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ETSI

650 Route des Lucioles
F-06921 Sophia Antipolis Cedex - FRANCE

Tel.: +33 4 92 94 42 00 Fax: +33 4 93 65 47 16

Siret N° 348 623 562 00017 - APE 7112B
Association à but non lucratif enregistrée à la
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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 DEN service is an application support functionality facility at the facilities layer. It generates, manages and processes the Decentralized Environmental Notification Message (DENM). The generation of a DENM is triggered by an ITS-S application. A DENM contains information related to a road hazard or an abnormal traffic condition, such as its type and its position. The DEN service delivers the DENM as payload to the ITS networking & transport layer for the message dissemination. Typically for an ITS application, a DENM is disseminated to ITS-Ss that are located in a geographic area through communications among ITS stations. At the receiving side, the DEN service of an receiving ITS-S processes the received DENM and provides the DENM content to an ITS-S application. This ITS-S application may present the information to the driver if information of the road hazard or traffic condition is assessed to be relevant to the driver. The driver is then able to take appropriate actions to react to the situation accordingly.

The Release 1 edition of the DEN service has been published as ETSI EN 302 637-3 [i.9] called the DEN basic service. The first Release 2 version of the present document provides an improved specification of the Release 1 version as a basis for future Release 2 versions of the DEN service. The present document specifies extensions to the DENM Release 1 format to support additional use cases in a way allowing the facilities layer standard to be used with different security and lower layer technologies.

All future Release 2 versions will be based on the latest Release 1 version of the DEN service and will be backwards compatible with it in the sense that Release 1 implementations can receive and decode Release 2 DENM and utilize the Release 1 content without the need to understand the Release 2 content.

1 Scope

The present document provides the specification of the Release 2 DEN service.

More specifically, the present document specifies the syntax and semantics of the "Decentralized Environmental Notification Message" (DENM) and the DENM protocol handling.

The DEN service may be implemented in a vehicle ITS-S, a road side ITS-S, a personal ITS-S or a central ITS-S.

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.

Referenced documents which are not found to be publicly available in the expected location might be found at https://docbox.etsi.org/Reference.

NOTE: While any hyperlinks included in this clause were valid at the time of publication, ETSI cannot guarantee their long term validity.

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

[1] 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".

[2] 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".

[3] ETSI TS 102 965: "Intelligent Transport Systems (ITS); Application Object Identifier (ITS-AID); Registration; Release 2".

[4] ETSI TS 103 899: "Intelligent Transport Systems (ITS); Vehicular Communications; Geographical Area Definition; Release 2".

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

[6] Recommendation ITU-T X.691/ISO/IEC 8825-2: "Information technology - ASN.1 encoding rules: Specification of Packed Encoding Rules (PER)".

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

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

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

[10] 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

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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 102 638 (V2.1.1): "Intelligent Transport Systems (ITS); Vehicular Communications; Basic Set of Applications; Release 2".

[i.2] Car2Car Communication Consortium: "Basic System Profile".

[i.3] Car2Car Communication Consortium: "Guidance for day 2 and beyond roadmap".

[i.4] C-Roads: "Harmonised C-ITS Specifications for Europe".

[i.5] ETSI TS 103 938: "Intelligent Transport Systems (ITS); Vehicular Communications; Basic Set of Applications; Local Dynamic Map (LDM); Release 2".

[i.6] ETSI TS 103 898: "Intelligent Transport Systems (ITS); Communications Architecture; Release 2".

[i.7] ETSI TS 103 836-3: "Intelligent Transport Systems (ITS); Vehicular Communications; GeoNetworking; Part 3: Network Architecture; Release 2".

[i.8] ISO EN 17419: "Intelligent Transport Systems - Cooperative Systems - Classification and management of ITS applications in a global context".

[i.9] ETSI EN 302 637-3 (V1.3.1): "Intelligent Transport Systems (ITS); Vehicular Communications; Basic Set of Applications; Part 3: Specifications of Decentralized Environmental Notification Basic Service".

[i.10] 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".

[i.11] ETSI TR 103 832: "Intelligent Transport Systems (ITS); Vehicular Communications; Basic Set of Applications; Study on ITS Support for Pre-Crash based Applications; Release 2".

3 Definition of terms, symbols and abbreviations

3.1 Terms

For the purposes of the present document, the terms given in ETSI TS 103 301 [i.10], ETSI TS 103 898 [i.6], ETSI TS 102 894-2 [5], ETSI TS 103 938 [i.5] and the following apply:

actionId: identifier of a detected event

À La Carte container: container of DENM that includes information of the detected event in addition to management container, situation container and location container

NOTE: Due to coding constraints in programming language, the term "alacarte" is also used.

awareness area: geographic area in which information concerning the event is potentially applicable for use or for further distribution

basic set of applications: group of applications, supported by the vehicular communication system

NOTE: The BSA is defined in ETSI TR 102 638 [i.1].

cancellation Decentralized Environmental Notification Message (DENM): DEN message type generated by the ITS-S, which originated the new DENM, indicating the event termination

Decentralized Environmental Notification (DEN) basic service: facility at the facilities layer to support ITS-S applications, DENM management and DENM dissemination

Decentralized Environmental Notification Message (DENM): ITS facilities layer PDU providing event information

Decentralized Environmental Notification Message (DENM) protocol: ITS facilities layer protocol that operates the DENM transmission, forwarding and reception

destination area: geographical area for DENM dissemination

NOTE: The destination area is specified in ETSI TS 103 899 [4].

downstream traffic: portion of traffic in a given direction that is beyond (past) a certain point and is going away from it

event: road hazard, driving environment, or traffic condition

facility: functionality, service or data provided by the ITS facilities layer

forwarding Intelligent Transport System Station (ITS-S): ITS-S that forwards DENMs and implements the DENM protocol

location container: container of DENM that includes location data of the detected event

management container: container of DENM that includes management data for DENM protocol

negation Decentralized Environmental Notification Message (DENM): DEN message type generated by an ITS-S other than the ITS-S, which originated the new DENM, indicating the event termination

new Decentralized Environmental Notification Message (DENM): DEN message type indicating that the event is detected for the first time

originating Intelligent Transport System Station (ITS-S): ITS-S that generates DENMs and implements the DENM protocol

receiving Intelligent Transport System Station (ITS-S): ITS-S that receives DENMs from the ITS networking & transport layer and implements the DENM protocol

situation container: container of DENM that includes data related to the detected event

update Decentralized Environmental Notification Message (DENM): DEN message type indicating the evolution of the event

upstream traffic: portion of traffic in a given direction that has not yet arrived at a certain point and is going towards it

3.2 Symbols

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

actionId	Identifier of an event that is detected by an ITS-S
appDENM_trigger	Application request type to generate a new DENM for a newly detected event
appDENM_update	Application request type to generate an update DENM for an update of the event
appDENM_termination	Application request type to generate a cancellation or negation DENM for termination of the event
detectionTime	Timestamp at which an event or event update/termination is detected
IF.DEN1	Interface between the DEN service and ITS-S applications for DENM transmission
IF.DEN2	Interface between the DEN service and ITS-S applications for DENM reception
IF.Mng	Interface between the DEN service and the ITS management entity

IF.MCO	Interface between the DEN service and the MCO facility layer entity
IF.N&T	Interface between the DEN service and the ITS networking & transport layer
IF.SEC	Interface between the DEN service and the ITS security entity
referenceTime	Timestamp at which a new, update or cancellation DENM is generated by the DEN service

