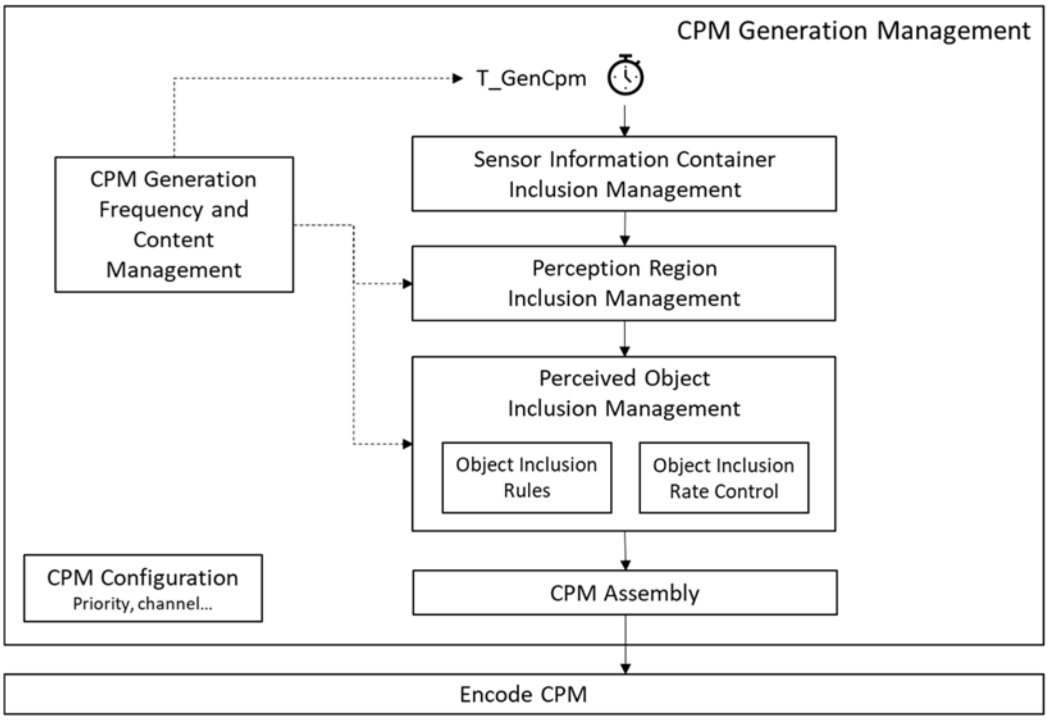

Figure 3: CPM generation management scheme: single channel operation

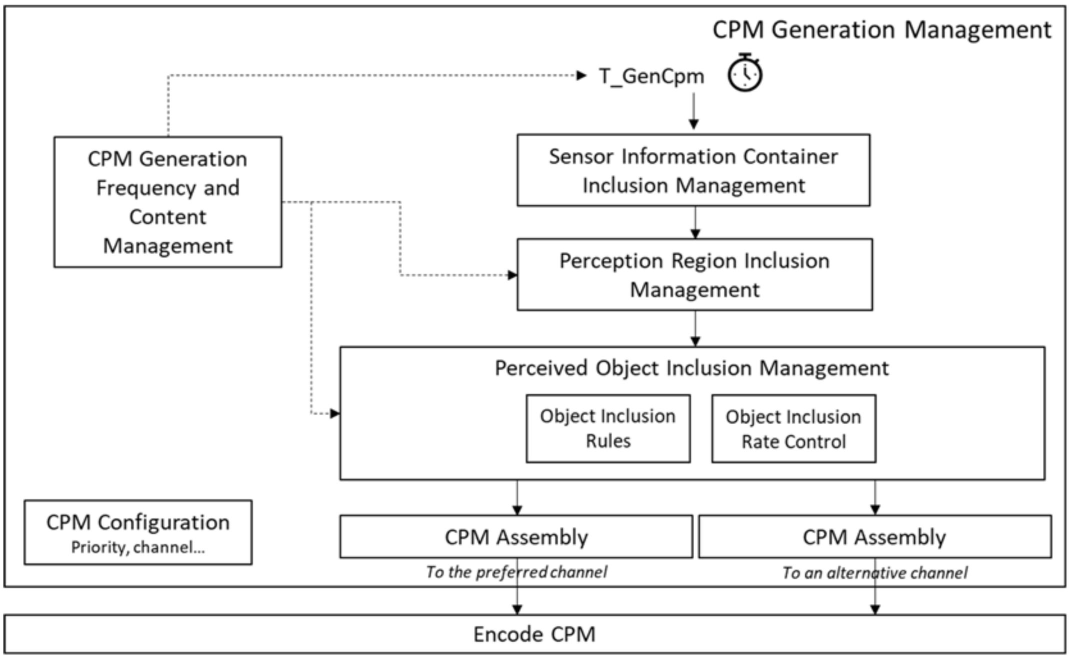

Figure 4: CPM generation management scheme: multi-channel operation

6.1.2 CPM data inclusion

6.1.2.1 CPM generation events

CPMs are generated during periodic CPM generation events. The time elapsed between the triggering of consecutive CPM generation events shall be equal to *T_GenCpm*. *T_GenCpm* is limited to *T_GenCpmMin* ≤ *T_GenCpm* ≤ *T_GenCpmMax*. During each generation event, the inclusion of the *SensorInformationContainer*, *PerceivedObject*, and *PerceptionRegion* shall be determined as defined in clause 6.1.2.2, clause 6.1.2.3 and clause 6.1.2.3, respectively. Based on these inclusion rules, each generation may result in the generation of none, one or a set of CPMs.

If the ITS-S supports MCO, *T_GenCpm* and the number of perceived objects and regions selected for inclusion during a generation event shall be managed to satisfy the maximum amount of channel resources *resources_limit* that can be consumed by the CPS provided by MCO_FAC, as specified in ETSI TS 103 141 [7], and following the process described in Annex D.

NOTE: Depending on its size, data selected for inclusion is assembled into complementary data segments, each representing an independently interpretable CPM, following the assembly process specified in clause 6.1.3.

6.1.2.2 Sensor Information Container Inclusion Management

A CPM shall include a *SensorInformationContainer* in the first generated CPM and whenever the time elapsed since the last time a CPM included a *SensorInformationContainer* is equal or greater than *T_AddSensorInformation*.Perception Region Inclusion Management.

A CPM shall include a perception region whenever the CPS detects relevant deviations of the available dynamic perception capabilities (*perceptionRegionShape*, *perceptionRegionConfidence*, *shadowingApplies*) with respect to the static perception capabilities described in the Sensor Information Container or previously included Perception Region Containers.

If two perception regions overlap and involve the same sensor (as described in the *sensorIdList* of the *PerceptionRegion*), the perception region added later to the *PerceptionRegionContainer* is referred to as dominating, i.e. it defines the perception region confidence and the *shadowingApplies* value of the intersection between the 2 regions. Additionally, perceived objects are only referenced in the component *perceivedObjectIds* in the most dominating region at the reference location of the object. The other region is called dominated.

To reduce the load on the communication channel:

- the number of *PerceptionRegion* instances in the Perception Region Container shall be limited to *MaxPerceptionRegions*;
- the amount of data contained in the Perception Region Container shall be limited, in order that the Sensor Information Container and the Perception Region Container may fit into one CPM.

6.1.2.3 Perceived Object Inclusion Management

A CPM shall include available information about perceived objects inside the *perceivedObjectContainer* using one instance of *PerceivedObject* per object in accordance with their type. The inclusion management depends on the CPS configuration, e.g. as a configuration stored in the MIB and listed in Annex F:

- If *ObjectInclusionConfig* is set to "0", no rules are defined in the present document. The sender decides based on its own rules about the inclusion of perceived objects.
- If *ObjectInclusionConfig* is set to "1", the inclusion rules defined in the present document shall apply.

The perceived object inclusion rules depend on the object type. Two object types are defined based on the object class with highest classification confidence:

- Type-A objects are objects of class vruSubclass with a VRU profile pedestrian, bicyclistAndLightVruVehicle or animal or class groupSubclass or otherSubclass.
- Type-B objects are objects of any class not included in Type-A (i.e. objects of class vehicleSubclass, or vruSubclass with a VRU profile motorcyclist).

NOTE 1: Both object types are introduced only for the readability of this clause and have no implications outside of the present document

An object whose object perception quality exceeds *ObjectPerceptionQualityThreshold* shall be selected for transmission from the object list as a result of the current CPM generation event if the object complies to any of the following conditions (all CPS configuration parameters and their recommended values can be found in Annex F):

1) If the object is of Type-A:

    a) The object has first been detected by the perception system after the last CPM generation event.

b) If the object list contains at least one object of Type-A which has not been included in a CPM for a time equal or larger than *T_GenCpmMax/*2, all objects of Type-A should be included in the currently generated CPM.

2) If the object is of Type-B:

a) The object has first been detected by the perception system after the last CPM generation event.

b) The Euclidean distance between the current estimated position of the reference point of the object and the estimated position of the reference point of this object lastly included in a CPM exceeds *minPositionChangeThreshold*.

c) The difference between the current estimated ground speed of the reference point of the object and the estimated absolute speed of the reference point of this object lastly included in a CPM exceeds *minGroundSpeedChangeThreshold*.

d) The orientation of the object's estimated ground velocity at its reference point has changed by at least *minGroundVelocityOrientationChangeThreshold* since the last inclusion of the object in a CPM.

e) The time elapsed since the last time the object was included in a CPM is equal or larger than T*_GenCpmMax*.

To reduce the number of generated messages, at each message generation event, objects belonging to Type-B that are to be included in a CPM in the next generation event (i.e. after *T_GenCpm)* may be included in the currently generated CPM. For this purpose, objects that are not selected for transmission in the currently generated CPM may be predicted to the next CPM generation event (i.e. after *T_GenCpm*), for example assuming a constant velocity model. Following this prediction, all objects that would then need to be included in a CPM in the next generation event may also be selected for inclusion in the currently generated CPM by including the latest available kinematic and attitude state. If applied, this mechanism may lead to generation events that do not result in the generation of CPMs.

If the ITS-S supports MCO, *T_GenCpm* and the amount of data generated per channel and generation event shall be adjusted by the CPS to satisfy the limits provided by MCO_FAC as defined in ETSI TS 103 141 [7]. To this end, perceived objects selected for transmission in the currently generated CPM that have the lowest Value of Information (VoI) should be omitted.