NOTE: A negation DENM contains the *referenceTime* of the DENM that is negated.

repetitionDuration	Duration of the DENM repetition
repetitionInterval	Time interval of the DENM repetition
stationId	Identifier of an ITS-S
T_F_Validity	Timer that indicates the end of the DENM processing of one specific actionId of the forwarding ITS-S
T_Forwarding	Timer for the scheduling of the DENM forwarding by the forwarding ITS-S
T_O_Validity	Timer that indicates the end of the DENM processing of one specific actionId of the originating ITS-S
T_R_Validity	Timer that indicates the end of the DENM processing of one specific actionId of the receiving ITS-S
T_Repetition	Timer for the scheduling of the DENM repetition by the originating ITS-S
T_RepetitionDuration	Timer that indicates the end of the DENM repetition
termination	Parameter that indicates the termination of an event
transmissionInterval	Time interval for DENM transmission
validityDuration	Duration of the DENM validity

3.3 Abbreviations

For the purposes of the present document, the abbreviations given in ETSI TS 103 898 [i.6] and the following apply:

ASN.1	Abstract Syntax Notation One
BSA	Basic Set of Applications
BTP	Basic Transport Protocol
C2C-CC	Car to Car Communication Consortium
DE	Data Element
DEN	Decentralized Environmental Notification
DENM	Decentralized Environmental Notification Message
DF	Data Frame
EEBL	Electronic Emergency Break Light
GN	GeoNetworking
HMI	Human Machine Interface
ISO	International Standardization Organization
ITS	Intelligent Transport System
ITS-AID	ITS-Application IDentifier
ITS-S	ITS Station
IVIM	In-Vehicle Information Message
KAF	Keep Alive Forwarding
LDM	Local Dynamic Map
MAPEM	MAP Extended Message
MSB	Most Significant Bit
MCI	MCO Control Information
MCO	Multi Channel Operations
OSI	Open System Interconnection
PCI	Protocol Control Information
PDU	Protocol Data Unit
PER	Packed Encoding Rules
SSP	Service Specific Permissions
TS	Technical Specification

4 DEN service introduction

4.1 Background

The Decentralized Environmental Notification service (DEN) is an application support functionality operating at the facilities layer. The DEN service is responsible for the generation of DEN Messages (DENMs) based on received triggering information from applications. It is also responsible for the processing of received DENMs from other C-ITS stations. The DEN service is especially suited for the exchange of event based safety related information. The DENM information is mainly used by ITS applications in order to alert road users of a detected event using ITS communication technologies. DENM is used to describe a variety of events that can be detected by ITS Stations (ITS-S). A set of ITS applications, ITS services and use cases are specified in the ETSI Basic Set of Applications [i.1], in the C2C-CC Basic System Profile [i.2] and the C-Roads Release [i.4]. Further use cases are specified in the C2C-CC Roadmap [i.3].

The dissemination of DENM by an ITS-S is operated by DENM protocol.

The general processing procedure of an ITS use case that is supported by the DENM protocol is as follows:

- Upon detection of an event, an ITS-S transmits DENMs in order to disseminate the information about this event to other ITS-Ss located inside a destination area. The ITS-S that generates the DENM is denoted as originating ITS-S.
- DENM transmission is initiated and terminated by an ITS-S application at the ITS application layer.
- The transmission of a DENM may be repeated.
- DENM transmission may persist as long as the event is present.
- An ITS-S may forward a DENM. This ITS-S is denoted as forwarding ITS-S.
- The termination of DENM transmission is either automatically achieved by the facilities layer, i.e. the DEN service of the originating ITS-S when a predefined expiry time is reached, or by an ITS-S application that requests the generation of a DENM to inform that the event has terminated.
- An ITS-S, which receives a DENM, processes the information and may decide to present an appropriate warning or information to user, as long as the information in the received DENM is relevant to the ITS-S. This ITS-S is denoted as receiving ITS-S.

A general inter-layer and inter-ITS-Ss dataflow for DENM exchange is provided in Figure 1.

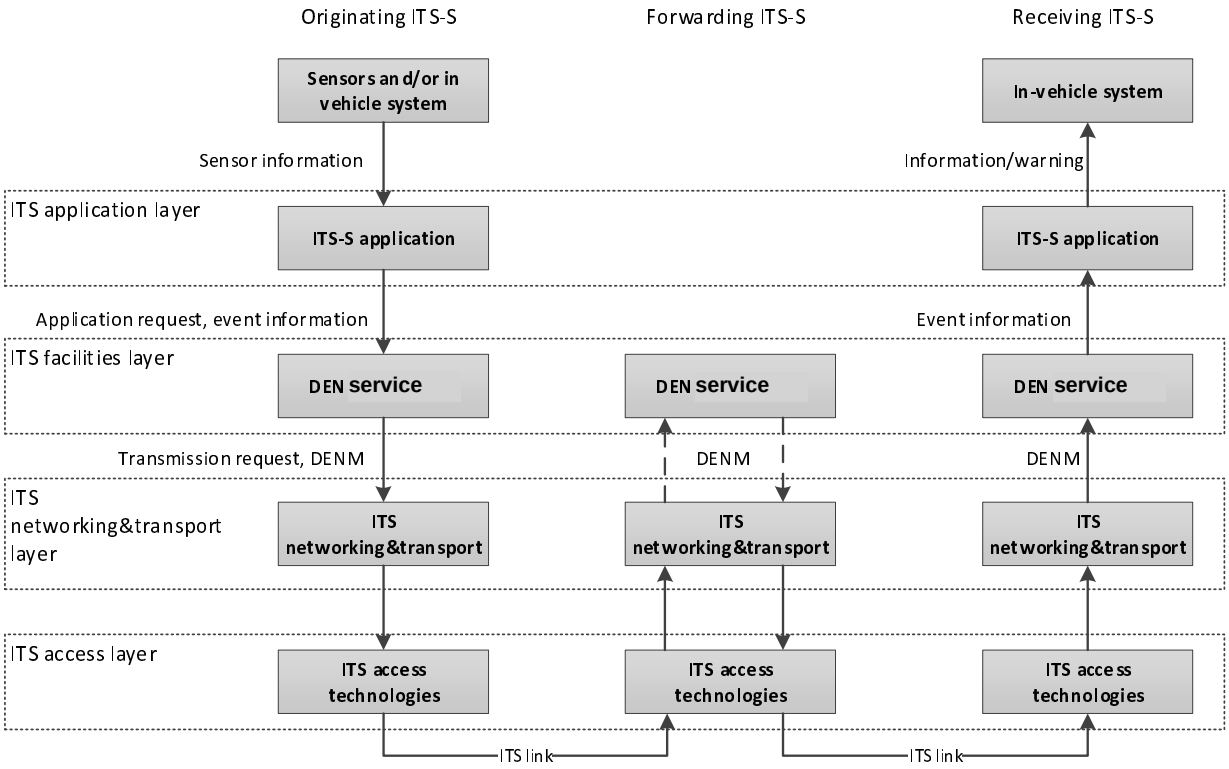

Figure 1: General data flow for ITS-S application supported by the DEN service

The solid lines illustrate the dataflow that is mandatory for all ITS applications using the DENM protocol. The dotted lines illustrate the dataflow that may apply only in certain situations.

NOTE: A DENM may be forwarded by intermediate ITS-Ss in order to disseminate DENM from the originating ITS-S to the receiving ITS-S, if the receiving ITS-S is not located in the direct communication range of the originating ITS-S. This forwarding is realized by the ITS networking & transport layer. In addition, the DEN service may provide forwarding functionality at the facilities layer, in order to maintain the DENM retransmission in certain situations, for example when the originating ITS-S has lost the capability to repeat DENM transmission. This optional facilities layer forwarding functionality is illustrated as dotted lines in Figure 1.

4.2 Services provided by the DEN service

The DEN service provides services to entities at the ITS application layer. At the originating ITS-S, an ITS-S application may trigger, update and terminate the transmission of DENMs. At the receiving ITS-S, the DEN service processes received DENMs and makes the information available for usage by ITS-S applications. Optionally, the DEN service may also provide forwarding functionality.

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

NOTE 1: Typically, for road safety ITS applications, the destination of a DENM transmission are ITS-Ss that are located in a pre-defined geographic area in which the event information may be relevant for traffic participants, e.g. close to the detected event reference position.

NOTE 2: A DENM may also be disseminated over a long distance or to a central ITS-S, such as for vehicle rerouting or road traffic management purposes.

A DENM contains information related to an event that has potential impact on road safety or traffic condition. An event is characterized by an event type, an event reference position, a detection time and a duration. These attributes may change over space and over time.

In some situations, the originating ITS-S transmits a DENM of an event originated by the vehicle itself, such as an electronic brake light event. The originating ITS-S manages the transmission and the termination of the DENM for this event. However, in some other situations, DENMs related to the same event may be transmitted by more than one originating ITS-Ss that detect the same event, such as several vehicle ITS-Ss travelling through the same location. In yet some other situations, the event might instead or additionally be detected by roadside sensors connected to a traffic management centre and the event information relayed to selected roadside ITS-S(s) to generate and transmit DENMs within or near to the destination area. In addition, in case the originating ITS-S is mobile (e.g. vehicle ITS-S or personal ITS-S), an event may persist even after the originating ITS-S has moved to a position far from the event reference position where the event was originally detected. For example, multiple vehicle ITS-Ss may detect black ice on the road surface and transmit DENMs. These DENMs can optionally be maintained by and relayed to other ITS-Ss, even after the detecting vehicle ITS-Ss have left the black ice location.

The DENM protocol is designed to manage these situations. The following DENM types are defined:

- **New DENM:** A DENM generated by the DEN service when:
  - an event is detected by the ITS-S application of an originating ITS-S; or
  - when information about an event is received by the ITS-S application of an originating ITS-S from a connected system;
  - for the first time and a corresponding trigger is sent to the DEN service. Each new DENM is assigned with a new identifier, denoted as *actionId*. A new DENM provides event attributes, such as event reference position, event type, event detection time, and other attributes as defined in clause 7.
- **Update DENM:** A DENM generated by the DEN service that includes update information of an event. An update DENM is transmitted by the same originating ITS-S, which had generated the new DENM for the same event.
- **Cancellation DENM:** A DENM that informs about the termination of an event. A cancellation DENM is transmitted by the same originating ITS-S which has generated the new DENM for the same event.
- **Negation DENM:** A DENM that informs about the termination of an event for which a DENM has been received by the originating ITS-S from another ITS-S. A negation DENM may be used to announce the termination of an event if the originating ITS-S has the capacity to detect the termination of an event which has been previously announced by other ITS-Ss. As example, the originating ITS-S of a DENM indicating black ice has left the event reference position, some time later, another ITS-S receiving this new DENM reaches the indicated black ice position and detects that the back ice has disappeared. The latter ITS-S may in this case generate a negation DENM for this event.

NOTE 3: Whether a negation DENM is transmitted may depend on the application requirements and the deployment requirements defined for example in the C2C-CC Basic System Profile [i.2] and the C-Roads Release [i.4]. Therefore, definition of conditions under which the generation and transmission of negation DENM is allowed is out of scope of the present document.

The DEN service of the originating ITS-S shall be able to generate at least DENMs of type New and Update. The generation of Cancellation and Negation DENMs is optional. The ITS-S application of the originating ITS-S sends an application request to the DEN service in order to trigger the generation of DENMs. The type of the DENM to be generated depends on the type of the application request.

Due to the different detection capabilities of ITS-Ss, the quality of the provided information in a DENM may vary. However, predefined conditions are to be satisfied by an ITS-S in order to initiate and terminate the transmission of DENMs for a specific event. These conditions are specified as ITS application requirements in the C2C-CC Basic System Profile [i.2] and the C-Roads Release [i.4].

5 DEN service functional specification

5.1 Introduction

The DEN service features several functionalities which are specified hereafter. The present clause is organized as following:

- Clause 5.2 introduces the DEN service.
- Clause 5.3 defines functionalities of the DEN service.
- Clause 5.4 defines interfaces of the DEN service.

5.2 DEN service in the ITS architecture

The DEN service is a facilities layer entity that implements the DENM protocol. It interfaces with ITS-S applications in order to receive the application request for DENM transmission and to provide the received DENM content to the ITS-S applications. Furthermore, the DEN service may interact with other facilities layer entities, in particular:

- The Local Dynamic Map (LDM) as defined in ETSI TS 103 938 [i.5], which is a facilities layer database that at the receiving ITS-S may be updated with a received DENM. ITS-S applications may then retrieve event related information from the LDM database for further processing.
- The Position and Time management (POTI) as defined in ETSI EN 302 890-2 [7], which provides estimates of the kinematic state of the ITS-S and of time information to the sending DEN service.
- The facility layer Multi-Channel Operation as defined in ETSI TS 103 141 [10].

NOTE 1: The specification of LDM, POTI and MCO_FAC is out of scope of the present document.

Figure 2 presents the DEN service in the ITS-S architecture as defined in ETSI TS 103 898 [i.6] as well as its logical interfaces with other entities and layers.

NOTE 2: The DEN service may exchange information with additional facilities layer entities for the purpose of generation, transmission, forwarding and reception of DENM. For simplicity reason, these interfaces are not illustrated in Figure 2.