NOTE 2: Annex E describes possible methods to compute the VoI.

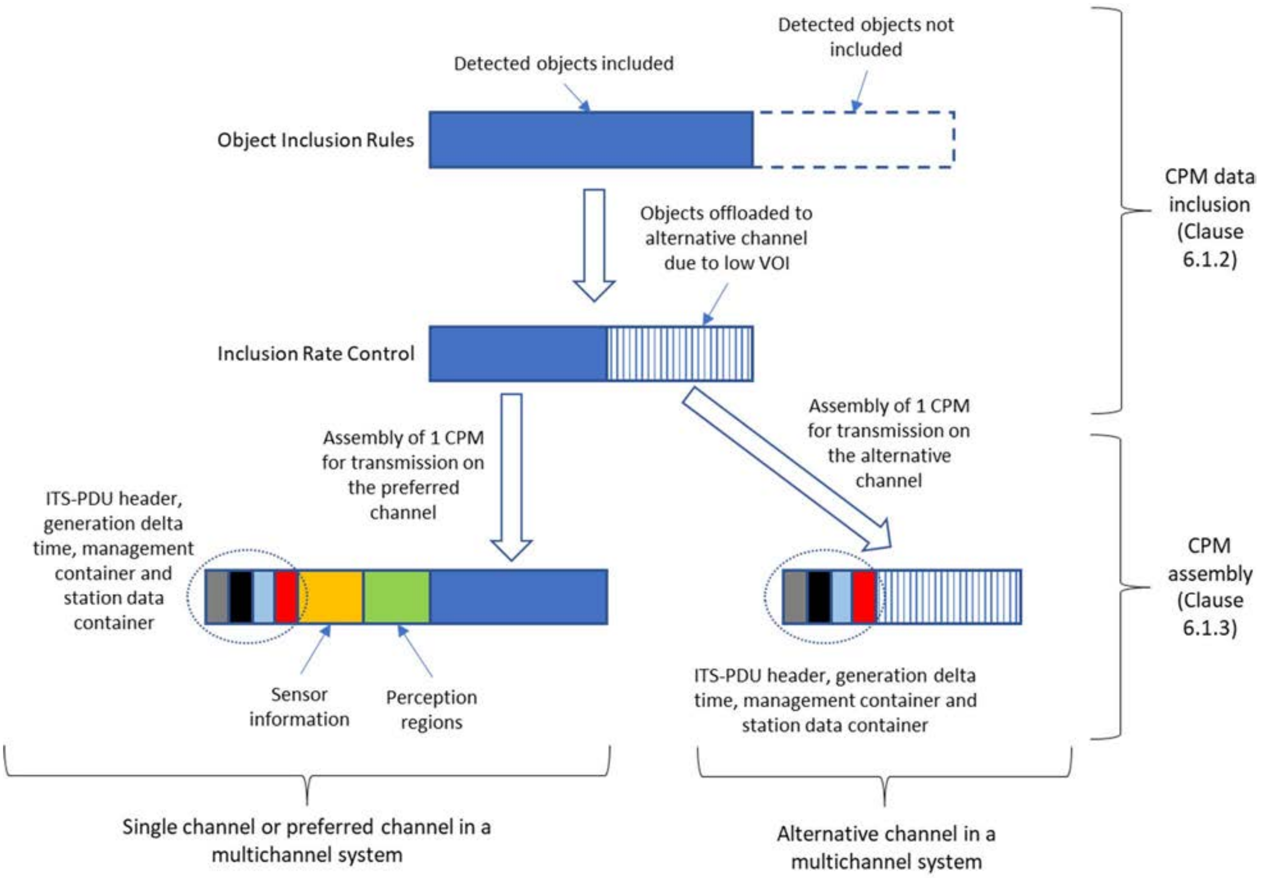

Figure 5: CPM generation management (data selection and assembly) if the ITS-S supports MCO

If the ITS-S supports MCO, when objects are omitted from the currently generated CPM due to low VoI, one or more additional CPMs can be generated for transmission on alternative channels. To this aim, the VoI is used to rank the objects and select the alternative channel where each of them can be included in a CPM, taking into account the limits provided by MCO_FAC. The VoI of an object to be transmitted on a channel shall depend only on data transmitted or received on channels of higher or equal priority than the channel where the object is to be transmitted.

6.1.3 CPM assembly

6.1.3.1 General

The size of an ASN.1 UPER encoded CPM shall not exceed MTU_CPM, i.e. the MTU_CPM depends on the MTU of the access layer technology (MTU_AL) over which the CPM is transported. If multiple channels are available and, e.g. the ITS-S supports MCO, these restrictions shall apply to each channel individually.

MTU_CPM shall be less than or equal to MTU_AL reduced by the header size of the facilities layer protocol (HD_CPM) and the header size of the networking and transport layer protocol (HD_NT) with MTU_CPM ≤ MTU_AL - HD_CPM - HD_NT.

CPM assembly shall be performed taking these size constraints into account by following one of the following configuration-specific assembly mechanisms:

- If the configuration parameter *MessageAssemblyConfig* is set to "0", the CPM assembly shall be performed based on an object utility function following clause 6.1.3.2.
- If the configuration parameter *MessageAssemblyConfig* is set to "1", the CPM assembly shall be performed based on the perception regions selected for inclusion following clause 6.1.3.3.

All assembled CPMs shall indicate the same *referenceTime*.

NOTE: CPMs should be transmitted in the same order in which they have been generated. This is to ensure that CPMs containing information of higher priority are not deferred in favour of CPMs containing information of lower priority by lower layer mechanisms.

6.1.3.2 Object utility function

If the *SensorInformationContainer* or the *PerceptionRegions* need to be transmitted, they shall be added to the first CPM generated for transmission on the preferred CPM channel.

Perceived objects selected for transmission shall be included in CPMs in a descending priority order following a per-object utility function defined as the sum of the following parameters:

- **Object perception quality:**

  The priority contribution of the object perception quality shall be determined as:

$$\mathrm{p_{qual}} = \begin{cases} 0 & \text{if } objectPerceptionQuality \text{ is unknown or unavailable} \\ objectPerceptionQuality/15 & \text{else} \end{cases}$$

  where the computation of the parameter $objectPerceptionQuality$ is defined in clause 7.1.8.6.

- **Object position change:**

  The priority contribution of the object position change shall be determined as follows:

$$\mathrm{p_{pos}} = \begin{cases} 0 & \Delta p \leq \Delta p_{min} \\ \dfrac{\Delta p - \Delta p_{min}}{\Delta p_{max} - \Delta p_{min}} & \Delta p_{min} < \Delta p < \Delta p_{max} \\ 1 & \Delta p_{max} \leq \Delta p \end{cases}$$

  where Δp corresponds to the Euclidean distance between the current estimated position of the reference point of the object and the estimated position of the reference point of this object lastly included in a CPM by the disseminating ITS-S. The parameters $minPositionChangePriorityThreshold\ \Delta p_{min}$ and $maxPositionChangePriorityThreshold\ \Delta p_{max}$ are defined in Annex F.

- **Object speed change:**

  The priority contribution of the object speed change shall be determined as follows:

$$\mathrm{p_{speed}} = \begin{cases} 0 & \Delta v \leq \Delta v_{min} \\ \dfrac{\Delta v - \Delta v_{min}}{\Delta v_{max} - \Delta v_{min}} & \Delta v_{min} < \Delta v < \Delta v_{max} \\ 1 & \Delta v_{max} \leq \Delta v \end{cases}$$

  where Δv corresponds to the difference between the current estimated ground speed of the reference point of the object and the estimated absolute speed of the reference point of this object lastly included in a CPM by the disseminating ITS-S. The parameters $minGroundSpeedChangePriorityThreshold\ \Delta v_{min}$ and $maxGroundSpeedChangePriorityThreshold\ \Delta v_{max}$ are defined in Annex F.

- **Object orientation change:**

  The priority contribution of the object orientation change shall be determined as follows:

$$\mathrm{p_{orient}} = \begin{cases} 0 & \Delta\theta_z \leq \Delta\theta^z_{min} \\ \dfrac{\Delta\theta_z - \Delta\theta^z_{min}}{\Delta\theta^z_{max} - \Delta\theta^z_{min}} & \Delta\theta^z_{min} < \Delta\theta_z < \Delta\theta^z_{max} \\ 1 & \Delta\theta^z_{max} \leq \Delta\theta_z \end{cases}$$

  where $\Delta\theta_z$ corresponds to the difference between the orientation of the vector of the current estimated ground velocity of the reference point of the object and the estimated orientation of the vector of the ground velocity of the reference point of this object lastly included in a CPM by the disseminating ITS-S. The parameters $minGroundVelocityOrientationChangePriorityThreshold\ \Delta\theta^z_{min}$ and $maxGroundSpeedChangePriorityThreshold\ \Delta\theta^z_{max}$ are defined in Annex F.

- **Object last inclusion time:**

  The priority contribution of the object last inclusion time shall be determined as follows:

$$\mathrm{p_{time}} = \begin{cases} 0 & \Delta\tau \leq \Delta\tau_{min} \\ \dfrac{\Delta\tau - \Delta\tau_{min}}{\Delta\tau_{max} - \Delta\tau_{min}} & \Delta\tau_{min} < \Delta\tau < \Delta\tau_{max} \\ 1 & \Delta\tau_{max} \leq \Delta\tau \end{cases}$$

  where $\Delta\tau$ corresponds to the time elapsed since the last time the object was included in a CPM by the disseminating ITS-S. The parameters $minLastInclusionTimePriorityThreshold\ \Delta\tau_{min}$ and $maxLastInclusionTimePriorityThreshold\ \Delta\tau_{max}$ are defined in Annex F.

A CPM should be populated with selected objects as long as the resulting ASN.1 UPER encoded message size of the CPM to be assembled does not exceed MTU_CPM. CPMs are assembled in this fashion until all perceived objects selected for transmission are included in a CPM. Each CPM is made available to the corresponding entities of the protocol stack for transmission.

NOTE: All generated CPMs can be made available over the interface to the Networking and Transport layer or, if the ITS-S supports MCO, over the MCO_FAC interface.

6.1.3.3 Perception region based

In case the *SensorInformationContainer* also needs to be transmitted, it shall be added to the first CPM transmitted on the preferred CPM channel. In case only one channel is available the preferred CPM channel corresponds to this channel.