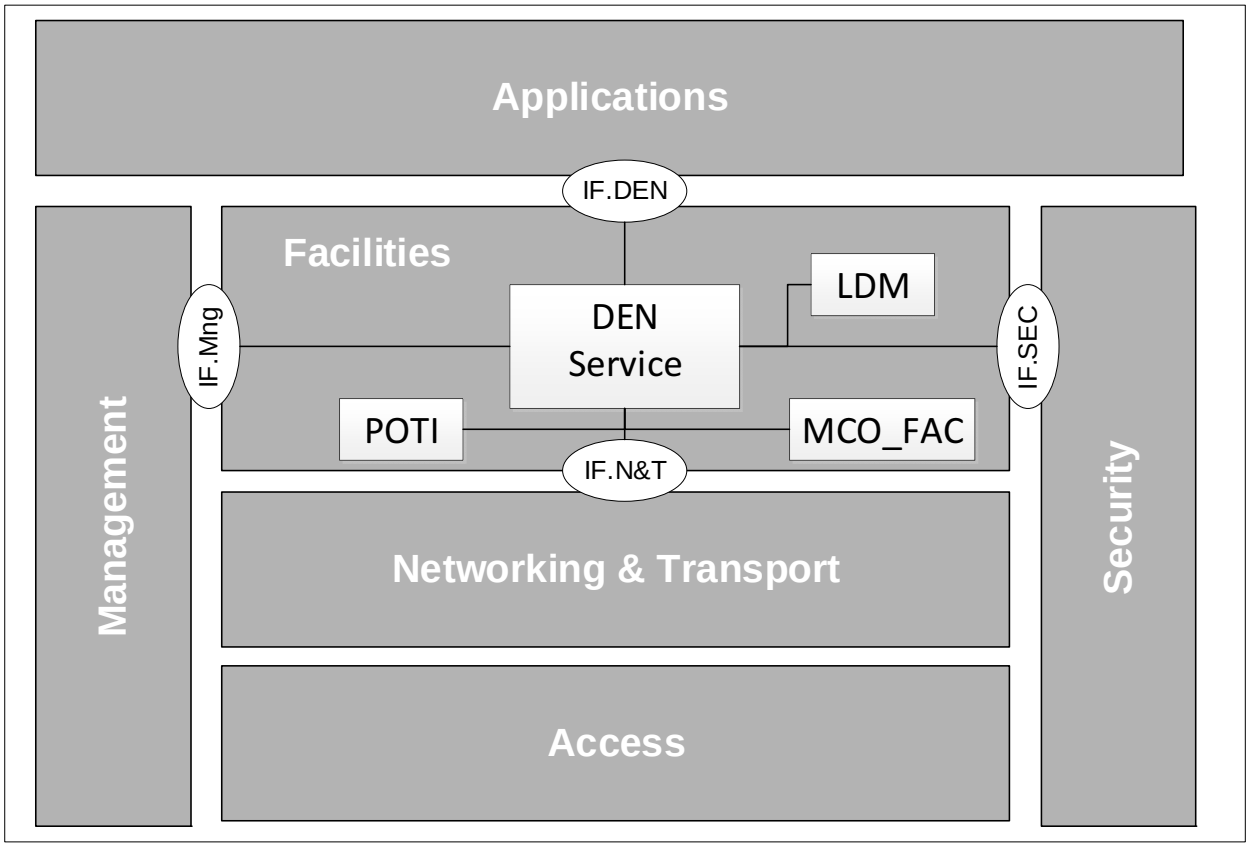

Figure 2: DEN service and logical interfaces

The operation of the DEN service on ITS infrastructure devices is specified in ETSI TS 103 301 [i.10].

5.3 DEN service functional architecture

The DEN service shall provide the following sub-functions:

- Generate DENM:
  - This sub-function defines the actual content of the DENM based on input from the ITS-S applications and encodes a DENM according to the format specified in Annex A of the present document.
- Decode DENM:
  - This sub-function decodes a received DENM.
- DENM transmission management:
  - This sub-function implements the DENM protocol operation of the originating ITS-S as specified in clause 8.2, including in particular:
    - The generation of a new DENM as requested by the ITS-S applications at the originating ITS-S.
    - The generation of an update DENM as requested by the ITS-S applications at the originating ITS-S.
    - The termination of the DENM transmission as requested by the ITS-S applications at the originating ITS-S.

NOTE 1: DENM termination refers to the generation of a cancellation DENM or a negation DENM as defined in clause 4.2.

    - The repetitive transmission of DENMs.

- DENM reception management:
  - This sub-function implements the DENM protocol operation of the receiving ITS-S as specified in clause 8.4, including in particular:
    - The update of the receiving ITS-S message table as defined in clause 8.4.1.
    - The discarding of received invalid DENMs.
    - The provisioning of received DENM data to ITS-S applications and/or to other facilities layer entities of the receiving ITS-S.
- DENM Keep Alive Forwarding (KAF):
  - This sub-function implements the DENM protocol operation of the forwarding ITS-S. In one possible KAF protocol, the KAF stores a received DENM during its validity duration, and forwards the DENM when applicable as specified in clause 8.3.
  - This sub-function is optional. The usage conditions of the KAF may either be defined by the ITS applications requirements or by a cross-layer functionality of the management entity.

NOTE 2: The conditions to enable KAF are beyond the scope of the present document.

Figure 3 illustrates sub-functions and interfaces of the DEN service in a component diagram.

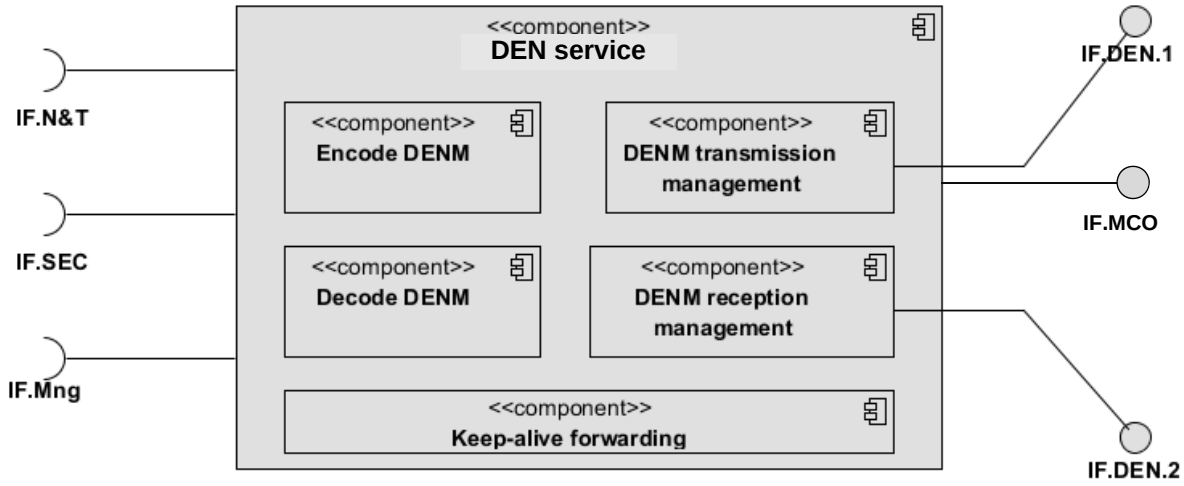

Figure 3: DEN service component diagram

5.4 Interfaces of the DEN service

5.4.1 Interfaces to the ITS application layer

5.4.1.1 Introduction

An ITS-S application can request the generation of different types of DENM as specified in clause 4.2, according to pre-defined conditions, for example as specified in the C2C-CC Basic System Profile [i.2] and the C-Roads Release [i.4].

The DEN service provides interfaces to ITS-S applications for the processing of the DENM protocol of the originating ITS-S, the forwarding ITS-S and the receiving ITS-S. As illustrated in Figure 3, the interface IF.DEN.1 is the interface for DENM transmission and the interface IF.DEN.2 is the interface for DENM reception. Data is exchanged between the DEN service and ITS-S applications via these interfaces.

At the originating ITS-S, the ITS-S application sends a request to the DEN service to generate DENM and to start the DENM transmission. Three types of application request are defined:

- *AppDENM_trigger*: The ITS-S application of the originating ITS-S detects or receives information about a new event and triggers the transmission of a new DENM.
- *AppDENM_update*: The ITS-S application of the originating ITS-S detects or receives information about the evolution of a detected event and requests the transmission of an update DENM with update information.
- *AppDENM_termination*: The ITS-S application of the originating ITS-S detects or receives information about the termination of an event and requests the transmission of a cancellation DENM or a negation DENM to inform other ITS-Ss of the event termination.

According to the application request type, a DENM of a specific type as defined in clause 4.2 is generated and transmitted by the DEN service. Table 1 defines the mapping between the application request types and generated DENM types.