Every set of overlapping perception region and the objects selected for inclusion contained within these regions shall be included into the same CPM. If the MTU_CPM does not allow to transmit this set of information in the same CPM, the regions shall be divided into smaller regions, so that each separate region and the corresponding perceived objects contained within them fit into one CPM.

As long as the resulting ASN.1 UPER encoded CPM to be generated does not exceed MTU_CPM a CPM should be populated in arbitrary order with:

- perception regions and the corresponding perceived objects selected for transmission within these regions in the same CPM;
- perceived objects that are not contained in any of the transmitted perception regions. These perceived objects shall be added in the order as defined in clause 6.1.3.2, and may be spread over several assembled CPMs.

CPMs are generated in this fashion until all perception regions and objects selected for transmission are included in a CPM. Each CPM is made available to the corresponding entities of the protocol stack for transmission.

NOTE: All generated CPMs can be made available over the interface to the Networking and Transport layer or, if the ITS-S supports MCO, over the MCO_FAC interface.

6.2 CPM dissemination constraints

6.2.1 Security constraints

6.2.1.1 Introduction

Clause 6.2.1 is applicable to ITS stations that use the trust model according to ETSI TS 102 940 [i.9] and ITS certificates according to ETSI TS 103 097 [1].

NOTE: For other scenarios, the trust model and the mechanisms for trust enforcement for inter-connected ITS stations can be agreed among participating actors.

The security mechanisms for ITS consider the authentication of messages transferred between ITS-Ss with certificates. A certificate indicates its holder's permissions to send a certain set of messages and optional privileges for specific data elements within these messages. The format for the certificates is specified in ETSI TS 103 097 [1].

Within the certificate, the permissions and privileges are indicated by an identifier (the ITS-AID) and optional attributes of a given AID, allowing for definition of different levels of permissions/ rights (the SSP).

The ITS-Application Identifier (ITS-AID) as given in ETSI TR 102 965 [i.8] indicates the overall type of permissions being granted. For example, there is an ITS-AID indicating that the sender is entitled to send CPMs.
The Service Specific Permissions (SSP) is a field that indicates specific sets of permissions within the overall permissions indicated by the ITS-AID: for example, there may be an SSP value associated with the ITS-AID for CPM that indicates that the sender is entitled to send CPMs for a specific role.

The following security objectives and required security services are identified:

- For establishing CPM secure communications, the Message Signature service as specified in ETSI TS 103 097 [1] shall be supported by ITS-S sending/receiving CPM.
- A CPM shall be accepted by a receiving ITS-S if it is consistent with the ITS-AID and SSP of the signing certificate (authorization ticket).
- Signed message shall use the ITS-AID as specified in ETSI TR 102 965 [i.8].

6.2.1.2 Service Specific Permissions (SSP)

CPMs shall be signed using private keys associated to Authorization Tickets that contain SSPs of type BitmapSsp as specified in ETSI TS 103 097 [1].

The SSP for the CPM shall be of CHOICE BitmapSsp. It is defined by a variable number of octets and shall correspond to the octet scheme illustrated in Figure 6. This octet scheme allows the SSP format to accommodate current and future versions of the present document.

0							
0	1	2	3	4	5	6	7
Octet 0							

Figure 6: Format for SSP Octet Scheme (BitmapSsp)

The SSP has a maximum length as specified in ETSI TS 103 097 [1]. The first octet shall reflect the version of the SSP (see Table 4). In the current version of the present document, the SSP field contains only the SSP version byte.

Table 4: Octet Scheme for CPM SSPs

Octet #	Description	Value
0	SSP version control	1

At reception of a message, the ITS-S shall check whether the message content is consistent with the ITS-AID and SSP contained in the Authorization Ticket in its signature. If the consistency check fails, the message shall be discarded.

6.2.2 General priority constraints

If the GeoNetworking/BTP stack is used, the priority constraint shall be as given by the Traffic Class as specified in ETSI TS 103 836-4-1 [5].

7 CPM Specification

7.1 CPM structure

7.1.1 General structure of a CPM PDU

A CPM is a PDU composed of one common ITS PDU header and multiple containers, which together constitute the CPM payload.

The general structure of a CPM is illustrated in Figure 7.

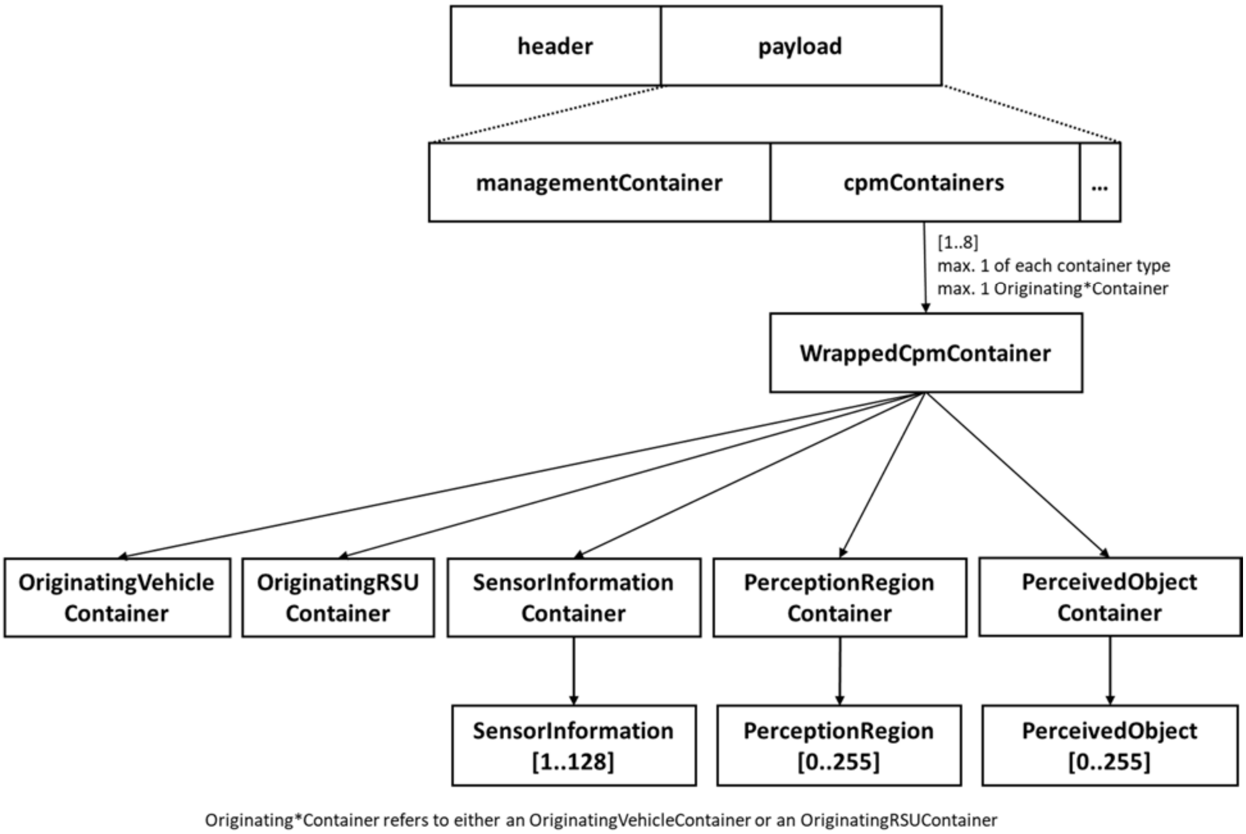

Figure 7: General Structure of a CPM

The component *header* is a common header for facility layer PDUs.

The component *payload* represents the CPM payload and consists of two components: the component *managementContainer* containing the Management Container and the component *cpmContainers* containing the other CPM containers wrapped in a structure called *WrappedCpmContainer* that includes the type identifier of the container and the container data itself.

The Management Container provides basic information which is necessary to process the other information in the CPM. To allow for simplified future extensibility of the CPM, 1 to 8 further CPM containers of type *OriginatingVehicleContainer* (clause 7.1.4), *OriginatingRsuContainer* (clause 7.1.5), *SensorInformationContainer* (clause 7.1.6), *PerceptionRegionContainer* (clause 7.1.7), or *PerceivedObjectContainer* (clause 7.1.8) may be included in the component *cpmContainers* (wrapped in *WrappedCpmContainer*, as shown in Figure 7) as follows:

In case of a CPM generated by a vehicle ITS-S, one Originating Vehicle Container of type *OriginatingVehicleContainer* shall be present and contain information regarding the orientation of the vehicle and possible trailers attached to it.

In case of a CPM generated by a roadside ITS-S, one Originating RSU Container of type *OriginatingRsuContainer* shall be present.

A CPM shall contain only one container describing the disseminating ITS-S: in the present document either the Originating Vehicle Container or the Originating RSU Container. In future versions of the present document other additional originating containers may be specified.

One Sensor Information Container of type *SensorInformationContainer* may be present to provide information about the sensory capabilities that are available to an ITS-S. The Sensor Information Container shall be included as defined in clause 6.1.2.2.

One Perception Region Container of type *PerceptionRegionContainer* may be present to describe deviations from the sensing capabilities described in the Sensor Information Container. Perception regions shall be selected for inclusion in a Perception Region Container as defined in clause 6.1.2.3.

One Perceived Object Container of type *PerceivedObjectContainer* shall be present to provide information about objects that have been perceived through the sensory capabilities. Perceived objects shall be selected for inclusion in a Perceived Object Container as defined in clause 6.1.2.4.

Each container is composed of a sequence of components, their component type being either a Data Element (DE) or a Data Frame (DF). A component is either optional or mandatory in the CPM Format. If not specified as optional in the ASN.1 specification of the present document, a component is considered as mandatory.

7.1.2 ITS PDU Header

The ITS PDU Header is a common header that includes the information of the protocol version, the message type and the ITS-S ID of the originating ITS-S.

The ITS PDU header shall be included as specified in ETSI TS 102 894-2 [3]. Detailed data presentation rules of the ITS PDU header in the context of a CPM shall be as specified in Annex A.

7.1.3 Management Container

The management container shall include the components *referenceTime* and *referencePosition*.

For vehicle ITS-Ss, the reference position shall refer to the ground position of the centre of the front of the bounding box of the vehicle. The vehicle reference position is further detailed in ETSI EN 302 890-2 [4]. This position is used to determine the offset to other data points.

In case of roadside ITS-S disseminating the CPM, the reference position shall be chosen by the disseminating ITS-S.

The management container shall include information about the data segment contained in the CPM as part of the component *messageSegmentInfo*, if more than one CPM is assembled from the data selected for transmission, as specified in clause 6.1.3.

The management container may further include information about the planned or expected message rate as part of the component *messageRateRange*.

7.1.4 Originating Vehicle Container

The Originating Vehicle Container shall include the component *orientationAngle*. The vehicle orientation angle represents the actual orientation of the vehicle opposed to the vehicle heading which references the orientation of the provided velocity vector magnitude only, as depicted in Figure 8 and as defined in ETSI EN 302 890-2 [4]. Such information is required to interpret the data contained in the Sensor Information Container.

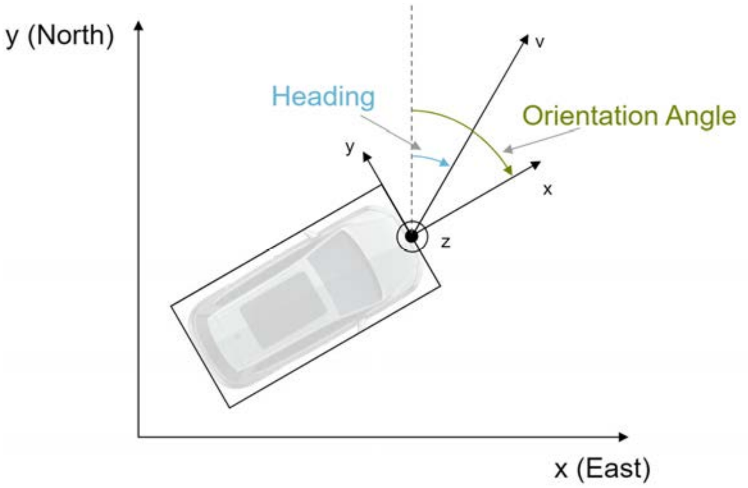

Figure 8: Vehicle Orientation Angle

The Originating Vehicle Container may include the components *pitchAngle* and *rollAngle*. If *pitchAngle* and *rollAngle* are not included, they are assumed to be zero.

The Originating Vehicle Container shall include the component *trailerData* if some of the sensors that provide data to the CPS are mounted on a trailer.

The component *trailerDataSet* shall include an instance of *TrailerData* for each trailer up to the last trailer on which sensors are mounted that provide data to the CPS. Figure 9 depicts several possible layouts.

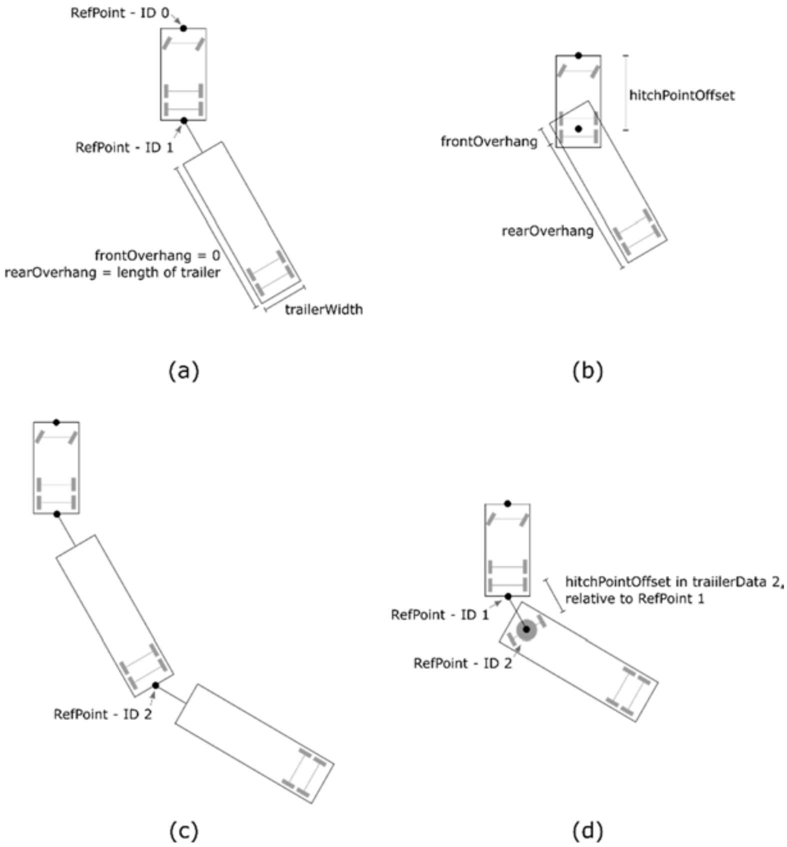

Figure 9: Describing the setup of trailers attached to a towing vehicle in the CPM

Each *TrailerData* instance shall include in the component *refPointId* a new reference point ID, incrementing from 1. The reference point ID 0 shall refer to the reference point of the towing vehicle. More configurations for providing reference points for ITS-S can be found in ETSI EN 302 890-2 [4].

Each *TrailerData* instance shall include the component *hitchPointOffset* and shall include the component *hitchAngle*.

TrailerData instance shall not include the components *frontOverhang*, *rearOverhang*, *trailerWidth*.

7.1.5 Originating RSU Container

The Originating RSU Container may contain the component *mapReference* if a corresponding MAPEM [i.13] is being transmitted to ITS-S that receive the CPM, otherwise the component *mapReference* shall be omitted.

If *mapReference* is used, either the *IntersectionReferenceID* or the *RoadSegmentID* component of the component *mapReference* may be used to refer to the road infrastructure information provided by the road lane topology service.

7.1.6 Sensor Information Container

The Sensor Information Container shall list information about individual sensors or sensor systems which originated the perceived object information using the type *SensorInformation*.

SensorInformation shall include the component *sensorId*. This identifier is in turn utilized in the *PerceivedObjectContainer* to connect information about an object to the sensor that provided that information. After a pseudonym change the current *sensorId* of all *SensorInformation* may be replaced by a new *sensorId* randomly selected among identifiers which were not used for *UnusedSensorIdRetentionPeriod*.

SensorInformation shall include the component *sensorType*.

SensorInformation shall include the component *perceptionRegionShape* except for sensors with *type* value: *undefined (0)*, *localAggregation* (12), *itssAggregation* (13). For these values of *sensorType*, *perceptionRegionShape* may be included.

The sensor perception region shape is specified as a geographical area or volume with respect to the reference position. For vehicle sensors, it shall be expressed in the body-fixed coordinate system of the vehicle. Figure 10 illustrates two possible perception regions of vehicle sensors.

NOTE: This definition of the vehicle sensor perception region coordinate system overwrites the definition of ETSI TS 102 894-2 [3], which defines the components of the DF *Shape* in an East-North-Up coordinate system.

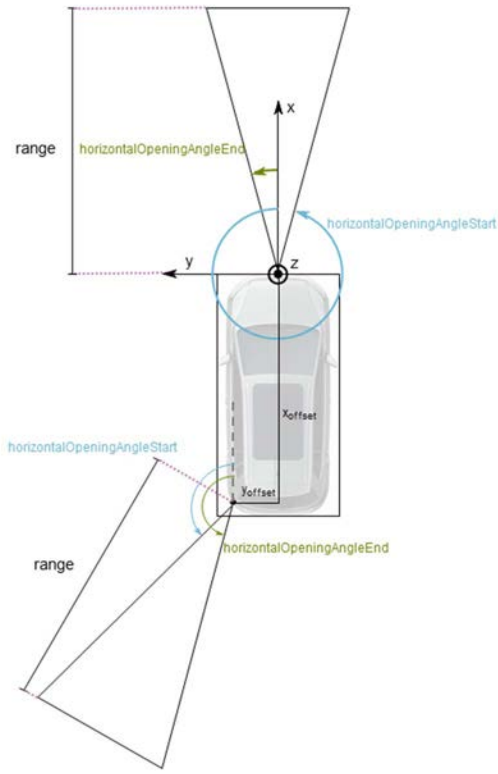

Figure 10: Exemplary perception regions of vehicle sensors

For infrastructure sensors, the perception region is expressed in the East-North-Up coordinate system, as shown in Figure 11.

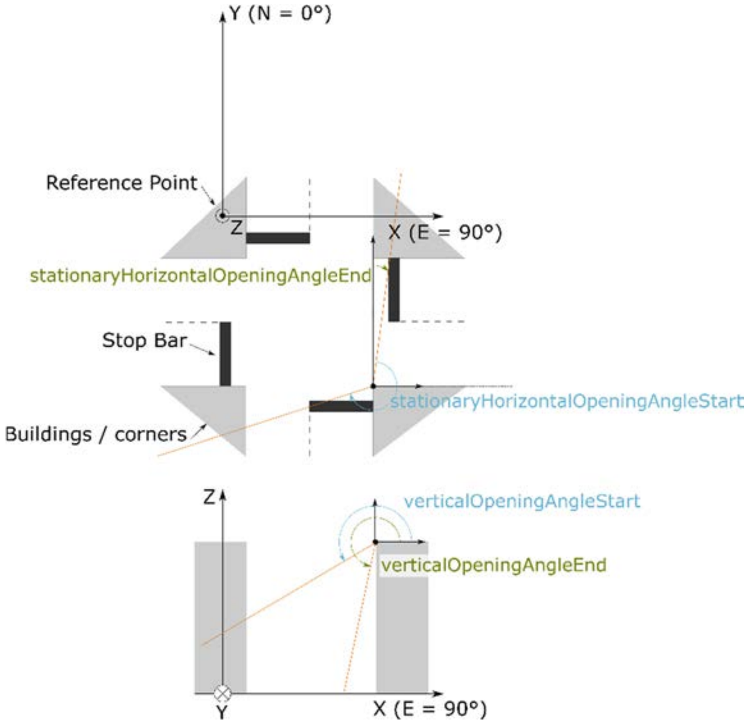

Figure 11: Exemplary perception regions of infrastructure sensors

SensorInformation shall include the component *shadowingApplies* to indicate the application of the shadowing mechanism within the given *perceptionRegionShape*. If the *perceptionRegionConfidence* provided in *SensorInformation* is not valid for shadowed regions in the given *perceptionRegionShape*, *shadowingApplies* shall be set to "True" for this *SensorInformation*. If the *perceptionRegionConfidence* provided in *SensorInformation* is also valid for shadowed regions in the given *perceptionRegionShape*, *shadowingApplies* shall be set to "False" for this *SensorInformation*.