Table 1: Mapping between application request types and DENM types

Application request type	DENM type to be generated
AppDENM_trigger	New DENM
AppDENM_update	Update DENM
AppDENM_termination	Cancellation DENM if the originating ITS-S has generated the DENM or Negation DENM otherwise

Clause 5.4.1.2 to clause 5.4.1.5 provide examples of data being passed via the interfaces IF.DEN.1 and IF.DEN.2. For the sake of the presentation clearness, the data is categorized into data passed from the ITS-S application to the DEN service and data returned from the DEN service to the requesting ITS-S application.

5.4.1.2 Data passed via interface IF.DEN.1 for the request type *AppDENM_trigger*

For the application request type *AppDENM_trigger*, Table 2 presents data being exchanged via the interface IF.DEN.1.

Table 2: Data passed via the interface IF.DEN.1 for *AppDENM_trigger*

Category	Data	Definition (see note 9)	Remarks
Data passed from ITS-S application to DEN service	actionId	*{DENM.denm.management.actionId}* as specified in Annex A.	Optional (see Note 10)
	Event detection time	*{DENM.denm.management.detectionTime}* as specified in Annex A.	
	Event reference position	*{DENM.denm.management.eventPosition}* as specified in Annex A.	
	Awareness area of the event	*Additionally to the event reference position: {DENM.denm.management.awarenessDistance}* and *{DENM.denm.management.trafficDirection}* as specified in Annex A.	Optional (see note 6)
	Event validity duration	*{DENM.denm.management.validityDuration}* as specified in Annex A.	Optional (see note 1)
	Repetition duration	Duration of the DENM repetition in units of milliseconds, denoted as *repetitionDuration*.	Optional (see note 2)
	Transmission interval	*{DENM.denm.management.transmissionInterval}* as specified in Annex A.	Optional (see note 3)
	stationType	*{DENM.denm.management.stationType}* as specified in Annex A.	Optional (see Note 10)
	Repetition interval	Interval of DENM repetition in units of milliseconds, denoted as *repetitionInterval.*	Optional (see note 2)
	Information contained in the situation container	*{DENM.denm.situation}* as specified in Annex A. This also contains the relevance zone information.	Optional (see note 4 and note 6)
	Information contained in the location container	*{DENM.denm.location}* as specified in Annex A.	Optional (see note 4)

Category	Data	Definition (see note 9)	Remarks
	Information contained in the À La Carte container	*{DENM.denm.alacarte}* as specified in Annex A.	Optional (see note 5)
	Destination area	Destination area for DENM dissemination as specified in ETSI TS 103 899 [4].	
	Traffic class	GN traffic class of the DENM as defined in ETSI TS 103 836-4-1 [1], if GeoNetworking/BTP is used.	
Data returned from DEN service to the requesting ITS-S application	actionId or other applicable identifier (see note 7)	*{DENM.denm.management.actionId*} as specified in Annex A. The DEN service returns the *actionId* or other applicable identifier created by the DEN service to the requesting ITS-S application, in case the request was successfully handled.	
	Failure notification	The DEN service returns a failure notification to the requesting application under the condition as specified in clause 8.	Optional (see note 8)

NOTE 1: Applicable if the ITS-S application detects or estimates the event expiration time.
NOTE 2: Applicable if the ITS-S application requests the DENM repetition.
NOTE 3: Applicable if the ITS-S application requests the KAF for the DENM.
NOTE 4: As alternative of providing data via IF.DEN.1, the requesting ITS-S application may request DEN service to collect data from other facilities of the facilities layer.
NOTE 5: Applicable if the ITS-S application requests the transmission of an À La Carte container.
NOTE 6: Alternatively applicable if the ITS-S application has the knowledge of the awareness area or relevance zone (see clauses 6.1.3.1 and 6.1.3.2).
NOTE 7: An applicable identifier is associated to the *actionId* as created by the DEN service, it may be used for the interaction between the ITS-S application and the DEN service.
NOTE 8: Applicable as specified in clause 8.
NOTE 9: Data format is up to implementation.
NOTE 10: Present if provided by the ITS-S application, e.g. when the information is assigned by a central entity that provides the information to the ITS-S, e.g. a traffic management centre.

5.4.1.3 Data passed via interface IF.DEN.1 for the request type *AppDENM_update*

For the application request type *AppDENM_update*, Table 3 defines data being exchanged via the interface IF.DEN.1.

Table 3: Data passed via the interface IF.DEN.1 for *AppDENM_update*

Category	Data	Definition (see note 7)	Remarks
Data passed from application to DEN service	*actionId* or other applicable identifier	*ActionID* or other applicable identifier for which the update is detected (see note 1). *{DENM.denm.management.actionId*} as specified in Annex A.	
	Event update detection time	*{DENM.denm.management.detectionTime*} as specified in Annex A.	
	Event reference position	*{DENM.denm.management.eventPosition*} as specified in Annex A.	
	Awareness area of the event	*Additionally to the event reference position: {DENM.denm.management. awarenessDistance}* and {*DENM.denm.management. trafficDirection}* as specified in Annex A.	Optional (see note 2 and note 5)
	Event validity duration	*{DENM.denm.management.validityDuration}* as specified in Annex A.	Optional (see note 2)
	Repetition duration	Duration of the DENM repetition in units of milliseconds, denoted as *repetitionDuration*.	Optional (see note 2 and note 3)
	Transmission interval	*{DENM.denm.management.transmissionInterval}* as specified in Annex A.	Optional (see note 2 and note 4)
	Repetition interval	Interval of DENM repetition in units of milliseconds, denoted as *repetitionInterval.*	Optional (see note 2 and note 3)

Category	Data	Definition (see note 7)	Remarks
	Information contained in the situation container	*{DENM.denm.situation}* as specified in Annex A. This also contains the relevance zone information.	Optional (see note 2 and note 5)
	Information contained in the location container	*{DENM.denm.location}* as specified in Annex A.	Optional (see note 2)
	Information contained in the À La Carte container	*{DENM.denm.alacarte}* as specified in Annex A.	Optional (see note 2)
	Destination area	Destination area for DENM dissemination as specified in ETSI TS 103 899 [4].	
	Traffic class	GN traffic class of the DENM as defined in ETSI TS 103 836-4-1 [1], if GeoNetworking/BTP is used.	Optional (see note 2)
Data returned from DEN service to the requesting application	*actionId* or other applicable identifier (see note 1)	*{DENM.denm.management.actionId}* as specified in Annex A. The DEN service returns the *actionId* or other applicable identifier created by the DEN service to the requesting ITS-S application.	
	Failure notification	The DEN service returns a failure notification to the requesting application under the condition as specified in clause 8.	Optional (see note 6)

NOTE 1: An applicable identifier is associated to the *actionId* as created by the DEN service, it may be used for the interaction between the ITS-S application and DEN service.
NOTE 2: Applicable if an update of the data is detected.
NOTE 3: Applicable if the ITS-S application requests the DENM repetition.
NOTE 4: Applicable if the ITS-S application requests the KAF for the DENM.
NOTE 5: Applicable if the ITS-S application has the knowledge of the awareness area or the relevance zone (see clause 6.1.3.1 and 6.1.3.2).
NOTE 6: Applicable as specified in clause 8.
NOTE 7: Data format is up to implementation.

5.4.1.4 Data passed via interface IF.DEN.1 for the request type *AppDENM_termination*

For the application request type *AppDENM_termination*, Table 4 defines data being exchanged via the interface IF.DEN.1.

Table 4: Data passed via the interface IF.DEN.1 for *AppDENM_termination*

Category	Data	Definition (see note 7)	Remarks
Data passed from application to DEN service:	*actionId* or other applicable identifier	*actionId* or other applicable identifier for which the termination is detected (see note 1). *{DENM.denm.management.actionId}* as specified in Annex A.	
	Event termination detection time	*{DENM.denm.management.detectionTime}* as specified in the Annex A.	
	Event reference position	Position at which the event termination is detected. *{DENM.denm.management.eventPosition}* as specified in Annex A.	
	Awareness area of the event	*Additionally to the event reference position: {DENM.denm.management.awarenessDistance}* and *{DENM.denm.management.trafficDirection}* as specified in Annex A.	Optional (see note 2 and note 5)
	Event validity duration	Validity of the event termination information. *{DENM.denm.management.validityDuration}* as specified in Annex A.	Optional (see note 2)

Category	Data	Definition (see note 7)	Remarks
	Repetition duration	Duration of the DENM repetition in units of milliseconds, denoted as *repetitionDuration*.	Optional (see note 3)
	Transmission interval	*{DENM.denm.management.transmissionInterval}* as specified in Annex A.	Optional (see note 4)
	Repetition interval	Interval of DENM repetition in units of milliseconds, denoted as *repetitionInterval*.	Optional (see note 3)
	Destination area	Destination area for DENM dissemination as specified in ETSI TS 103 899 [4].	
	Traffic class	GN traffic class of the DENM as defined in ETSI TS 103 836-4-1 [1], if GeoNetworking/BTP is used.	
Data returned from DEN service to the requesting application	*actionId* or other applicable identifier (see note 1)	*{DENM.denm.management.actionId}* as specified in Annex A. The DEN service returns the *actionId* or other applicable identifier created by the DEN service to the requesting ITS-S application.	
	Failure notification	The DEN service returns a failure notification to the requesting application under the condition as specified in clause 8.	Optional (see note 6)
NOTE 1: An applicable identifier is associated to the *actionId* as created by the DEN service, it may be used for the interaction between the ITS-S application and DEN service. NOTE 2: Applicable if the application detects the event termination information expiry time. NOTE 3: Applicable if the application requests the DENM repetition. NOTE 4: Applicable if the ITS-S application requests the KAF for the DENM. NOTE 5: Applicable if the ITS-S application has the knowledge of the awareness area (see clause 6.1.3.1 and 6.1.3.2). NOTE 6: Applicable as specified in clause 8. NOTE 7: Data format is up to implementation.			

5.4.1.5 Data passed via interface IF.DEN.2 for received DENM

At the receiving ITS-S, the DEN service may provide the received DENM content in whole or in part to ITS-S applications via the interface IF.DEN.2. The list of data passed via the interface IF.DEN.2 from the DEN service may vary depending to the ITS application needs.

Alternatively, ITS-S applications may receive DENM information via the LDM database as described in clause 5.2.

Table 5 provides an example of data passed via IF.DEN.2.

Table 5: Data passed via the interface IF.DEN.2

Category	Data	Definition (see note 2)	Remarks
Data passed from DEN service to ITS-S applications	DENM	*{denm}* in whole or in part as specified in Annex A.	Optional (see note 1)
NOTE 1: Applicable if ITS-S application of the receiving ITS-S requests the content of received DENM. NOTE 2: Data format is up to implementation.			

5.4.1.6 Methods for data exchanges between DEN service and ITS application layer

In one possible implementation of IF.DEN.2, DENM content is provided directly by the DEN service to the ITS-S application when a DENM is received (push mode), or on demand when an ITS-S application requests specific DENM content to the DEN service (pull mode). In another possible implementation, both - push and pull - modes may be implemented.

Similar data exchange method may also be used for the implementation of the interface IF.DEN.1. When the ITS-S application sends a request to the DEN service, data is pushed from the application to the DEN service. DEN service returns data as specified in clauses 5.4.1.2, 5.4.1.3 and 5.4.1.4 to the ITS-S application.

NOTE: It is out of the scope of the present document to specify data exchange method of the interfaces between the DEN service and the ITS-S application.

5.4.2 Interface to MCO_FAC

If the ITS-S supports MCO, the DEN service exchanges information with the MCO_FAC via the interface IF.MCO depicted in Figure 2. This interface can be used to configure the default MCO settings for the generated DENMs and can also be used to configure the MCO parameters on a per message basis.

If the ITS-S supports MCO, at the originating ITS-S the DEN service shall provide the DENM embedded in a Facility-layer Service Data Unit (FL-SDU) together with protocol control information (PCI) to the MCO_FAC via the interface IF.MCO specified in ETSI TS 103 141 [10]. In addition, it can also provide MCO Control Information (MCI) following ETSI TS 103 141 [10] to configure the MCO parameters of the DENM being provided. At the receiving ITS-S, the MCO_FAC passes the received DENM to the DEN service.

If the ITS-S supports MCO, the data set that is passed between DEN service and the MCO_FAC for the originating and receiving ITS-S is specified in Table 6.

Table 6: Data exchanged between the DEN service and the MCO_FAC

Category	Data	Data requirement	Mandatory/Conditional /Optional
Data passed from the DEN service to the MCO_FAC	DENM	*{denm}* as specified in Annex A	Mandatory
	PCI	Depending on the protocol stack applied in the networking and transport layer.	Optional
	MCI	MCO parameters configuration. Required if the default MCO parameters have not been configured or need to be overwritten for a specific DENM	Conditional
Data passed from the MCO_FAC to the DEN service	Received DENM	*{denm}* 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 DEN service to the GeoNetworking/BTP stack shall comply with Table 8.

5.4.3 Interface to the ITS networking & transport layer

5.4.3.1 General requirements

If the ITS-S does not support MCO, the DEN service exchanges information with the ITS networking & transport layer via the interface IF.N&T (Figure 3).

If the ITS-S does not support MCO, at the originating ITS-S the DEN service shall provide a DENM to together with the Protocol Control Information (PCI) specified in Table 7 to the ITS networking & transport layer. At receiving ITS-S, if the receiving ITS-S is considered as the destination of the DENM dissemination, the ITS networking & transport layer delivers the received DENM to the DEN service.

If the ITS-S does not support MCO, the data set that is passed between DEN service and the ITS networking & transport layer for the originating and receiving ITS-S is specified in Table 7.

Table 7: Data passed between the DEN service and the ITS networking & transport layer

Category	Data	Definition (see note 3)	Remarks
Data passed from DEN service to the ITS networking & transport layer	DENM	*{denm}* as specified in Annex A.	
	Destination area	Destination area for DENM dissemination. The definition of DENM destination area shall be as specified in ETSI TS 103 899 [4].	
	Repetition interval	In units of milliseconds.	Optional (see note 1)
	its_aid	See ETSI TS 102 965 [3] for the ITS-AID value.	Optional (see note 4)
	permissions	See clause 6.2.2.2.	Optional (see note 4)
Data passed from the ITS networking & transport layer	Received DENM	*{denm}* as specified in Annex A.	Optional (see note 2)
	report	See ETSI TS 103 097 [8].	Optional (see note 4)
	Certificate_id	See ETSI TS 103 097 [8].	Optional (see note 4)
	its_aid	See ETSI TS 102 965 [3].	Optional (see note 4)
	permissions	See clause 6.2.2.2.	Optional (see note 4)
NOTE 1: Applicable if the ITS-S application requests the DENM repetition by the ITS networking & transport layer. The repetition may also be performed by the DEN service at the facility layer as described in clause 5.4.1. NOTE 2: Applicable of the receiving ITS-S is considered by the ITS networking & transport layer as inside the destination area. NOTE 3: Data format is up to implementation. NOTE 4: Present only if ETSI ITS security [8] and [9] at the network layer security is used.			