The component *perceptionRegionConfidence* describes the sender's confidence level for correctly detecting objects and unoccupied subregions present in a perception region. If present, the component *perceptionRegionConfidence* shall indicate the corresponding confidence as specified in clause 7.1.7.

The received geometric extension of a *PerceivedObject* can be used by a CPM receiver to compute the resulting shadowed regions for each object and sensor. For this purpose, a simple ray tracing approach can be utilized. A ray thereby connects from the origin of a particular sensor (indicated by the component *shapeReferencePoint* of *perceptionRegionShape*) to the outermost corner-points of the received object geometry and extends to the perception range of a particular sensor. The region behind the object from the perspective of the sensor mounting point is considered as shadowed, as visualized in Figure 12. The handling of shadowed regions can be evaluated as described by the component *shadowingApplies* to determine, if the specified *perceptionRegionConfidence* also applies to the shadowed region or if there may be occluded and undetected objects. A description in three dimensions may be applied, as depicted in Figure 12. In case an object is detected by a sensor with a certain height above ground (e.g. a signage gantry), the same ray tracing approach should be employed for a three-dimensional representation.

NOTE: Not all objects known to a transmitter are reported in every CPM. The receiver therefore has to ensure that suitable tracking and prediction mechanisms for previously transmitted objects are employed to update the shadowed region accordingly.

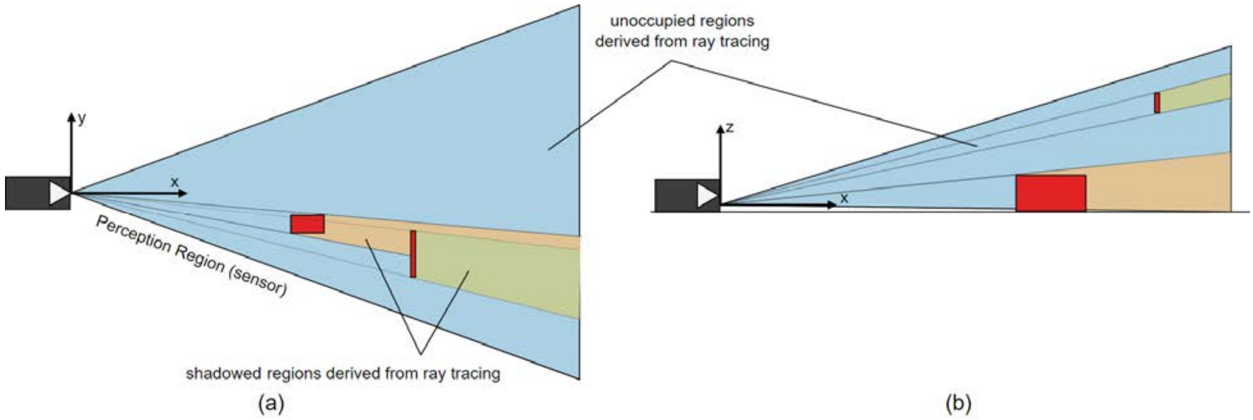

Figure 12: Three-dimensional representation of the derived shadowed and unoccupied regions

The perception capabilities specified in the *SensorInformation* (i.e. *perceptionRegionShape*, *perceptionRegionConfidence*, *shadowingApplies*) can be detailed or overruled using *PerceptionRegion* as defined in clause 7.1.7.

7.1.7 Perception Region Container

A Perception Region Container shall list information about perception regions using the type *PerceptionRegion.*

PerceptionRegion shall include the components *measurementDeltaTime*, *perceptionRegionConfidence* and *perceptionRegionShape* for a specific perception region.

A *PerceptionRegion* can be used to indicate a *perceptionRegionConfidence* different from the *perceptionRegionConfidence* given in the *SensorInformation*, or to mark regions where the shadowing model (detailed in clause 7.1.6) does not apply for a particular object (e.g. in case of a radar sensor measuring two vehicles driving behind each other).

The component *perceptionRegionShape* shall be specified as a geographical area or volume with respect to the reference position (in case of a vehicle ITS-S disseminating the CPM) or a reference point (in case of a roadside ITS-S disseminating the CPM) in the East-North-Up coordinate system.

Additionally, a *PerceptionRegion* can be used to divide the perception region of a sensor into smaller parts, e.g. in case more than one CPM needs to be assembled (clause 6.1.3).

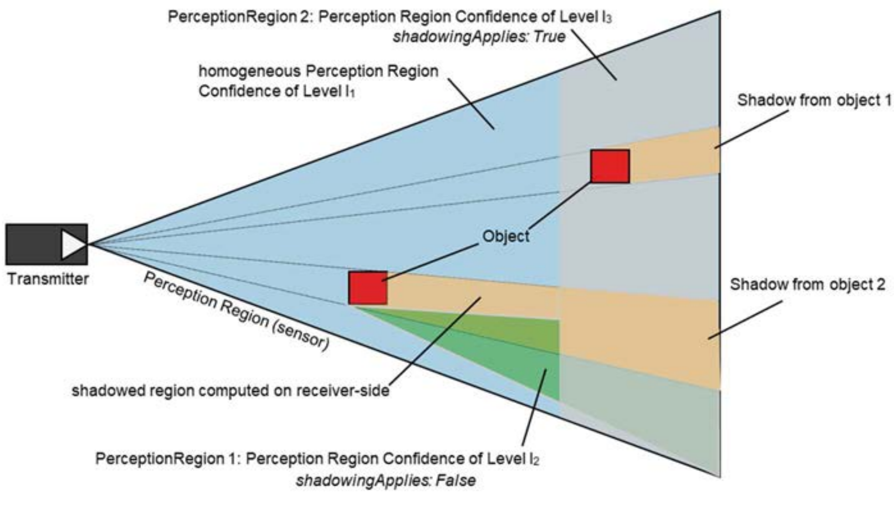

Figure 13: Perception Region to indicate different levels of perception region confidence

Figure 13 depicts two possible applications of the *PerceptionRegion*: The homogeneous perception region confidence provided in the *SensorInformation* of level l_1 does not apply to the entire perception region of the sensor. Instead, part of the computed shadowed region behind one of the objects has a different perception region confidence of level l_2 (e.g. as a result of sensor fusion processes). This region is described by providing a *perceptionRegionShape* as part of the *PerceptionRegion* 1. Additionally, the sensor system can provide a perception region confidence indication for a confined region within its sensor's *perceptionRegionShape*. A different perception region confidence level l_3 applies to the depicted grey region, expressed as an additional *PerceptionRegion.*

PerceptionRegion shall include the component *shadowingApplies* to indicate the application of the shadowing mechanism within the given *perceptionRegionShape*. The *shadowingApplies* applies for the *PerceptionRegion* as stated in clause 7.1.6 for the *SensorInformation*.

PerceptionRegion may include the component *sensorIdList*. If present, *sensorIdList* shall list the values of the component *sensorId* of the sensors described in the *SensorInformation* which are involved in perceiving the region.

PerceptionRegion may include the component *numberOfPerceivedObjects*. If present, *numberOfPerceivedObjects* shall contain the number of all currently perceived objects in the *PerceptionRegion*.

PerceptionRegion may include the component *perceivedObjectIds*. If present, *perceivedObjectIds* shall list the values of the component *objectId* of all perceived objects that are contained in *PerceptionRegionShape* that are not dominated by any other *PerceptionRegion*. Thus, each *objectId* is contained in at most one *PerceptionRegion*, while the value of *numberOfPerceivedObjects* may be higher than the number of elements in *perceivedObjectIds*.

7.1.8 Perceived Object Container

7.1.8.1 General

The Perceived Object Container shall include the component *numberOfPerceivedObjects*, describing the total number of perceived objects contained in the LDM at the time of generating the CPM. Due to the message generation rules as specified in clause 6.1.1 and the associated object inclusion scheme, the number of included objects does not have to equal the value of *numberOfPerceivedObjects*.

NOTE: In this context a VRU group or cluster generated as specified in clause 7.1.8.7 increases *numberOfPerceivedObjects* by 1 and not by the number of objects it contains, i.e. by the *clusterCardinalitySize*.

The Perceived Object Container shall include the component *perceivedObjects* to provide information about detected objects selected for transmission as defined in clause 6.1.2.3, using the type *PerceivedObject* constrained to have the component *objectId* always present.

In case of a vehicle ITS-S disseminating the CPM, an East-North-Up coordinate system centred around the vehicle reference position $(\varphi_{Ref}, \lambda_{Ref})$ shall be used for the description of the perceived object's state variables, as depicted in Figure 14.

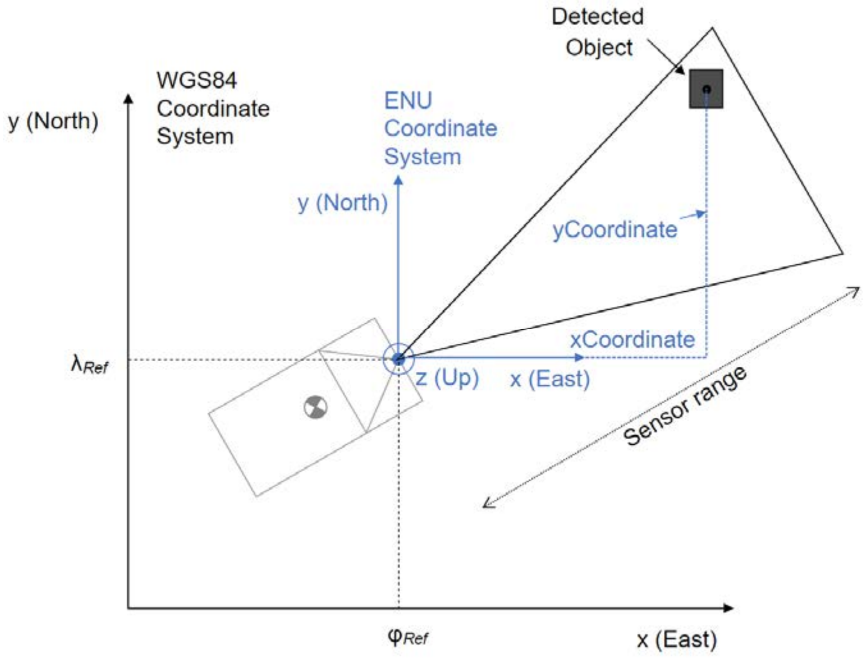

Figure 14: Coordinate system for detected objects given a disseminating vehicle ITS-S

In case of a roadside ITS-S disseminating the CPM, an East-North-Up coordinate system centred around a reference point shall be used for the description of the perceived object's state variables.