5.4.3.2 Interface to the GeoNetworking/BTP stack

The DEN service may use the GeoNetworking/BTP protocol stack to disseminate a DENM to a destination area.

If the GeoNetworking/BTP protocol stack is used, BTP header type B as specified in ETSI TS 103 836-5-1 [2] and GeoBroadcast protocol as specified in ETSI TS 103 836-4-1 [1] shall be used for the DENM dissemination.

Data being passed between the DEN service and the GeoNetworking/BTP stack is specified in Table 7 and in Table 8.

In case network layer security is used, GN security profile shall be set to SECURED.

In case facility layer security is used, GN security profile shall be set to UNSECURED.

Table 8: Data passed from DEN service to GeoNetworking/BTP at the originating ITS-S

Category	Data	Requirement (see note 3)	Remarks
Data passed from the DEN service to GeoNetworking/BTP	BTP type	BTP header type B (ETSI TS 103 836-5-1 [2], clause 7.2.2).	Optional (see note 1)
	Destination port	As specified in ETSI TS 103 836-5-1 [2]. (see note 2).	Optional (see note 1)
	Destination port info	As specified in ETSI TS 103 836-5-1 [2].	Optional (see note 1)
	GN Packet transport type	GeoNetworking GeoBroadcast protocol.	Optional (see note 1)
	GN Destination address	Specified as Destination area in Table 7.	
	GN communication profile	Unspecified, ITS G5 or LTE-V2X.	Optional (see note 1)
	GN security profile	SECURED or UNSECURED.	Optional (see note 1)
	Traffic class	As defined in ETSI TS 103 836-4-1 [1].	
	GN Maximum packet lifetime	Shall not exceed *validityDuration.*	Optional (see note 1)
	GN Hoplimit		Optional (see note 1)
	Length	Length of the DENM.	
NOTE 1: Applicable if the value is not provided or different from the ITS-S configuration. NOTE 2: When a global registration authority for ITS application ISO EN 17419 [i.8] is operational, the BTP destination port registered with this authority should be used. NOTE 3: Data format is up to implementation.			

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

The DEN service may use the IPv6 protocol stack or the combined IPv6/GeoNetworking protocol stack as defined in ETSI TS 103 836-3 [i.7] for DENM dissemination.

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

NOTE 2: In case IP based transport is used to transfer the facility layer DENM between interconnected actors, security constraints as outlined in clause 6.1.1.2 and clause 6.2.2 may not be applicable. This is because trust 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. need to be agreed among interconnected actors.

When the DENM dissemination makes use of the combined IPv6/GeoNetworking stack, the interface between the DEN service and the combined IPv6/GeoNetworking stack may be identical to the interface between the DEN service and IPv6 stack.

5.4.4 Interface to the ITS management entity

The DEN service may exchange information with the ITS management entity via the interface IF.Mng (Figure 3).

5.4.5 Interface to the ITS security entity

In case facility layer security is used, the DEN service exchanges information directly with the ITS security entity via the interface IF.SEC (Figure 3).

6 DENM dissemination requirements

6.1 DENM dissemination concepts

6.1.1 Event identification

6.1.1.1 actionId

The event identification is enabled by the component *actionId*. Each time a new DENM is generated upon an application request, a new *actionId* value shall be assigned.

The *actionId* shall be the combination of an ITS-S ID and a sequence number. The ITS-S ID corresponds to *stationId* of the originating ITS-S that detects an event for the first time or to the virtual *stationId* of a central entity that provides the information to the ITS-S, e.g. a traffic management centre that provides data to a roadside ITS-S to be sent as DENM. The sequence number is assigned to the *actionId* for each new DENM.

For each new DENM, a value shall be assigned to a sequence number that has not been assigned together with the *stationId* value in a period of configurable length in the past.

An *actionId* is linked to one originating ITS-S or a central entity. In case multiple originating ITS-Ss detect the same event for the first time, the assigned *actionId* should be different in each originating ITS-S.

The *actionId* is used in forwarding and receiving ITS-S for the DENM protocol operation. An *actionId* may enable an ITS-S to distinguish DENMs transmitted from different originating ITS-Ss and DENMs transmitted by the same originating ITS-S for different events.

6.1.1.2 *stationId* update and *actionId* management

ITS stations that are part of an ecosystem which use the trust model according to ETSI TS 102 940 [9] and ITS certificates according to ETSI TS 103 097 [8] and that are of type [Itss_WithPrivacy] as defined in ETSI TS 102 940 [9] shall implement functionalities that assigns temporal *stationIds* (pseudonyms) to be used at the facilities layer and to be included in a generated *actionId*. This *stationId* shall change over time as required in ETSI TS 102 940 [9] for [Itss_WithPrivacy].

When the DEN service generates an *actionId* for a new DENM, a valid value of *stationId* shall be used. When the *stationId* is updated, all *actionId* and *stationId* values in the DENM header that are generated and stored in the originating ITS-S shall be updated.

NOTE: ITS stations of type [Itss_NoPrivacy] as defined in ETSI TS 102 940 [9] may not implement functionalities that assigns temporal stationIds (pseudonyms). ITS stations that are not part of an ecosystem, which uses the trust model according to ETSI TS 102 940 [9] and ITS certificates according to ETSI TS 103 097 [8] may not need to implement functionalities that assigns temporal stationIds (pseudonyms) either.

6.1.2 Trigger, update, repetition and termination of DENM

6.1.2.1 DENM trigger

DENM trigger refers to the process of the generation and transmission of a DENM when the DEN service of the originating ITS-S receives an application request with the type *AppDENM_trigger*. A new DENM shall be generated.

For DENM trigger, an unused *actionId* value shall be created by the DEN service.

If the ITS-S supports MCO, the DENM shall be transmitted on the preferred channel and may be additionally transmitted on alternative channels.

NOTE: The definition of preferred and alternative channel is out of the scope of the present specification and is subject of an interoperability profile.

6.1.2.2 DENM update

The originating ITS-S may detect the evolution of an event some time after the DENM trigger. The ITS-S application provides the update information to the DEN service using the application request *AppDENM_update*. The DEN service shall then generate an update DENM. This process is denoted as DENM update.

The parameter *referenceTime* is the identifier for DENM update referring to a specific *actionId*. The *referenceTime* represents the time at which a DENM is generated by the DEN service, after receiving the application request. For each DENM update, the *referenceTime* shall be updated and the value shall be greater than the *referenceTime* value of the previous DENM update for the same *actionId*.

The *actionId* shall remain unchanged for DENM update, as long as the *stationId* of the originating ITS-S remains unchanged.

The *actionId* shall remain unchanged when the *validityDuration* is updated, as long as the *stationId* of the originating ITS-S remains unchanged.

6.1.2.3 DENM repetition

In between two consequent DENM updates, a DENM may be repeated by the DEN service of the originating ITS-S at a pre-defined repetition interval, in order that new ITS-Ss entering the destination area during the event validity duration may also receive the DENM. This process is referred to as DENM repetition.

The DENM repetition shall be activated under the request from the ITS-S application. If ITS-S application at the originating ITS-S requires the repetition of DENM, it shall provide following data in the application request as specified in clause 5.4.1:

- *repetitionInterval*.

- *repetitionDuration*.

If any of the above data are not provided by the ITS-S application, the DEN service shall not execute the DENM repetition. At the reception of the application request, the DENM repetition scheduling shall start from the *referenceTime*, corresponding to the time at which DENM is generated.