For state variables in polar coordinates, angles shall be expressed with positive values turning around the z-axis using the right-hand rule, starting from the x-axis.

The Perceived Object Container shall be encoded as specified in Annex A. More specifically, the rules following subclauses shall apply.

7.1.8.2 Object ID and time management

An *objectID* shall be assigned to each detected object. This ID is taken from a range of allowed numbers and is maintained per object, as long as an object is perceived and new sensor measurements are assigned to the object and there is no pseudonym change. The range of allowed *objectIDs* is between 0 and 65535. A new object shall be randomly assigned an available ID within the allowed range. IDs not used for *UnusedObjectIdRetentionPeriod* become available again. After a pseudonym change, the current object identifiers of all objects shall be replaced by new object identifiers randomly selected among identifiers which were not used for *UnusedObjectIdRetentionPeriod*.

A measurement delta time shall be provided for each object as the time difference for the provided measurement information with respect to the reference time of type *TimestampIts* stated in the Management Container. Figure 15 illustrates the *measurementDeltaTime* which describes the time associated to the given object state space of an object and is relative to the *referenceTime* encoded in the message. The measurement delta time shall therefore include any processing time of a sensor or data fusion system. In case the fused object state information is transmitted, the time of measurement shall reference the point in time to which the state space has been predicted.

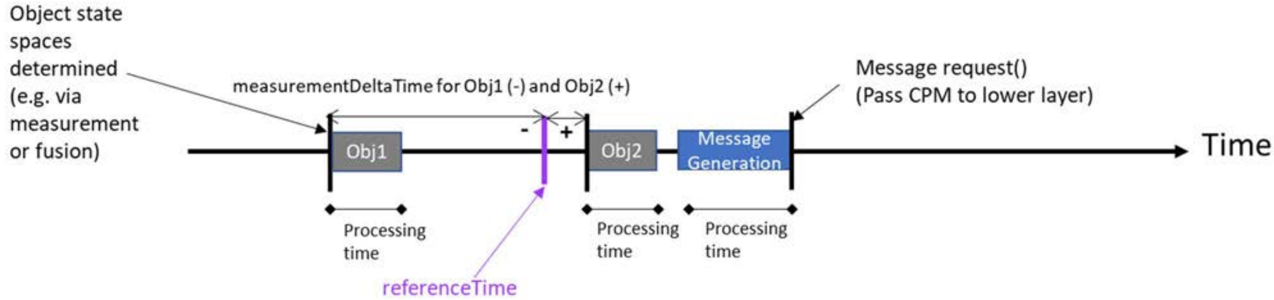

Figure 15: Transmitter-side for computing Time of Measurement

7.1.8.3 Kinematic and attitude state description

The full kinematic and attitude state of an object can be represented in a 13-dimensional kinematic and attitude space. The corresponding state vector can be written as:

$$\text{state}_{\text{Obj}} = \left(p_x, p_y, p_z, v_m, v_d, v_x, v_y, v_z, a_m, a_d, a_x, a_y, a_z, \theta_z, \theta_y, \theta_x, \omega_z,\right)^T$$

with p_i, v_i, a_i representing the position, velocity and acceleration components and θ_i, ω_i representing Euler angles and angular speed components. Note that, v_m, v_d (polar planar speed magnitude and direction) and v_x, v_y (cartesian planar speed) are mutually exclusive. The same applies to acceleration. Hence, the kinematic state is at most 13 dimensional.

PerceivedObject shall include at least the position components, i.e. the coordinates of the object using the component *position*.

PerceivedObject may include the component *velocity* appropriately configured to represent the polar or cartesian components of the velocity relative to ground, optionally including the z component.

PerceivedObject may include the component *acceleration* appropriately configured to represent the polar or cartesian components of the acceleration relative to ground, optionally including the z component.

PerceivedObject may include the component *angles* appropriately configured to represent at least the z-angle and optionally the y-angle and x-angle of the bounding box of the perceived object.

PerceivedObject may include the component *CartesianAngularVelocityComponent* representing the angular velocity around the z-axis.

For every component provided in the kinematic state and attitude space of an object in the CPM the corresponding confidence value shall be provided to a confidence level of 95 %.

PerceivedObject may include up to 4 *LowerTriangularPositiveSemidefiniteMatrix* as part of the component *lowerTriangularCorrelationMatrices*. Each *LowerTriangularPositiveSemidefiniteMatrix* contains *componentsIncludedIntheMatrix* describing the components of the kinematic and attitude state being part of this correlation matrix.

Correlations are represented in a vectorised form for each column of the corresponding lower-triangular positive semidefinite correlation matrix as described in Annex C. The rows and columns are ordered as stated in *componentsIncludedIntheMatrix*.

The correlation is mathematically symmetric i.e. corr(x,y)=corr(y,x) for any two given random variables. Therefore, every component of the kinematic and attitude state shall only provide the correlation information with the remaining, subsequent components.

If n components are indicated in *componentsIncludedIntheMatrix*, then the matrix has k=n-1 columns and each column i (with i=1..k) has k-i+1 entries.

7.1.8.4 Object dimensions and age

One or more of the components *objectDimensionX*, *objectDimensionY*, *objectDimensionZ* may be included for each object, indicating the size of the bounding box of the perceived object in each direction.

The component *objectAge* may be included for each perceived object. If present, the *objectAge* shall reflect the time the object is already known to the transmitting ITS-S at the time of message generation.

7.1.8.5 Link to Sensor Information Container

The component sensorIdList may be included. If present, it shall contain a list of *SensorInformation.sensorId* values from the Sensor Information Container, corresponding to sensors that provided the measurement data.

7.1.8.6 Object perception quality

A scalar-value indication about the overall information quality on a perceived object may be provided in the component *objectPerceptionQuality*.

The object characteristics contributing to the perception quality of an object first detected at time t=0, where t represents discrete time instants, are defined based on [i.4]:

1) Object age oa in milliseconds.

2) Sensor or system specific detection confidence at time t: c_t (between 0 for no detection confidence and 1 for high detection confidence).

3) Detection success, describing the assessment whether a given measurement has successfully perceived the object (binary assessment) at time t: d_t (0 if not detected or 1 if detected).

The *objectAge* is provided in the CPM, whereas the detection confidence and the detection success indication are system specific assessments of the ITS-S's object detection system.

The *objectPerceptionQuality* at a discrete time instant *t*, shall be determined according to the following process:

1) Compute the exponential moving average for the system specific detection confidence c_t with factor $\alpha, 0 \leq \alpha \leq 1$

   a) If $t == 0$: $EMA_0 = c_0$

   b) If $t > 0$: $EMA_t = \alpha * c_t + (1 - \alpha) * EMA_{t-1}$

2) Compute the rating $r_c = floor(EMA_t * 15)$

3) Repeat steps 1) and 2) for the detection success d_t to obtain rating r_d

4) Compute the object age rating $r_{oa} = \min\{\lfloor oa/100 \rfloor, 15\}$

5) Compute object perception quality as the weighted average of r_{oa}, r_c, r_d:

$$objectPerceptionQuality = floor\left(\frac{w_d * r_d + w_c * r_c + w_{oa} * r_{oa}}{w_d + w_c + w_{oa}}\right)$$ with weights w_d, w_c and w_{oa}.

7.1.8.7 Object classification

The component *classification* may be included for a perceived object to describe the class and associated subclass of a detected object. Several object classes and subclasses associated with a classification confidence level may be reported for the same object, if the disseminating ITS-S is not fully confident on the object class and associated subclass.

NOTE: A detected object may for example be classified using "*vehicleSubClass*" with the associated subclass "*passengerCar*" with a certain classification confidence level and "*vehicleSubClass*" with the associated subclass "*lightTruck*" with another classification confidence level.

The object class "*groupSubClass*" shall be used to report a VRU group or cluster.

A VRU group contains a set of VRUs perceived by the ITS-station generating the CPM. Reporting of group of VRUs as a single object aims at reducing the size of the CPM.

A VRU cluster contains a set of VRUs reported in a VRU Awareness Message (VAM) received by the ITS station generating the CPM.

VRU clustering operations are part of the VRU basic service specified in ETSI TS 103 300-3 [i.12] and are intended to optimize the resource usage in the ITS-S by reducing the number of individual messages.

In a CPM, a VRU group or cluster is characterized by parameters defining the size of the group in terms of number of objects (*clusterCardinalitySize*) and optionally the type of the group (*clusterProfiles*) to identify all the VRU profile types that are believed to be in the VRU group or cluster.

If the group is associated to a VRU cluster as indicated in a received VAM, the component *clusterId* shall indicate the identifier of the associated VRU cluster. Otherwise, no *clusterId* shall be indicated.

A VRU cluster or a VRU group can be updated by adding information (shape, cardinality, VRU profile) perceived by the ITS-S generating the CPM. Conditions for clustering operations are specified in ETSI TS 103 300-3 [i.12].

7.1.8.8 Link to MAPEM

The component *mapPosition* may be included for a perceived object only if the Originating RSU Container is present in the CPM. If *mapPosition* is present, the component *MapPosition.mapReference* shall be absent and the component *laneId* or *connectionId* shall refer to the MAPEM referenced in the Originating RSU Container.

7.2 CPM format specification

The CPM format shall be as specified in ASN.1 in Annex A of the present document.

DEs and DFs that are not defined in the present document shall be imported from the common data dictionary ETSI TS 102 894-2 [3] as specified in Annex A.

Detailed descriptions of all components of CPM are in Annex B of the present document.

Unaligned Packed Encoding Rules (UPER) as defined in Recommendation ITU-T X.691 [2] shall be used for CPM encoding and decoding.

Annex A (normative): ASN.1 modules

This clause provides the normative ASN.1 modules containing the syntactical definitions of the CPM PDU, its containers, and the data frames, and data elements defined in the present document. The semantical specification of the CPM components, its containers, the data frames, and data elements is contained in the same module, in the form of ASN.1 comments. For readability, the same semantical specification is presented in a different format in Annex B.

The CPM-PDU-Descriptions module is identified by the Object Identifier {itu-t (0) identified-organization (4) etsi (0) itsDomain (5) wg1 (1) ts (103324) cpm (1) major-version-1 (1) minor-version-1(1)}. The module can be downloaded as a file as indicated in Table A.1. The associated SHA-256 cryptographic hash digest of the referenced file offers a means to verify the integrity of that file.

Table A.1: CPM-PDU-Descriptions ASN.1 module information

Module name	CPM-PDU-Descriptions
OID	{itu-t (0) identified-organization (4) etsi (0) itsDomain (5) wg1 (1) ts (103324) cpm (1) major-version-1 (1) minor-version-1(1)}
Link	https://forge.etsi.org/rep/ITS/asn1/cpm_ts103324/-/raw/v2.1.1/asn/CPM-PDU-Descriptions.asn
SHA-256 hash	90c6b015bdc99917dd36bc8e7d1ede9355374f5d3a1c12e14bb4d560340fdfa2

The CPM-OriginatingStationContainers module is identified by the Object Identifier {itu-t (0) identified-organization (4) etsi (0) itsDomain (5) wg1 (1) ts (103324) originatingStationContainers (2) major-version-1 (1) minor-version-1(1)}. The module can be downloaded as a file as indicated in Table A.2. The associated SHA-256 cryptographic hash digest of the referenced file offers a means to verify the integrity of that file.

Table A.2: CPM-OriginatingStationContainers ASN.1 module information

Module name	CPM-OriginatingStationContainers
OID	{itu-t (0) identified-organization (4) etsi (0) itsDomain (5) wg1 (1) ts (103324) originatingStationContainers (2) major-version-1 (1) minor-version-1(1)}
Link	https://forge.etsi.org/rep/ITS/asn1/cpm_ts103324/-/raw/v2.1.1/asn/CPM-OriginatingStationContainers.asn
SHA-256 hash	333146879622e54a75969ee5d18c0b839ca5426f9f42c05744fc996ba921e10d

The CPM-SensorInformationContainer module is identified by the Object Identifier {itu-t (0) identified-organization (4) etsi (0) itsDomain (5) wg1 (1) ts (103324) sensorInformationContainer (3) major-version-1 (1) minor-version-1(1)}. The module can be downloaded as a file as indicated in Table A.3. The associated SHA-256 cryptographic hash digest of the referenced file offers a means to verify the integrity of that file.

Table A.3: CPM-SensorInformationContainer ASN.1 module information

Module name	CPM-SensorInformationContainer
OID	{itu-t (0) identified-organization (4) etsi (0) itsDomain (5) wg1 (1) ts (103324) sensorInformationContainer (3) major-version-1 (1) minor-version-1(1)}
Link	https://forge.etsi.org/rep/ITS/asn1/cpm_ts103324/-/raw/v2.1.1/asn/CPM-SensorInformationContainer.asn
SHA-256 hash	662653e5854b3d4057b98be70277d12fae2d14e8ea61808a9325b947201da462

The CPM-PerceptionRegionContainer module is identified by the Object Identifier {itu-t (0) identified-organization (4) etsi (0) itsDomain (5) wg1 (1) ts (103324) perceptionRegionContainer (5) major-version-1 (1) minor-version-1(1)}. The module can be downloaded as a file as indicated in Table A.4. The associated SHA-256 cryptographic hash digest of the referenced file offers a means to verify the integrity of that file.

Table A.4: CPM-PerceptionRegionContainer ASN.1 module information

Module name	CPM-PerceptionRegionContainer
OID	{itu-t (0) identified-organization (4) etsi (0) itsDomain (5) wg1 (1) ts (103324) perceptionRegionContainer (5) major-version-1 (1) minor-version-1(1)}
Link	https://forge.etsi.org/rep/ITS/asn1/cpm_ts103324/-/raw/v2.1.1/asn/CPM-PerceptionRegionContainer.asn
SHA-256 hash	e8fc77e0b10fe8cec191192f49d2049add8f3c1c3c4c63a364e6b64f77750910

The CPM-PerceivedObjectContainer module is identified by the Object Identifier {itu-t (0) identified-organization (4) etsi (0) itsDomain (5) wg1 (1) ts (103324) perceivedObjectContainer (4) major-version-1 (1) minor-version-1(1)}. The module can be downloaded as a file as indicated in Table A.5. The associated SHA-256 cryptographic hash digest of the referenced file offers a means to verify the integrity of that file.

Table A.5: CPM-PerceivedObjectContainer ASN.1 module information

Module name	CPM-PerceivedObjectContainer
OID	{itu-t (0) identified-organization (4) etsi (0) itsDomain (5) wg1 (1) ts (103324) perceivedObjectContainer (4) major-version-1 (1) minor-version-1(1)}
Link	https://forge.etsi.org/rep/ITS/asn1/cpm_ts103324/-/raw/v2.1.1/asn/CPM-PerceivedObjectContainer.asn
SHA-256 hash	71f3482ba2a43f874aaa5dce990baeb37c892f277529de83d1275f577ce2d533

Annex B (informative): Specification of CPM in readable format

The specification of CPM containers, data elements and data frames is available at the following URL:

- https://forge.etsi.org/rep/ITS/asn1/cpm_ts103324/-/blob/v2.1.1/docs/.

Annex C (informative): Interpretation of the kinematic and attitude state description

Given a transmitting ITS-S provides distance and speed in the x-y-plane as well as the yaw angle, the corresponding state vector is $\left(d_x, d_y, v_x, v_y, \theta_{yaw}\right)^T$ with correlation matrix:

$$Corr = \begin{bmatrix} 1 & corr_{\{d_x d_y\}} & corr_{\{d_x v_y\}} & corr_{\{d_x v_y\}} & corr_{\{d_x \theta_{yaw}\}} \\ corr_{\{d_x d_y\}} & 1 & corr_{\{d_y v_x\},} & corr_{\{d_y v_y\}} & corr_{\{d_y \theta_{yaw}\}} \\ corr_{\{d_x v_x\},} & corr_{\{d_y v_x\},} & 1 & corr_{\{v_x v_y\}} & corr_{\{v_x \theta_{yaw}\}} \\ corr_{\{d_x v_y\}} & corr_{\{d_y v_y\}} & corr_{\{v_x v_y\}} & 1 & corr_{\{v_y \theta_{yaw}\}} \\ corr_{\{d_x \theta_{yaw}\}} & corr_{\{d_y \theta_{yaw}\}} & corr_{\{v_x \theta_{yaw}\}} & corr_{\{v_y \theta_{yaw}\}} & 1 \end{bmatrix},$$

It follows that given a received state vector of length 5, to represent the corresponding correlation information in the CPM for this object, 5-1 columns with 5-i correlation values in column i are required.

In this example, the correlation matrix for the state vector shall be represented by

LowerTriangularPositiveSemidefiniteMatrix = [

$[corr_{\{d_x d_y\}},\ corr_{\{d_x v_x\},} corr_{\{d_x v_y\}}, corr_{\{d_x \theta_{yaw}\}}],$
$[corr_{\{d_y v_x\},} corr_{\{d_y v_y\}}, corr_{\{d_y \theta_{yaw}\}}],$
$[corr_{\{v_x v_y\}}, corr_{\{v_x \theta_{yaw}\}}],$
$[corr_{\{v_y \theta_{yaw}\}}]$
$],$

where every list of correlations corresponds to a data frame of type *correlationColumn* and every entry within a *correlationColumn* corresponds to a data element of type *correlationRowValue*.

From here, the receiver can compute the corresponding covariance matrix $\mathbf{C}$. Given the diagonal matrix $\mathbf{A} = \mathrm{diag}(\sigma_1, \ldots, \sigma_n)$ of standard deviations for the received kinematic state and attitude vector, and the correlation matrix $\mathbf{D} = \begin{pmatrix} 1 & \cdots & corr \\ \vdots & \ddots & \vdots \\ corr & \cdots & 1 \end{pmatrix}$, constructed from the received lower triangular matrix components, the covariance matrix can be computed as $\mathbf{C} = \mathbf{ADA}$.

Annex D (normative): Frequency and Content Management

If the ITS-S supports MCO, the Frequency and Content Management entity determines the optimal CPM generation period *T_GenCpm* and the number of perceived objects and regions to be included in the CPM, while ensuring that the amount of channel resources consumed by the CP service does not exceed the value *resources_limit* specified by MCO_FAC in ETSI TS 103 141 [7]. *resources_limit* is the upper bound of resources (in bits/s, measured at the facilities layer) that the CPS can use in its preferred and alternative channels. In particular, *T_GenCpm*, the number of perceived objects and the number of perception regions to be included in the CPM are chosen such that the estimated CPM size in bits (considering all included containers on the facility layer) divided by *T_GenCpm* is smaller or equal than *resources_limit.*

Furthermore, *T_GenCpm*, the number of perceived objects and the number of perception regions to be included in the CPM are selected based on the VoI of the perceived objects and regions in the last generated CPM (see computation methods in Annex E). On the one hand, if the perceived objects and regions are homogeneous with respect to their VoI, the CPM frequency is reduced (i.e. *T_GenCpm* is increased) before reducing the message size (i.e. the number of perceived objects and regions to be included in the CPM). The CPM size is only reduced if *T_GenCpm* is equal to *T_GenCpmMax* and the resources limit from MCO_FAC is still violated. On the other hand, if the VoI of perceived objects and regions is highly heterogeneous, the CPM size is reduced before reducing the CPM frequency (*T_GenCpm* is set to *T_GenCpmMin*), in order to include the perceived objects and the number of perception regions with highest VoI as often as possible. In a general case, *T_GenCpm* and the number of perceived objects and regions to be included in the CPM are chosen in a way that maximizes the overall VoI rate of the generated CPMs. The VoI rate is defined as the sum of the VoI of all objects and regions to be included in the CPM divided by *T_GenCpm.*

Annex E (informative): Object Inclusion Rate Control

In case of multiple ITS-Ss perceiving the same (physical) object (i.e. non-V2X capable object) or an ITS-S perceiving an object which is an ITS-S, i.e. capable to transmit and receive V2X messages such as the CAM, VAM or the CPM (i.e. V2X capable object), unnecessarily frequent updates about that object may be broadcasted, thereby increasing the network channel load. High channel load levels may lead to losses of CPMs, which may in turn degrade performance of the CPS. To address this problem, objects are included or not in a CPM based on their VoIs (see clause 6.1.2.3). The following table describes possible methods to compute the VoI of a given perceived object. Multiple methods can be combined. In all methods, a received CAM, VAM or CPM is considered to include information about the object only if the transmitting ITS-S can associate the information in the received messages with the locally perceived object with a confidence higher than a threshold *C_InclusionRateControl*. This association confidence corresponds to the overlap of the probability distributions related to the perceived and received object's kinematic and attitude state, respectively. In addition, only the messages received during the most recent time window of length *W_InclusionRateControl*.are used for the computation of the VoI. Additional rules could be added, e.g. to avoid that an object is not omitted more than *N_InclusionRateControl* times in a row.

Table E.1: Possible methods to compute the VoI of a perceived object

Score	Method	Interpretation
Frequency-based	The VoI of the perceived object is inversely proportional to the number of CPMs that the transmitting ITS-S has received from remote ITS-Ss containing information about the object in a given time window *W_InclusionRateControl*.	Perceived objects with a lower VoI have lower priority because data related to the perceived object has been recently broadcasted by a high number of remote ITS-Ss.
Dynamics-based	The VoI of the perceived object is equal to the Euclidean absolute distance between the current position of the object and the position of the object in the last CPM received from a remote ITS-S. In addition, the VoI could take into account the difference between the current estimated absolute speed of the object and the absolute speed of the same object received from a remote ITS-S in the last CPM.	Perceived objects with a lower VoI have lower priority because the position and speed of the object have not significantly changed since the last time, they were received in a CPM transmitted by a remote ITS-S.
Distance-based	The VoI of the perceived object is equal to the Euclidean absolute distance between the transmitting ITS-S and the farthest remote ITS-S that is transmitting CPMs including the object.	Perceived objects with a lower VoI have lower priority because the perceived object has been recently broadcasted by a remote ITS-S that is close to the transmitting ITS-S.
Angle-based	The VoI of the perceived object is equal to the highest absolute difference between the orientation of the transmitting ITS-S to object vector in the WGS84 coordinate system with respect to true north, and the orientation of all remote ITS-Ss to object vectors.	Perceived objects with a lower VoI have lower priority because the perceived object has been recently broadcasted by a remote ITS-S that is detecting it with a similar orientation.
Classification confidence based	The VoI of the perceived object is equal to the difference between the object confidence of the transmitting ITS-S and the highest object confidence of the remote ITS-Ss transmitting CPMs about the object.	Perceived objects with a lower VoI have lower priority because the perceived object has been recently broadcasted by a remote ITS-S that is detecting it with higher classification confidence.
Perception quality based	The VoI of the perceived object is equal to the difference between the object perception quality (defined in clause 7.1.8.6) of the transmitting ITS-S and the highest object perception quality of the remote ITS-Ss transmitting CPMs about the object.	Perceived objects with a lower VoI have lower priority because the perceived object has been recently broadcasted by a remote ITS-S that is detecting it with higher object perception quality.
Utility-based	The VoI of the perceived object is equal to the highest utility of including the object in the CPM for all the remote ITS-Ss. A possible utility metric is the relative entropy that indicates the information gain between the prior and posterior knowledge of a remote ITS-S about the state of a locally perceived object.	Perceived objects with a lower VoI have lower priority because the utility of the perceived object is low for the remote ITS-Ss.
Object Self-Announcement	The VoI of the perceived object is inversely proportional to the number of CAMs, VAMs and CPMs transmitted by the object (i.e. it is a V2X capable object) and received by the transmitting ITS-S.	Perceived objects with a lower VoI have lower priority because the perceived object has recently broadcasted a high number of messages informing about its presence.

Annex F (normative): Configuration parameter values

A list of the required system parameters and their recommended values or value ranges is provided below.

Table F.1: Configuration parameter values recommended for the CPS data inclusion management

Parameter	Type	Default Value	Description
T_GenCpmMin	Time (ms)	100	Lower limit for the time T_GenCpm elapsed between two consecutive CPM generation events. A value of 100 ms is recommended for vehicle ITS-S. For some use cases, roadside ITS-S may require a value down to 50 ms. It is used in clause 6.1.2.1.
T_GenCpmMax	Time (ms)	1 000	Upper limit for the time T_GenCpm elapsed between two consecutive CPM generation events. It is used in clause 6.1.2.1.
T_AddSensorInformation	Time (ms)	1 000	Time after which the SensorInformationContainer is usually included again into a CPM. For details see clause 6.1.2.2.
MaxPerceptionRegions	Number	8	Maximum number of perception regions included into a CPM to constrain the message size. It is used in clause 6.1.2.3.
ObjectInclusionConfig	Identifier	1	CPS configuration parameter that indicates the object inclusion management to be employed by the disseminating ITS-S. *ObjectInclusionConfig*=1 is recommended for vehicle ITS-S. For some use cases, roadside ITS-S may use *ObjectInclusionConfig*=0 in some cases. For its application see clause 6.1.2.4.
ObjectPerceptionQualityThreshold	Ratio	3	Threshold of the objectPerceptionQuality defining the lower limit for objects to be included into a CPM. For its computation see clause 7.1.8.6 and for its application see clause 6.1.2.4.
minPositionChangeThreshold	Distance (m)	4	Minimum Euclidean distance between the current estimated position of the reference point of a perceived object and the estimated position of the reference point lastly included in a CPM. It is used for the perceived object inclusion management in clause 6.1.2.4.
minGroundSpeedChangeThreshold	Speed (m/s)	0,5	Minimum difference between the current estimated ground speed of the reference point of a perceived object and the estimated ground speed of the reference point lastly included in a CPM. It is used for the perceived object inclusion management in clause 6.1.2.4.
minGroundVelocityOrientationChangeThreshold	Orientation (degrees)	4	Minimum difference between the current orientation of the vector of the current estimated ground velocity of the reference point of a perceived object and the estimated orientation of the vector of the current estimated ground velocity of the reference point lastly included in a CPM. It is used for the perceived object inclusion management in clause 6.1.2.4.

Table F.2: Configuration parameter values recommended for the CPM assembly

Parameter	Type	Default Value	Description
MessageAssemblyConfig	Identifier	0; 1	CPS configuration parameter that indicates the CPM assembly mechanism to be employed by the disemminating ITS-S. *MessageAssemblyConfig=0* is recommended if *ObjectInclusionConfig*=1. For some roadside ITS-S, *MessageAssemblyConfig=0* may be beneficial. It is used in clause 6.1.3.1.
minPositionChangePriorityThreshold	Distance (m)	0	Lower limit for which the Euclidean distance between the current estimated position of the reference point of the object and the estimated position of the reference point of this object lastly included in a CPM starts to contribute to the object utility function defined in clause 6.1.3.2.
maxPositionChangePriorityThreshold	Distance (m)	8	Upper limit for which the Euclidean distance between the current estimated position of the reference point of the object and the estimated position of the reference point of this object lastly included in a CPM stops to contribute to the object utility function defined in clause 6.1.3.2.
minGroundSpeedChangePriorityThreshold	Speed (m/s)	0	Lower limit for which the difference between the current estimated ground speed of the reference point of the object and the estimated absolute speed of the reference point of this object lastly included in a CPM starts to contribute to the object utility function defined in clause 6.1.3.2.
maxGroundSpeedChangePriorityThreshold	Speed (m/s)	1	Upper limit for which the difference between the current estimated ground speed of the reference point of the object and the estimated absolute speed of the reference point of this object lastly included in a CPM stops to contribute to the object utility function defined in clause 6.1.3.2.
minGroundVelocityOrientationChangePriorityThreshold	Orientation (degrees)	0	Lower limit for which the difference between the orientation of the vector of the current estimated ground velocity of the reference point of the object and the estimated orientation of the vector of the ground velocity of the reference point of this object lastly included in a CPM starts to contribute to the object utility function defined in clause 6.1.3.2.
maxGroundVelocityOrientationChangePriorityThreshold	Orientation (degrees)	8	Upper limit for which the difference between the orientation of the vector of the current estimated ground velocity of the reference point of the object and the estimated orientation of the vector of the ground velocity of the reference point of this object lastly included in a CPM stops to contribute to the object utility function defined in clause 6.1.3.2.
minLastInclusionTimePriorityThreshold	Time (ms)	100	Lower limit for which the time elapsed since the last time the object was included in a CPM starts to contribute to the object utility function defined in clause 6.1.3.2.
maxLastInclusionTimePriorityThreshold	Time (ms)	1000	Upper limit for which the time elapsed since the last time the object was included in a CPM stops to contribute to the object utility function defined in clause 6.1.3.2.

Table F.3: Configuration parameter values recommended for sensor and object ID management

Parameter	Type	Default Value	Description
UnusedSensorIdRetentionPeriod	Time (s)	60	Minimum time to ellapse before an ID used to identify a sensor can be reused after it has last been used. See clause 7.1.6.
UnusedObjectIdRetentionPeriod	Time (s)	60	Minimum time to ellapse before an ID used to identify an object can be reused after it has last been used. See clause 7.1.8.2.

Table F.4: Configuration parameter values recommended for the object perception quality assessment

Parameter	Type	Default Value	Description
α	Ratio	0,5	Moving average factor used in clause 7.1.8.6.
w_d	Ratio	1	Weight factor for detection success rating used in clause 7.1.8.6.
$\mathrm{w_c}$	Ratio	1	Weight factor for detection confidence rating used in clause 7.1.8.6.
$\mathrm{w_{oa}}$	Ratio	1	Weight factor for object age rating used in clause 7.1.8.6.

Table F.5: Configuration parameter values recommended for the object inclusion rate control

Parameter	Type	Default Value	Description
C_InclusionRateControl	Confidence level	50 %	Minimum required association confidence necessary to assume a perceived object corresponds to an object received by means of a CPM, CAM or VAM. It is defined in Annex E.
W_InclusionRateControl	Time (s)	2	Time window defined from the beginning of the current CPM generation event to the past, for which received CAM, VAM and CPM messages are considered for the computation of the VoI in Annex E.
N_InclusionRateControl	Number	10	Maximum number of times an object may be omitted due to low VoI before it is included into a CPM again. It is used in Annex E.

History

Document history		
V2.1.1	June 2023	Publication