For one particular *actionId*, DENM repetition should apply to the most updated DENM.

If the ITS-S supports MCO, *repetitionInterval* and *repetitionDuration* shall be adjusted by the DEN service to satisfy the limits provided by MCO_FAC in the preferred and alternative channels as defined in ETSI TS 103 141 [10].

6.1.2.4 DENM termination

The DENM termination indicates the end of the detected event. A DENM termination is either a cancelation or a negation. Cancellation DENM can only be transmitted by the originating ITS-S that originally requested the DENM trigger. Negation DENM can be transmitted by other ITS-Ss:

- DENM termination by the originating ITS-S that requested the DENM trigger:
  - For originating ITS-S that requested the DENM trigger, the DEN service shall stop the DENM repetition automatically at the end of the *repetitionDuration*. The *repetitionDuration* may be updated by the ITS-S application of the originating ITS-S.
  - Moreover, before the expiration of the *validityDuration*, the originating ITS-S may detect the termination of the event. In this case, the DEN service shall generate a cancellation DENM as defined in clause 4.2. The parameter *termination* is used for the cancellation DENM. For the generation of a cancellation DENM, *termination* shall be set to *isCancellation*.
  - For the generation of a cancellation DENM, the *actionId* value shall be identical to the *actionId* as set for the application request *appDENM_trigger*, as long as the *stationId* remains unchanged.

NOTE 1: In a cancellation DENM, the *stationId* value included in the *actionId* is identical to the *stationId* of the originating ITS-S.

- DENM termination by an originating ITS-S that has not requested the DENM trigger, i.e. that has not created *actionId* of the event for which the DENM termination is intended:
  - If an ITS-S has received a DENM from other ITS-S regarding an event, passes the indicated awareness area / relevance zone when the received DENM is still valid (i.e. *validityDuration* is not expired), and detects that the event has terminated, then the ITS-S application at this ITS-S may send a *AppDENM_termination* request to the DEN service, upon which the DEN service shall generate a negation DENM as defined in clause 4.2.
  - The parameter *termination* is used for the negation DENM. For the generation of a negation DENM, *termination* shall be set to *isNegation*.
  - For the generation of a negation DENM, the *actionId* shall be set to the *actionId* of the event for which the DENM negation refers to. The *referenceTime* shall be set to the value of the latest received DENM of the same *actionId* from the originating ITS, in order that the receiving ITS-S is able to match to which DENM the negation is reported by the negation DENM.

NOTE 2: In a negation DENM, the *stationId* value included in the *actionId* is not identical to the *stationId* value in the *itsPduHeader* (defined in Annex A) of the originating ITS-S that generates the negation DENM.

NOTE 3: The ITS-S that initiates the negation DENM satisfies some predefined conditions as defined by ITS applications.

For the cancellation DENM and negation DENM, the *detectionTime* shall be set as the time at which the event termination is detected by the originating ITS-S. Once the DENM is expired, the corresponding entry might be detected and the corresponding *actionId* may be used for future new DENM generation.

Once a cancellation DENM or a negation DENM is verified to be trustworthy by the receiving ITS-S, all information related to the previously received DENMs concerning the same *actionId* may be considered as not valid anymore, the DEN service may notify ITS-S applications of the event termination.

A cancellation DENM or negation DENM shall be transmitted at least once by the originating ITS-S per application request. It may be repeated by the DEN service of the originating ITS-S.

6.1.3 Geographic location information

6.1.3.1 Awareness area

Depending on the use case as identified by the event type, the awareness area is defined by the ITS-S application of the originating ITS-S. The provided information shall be included in the DENM as made available to the DEN service. A receiving ITS-S may make use of the awareness area information in order to prepare for possible actions, such as giving input to the vehicle´s Human Machine Interface.

According to the event type and the event location, the size and the shape of the awareness area varies. The awareness area may be defined as:

- Single circular awareness area, defined by a centre position and a radius: this option can be used for use cases where the event is located somewhere inside a (static or dynamic) circular area, such as:
  - The Hazardous Location Notification - Weather Condition Warning, Temporarily Slippery Road, or Animal or Person on the Road use cases defined in [i.4].
  - The Dangerous situation, Special Vehicle Warning, Stationary Vehicle Warning, Traffic Jam use cases defined in [i.2].
- Single linear awareness area, as a polyline from a start position: this option can be used for use cases where the event is located somewhere along a stretch of road such as the Hazardous Location Notification - Wrong Way Driver, Weather Condition Warning (first option) or Temporarily Slippery Road use cases defined in [i.4].
- Single linear awareness area, as a part of the road that starts at a start position and ends at an end position along that road.
- Multiple circular awareness areas, located at multiple positions along a stretch of road and all with the same radius: this option can be used for use cases where the event is located somewhere inside multiple circular areas, such as the Weather Condition Warning (second option) use case defined in [i.2].

One or more of the following information shall be used as longitudinal awareness area information as defined in Table 9:

- *eventPosition*: the event reference position, i.e. the centre position of the single circular awareness area or of the first of the multiple circular awareness areas, or the start position of the linear awareness area.
- *awarenessDistance*: the radius of the circular awareness area(s) in which the receiving ITS-S may encounter the event.
- *trafficDirection*: the traffic direction along which the receiving ITS-S may encounter the event.
- *eventZone*:
  - option with *eventDeltaTime* ABSENT: a list of waypoints that, including the *eventPosition*, represents a linear awareness area polyline: this is for example the case of a not precisely localized (dynamic) event detected by a roadside ITS-S or by a central entity, where each waypoint corresponds to a point in the linear awareness area.
  - option with *eventDeltaTime* PRESENT: a list of waypoints that, including the *eventPosition*, each represent the centre position of a circular awareness area: This is for example the case of an event detected by a vehicle ITS-S, where the *eventZone* consists of a list of event detection points along the path that the detecting ITS-S has travelled over some past time and/or distance. Each event point corresponds to a point at which the same event was detected along the path and includes the component *eventDeltaTime*.
- *eventEnd*: the end position of the awareness area, specified as a distance from the start position along that road.

Table 9: Longitudinal awareness area information

Awareness area type	*eventPosition*	*awareness Distance*	*trafficDirection*	*eventZone*	*eventEnd*
Single circular awareness area	Present	Present	Optional	Absent	Absent
Single linear awareness area - polyline	Present	Absent	Optional	Present, with eventDeltaTime ABSENT	Absent
Single linear awareness area - start & end	Present	Absent	Optional	Absent	Present
Multiple circular awareness areas (see note)	Present	Present	Optional	Present, with eventDeltaTime PRESENT	Absent

The components eventPosition, awarenessDistance, trafficDirection, eventZone and eventEnd shall be as specified in Annex A.

NOTE: If a DENM contains an *eventZone* and an *awarenessDistance* component, multiple awareness areas exist. One area is located at the *eventPosition* component and each point in the *eventZone* component creates an additional, individual awareness area, each with the *awarenessDistance* as radius.

The lateral extension of the awareness area is optionally provided by the components *lanePositions* and/or *occupiedLanes* of the Location container, see clause 7.1.5.

6.1.3.2 Relevance zone

Alternatively to the awareness area, and depending on the use case as identified by the event type, the relevance zone is defined by the ITS-S application of the originating ITS-S. The provided information shall be included in the DENM as made available to the DEN service. The *eventType* component implicitly indicates if an awareness area or a relevance zone is included in the DENM. A receiving ITS-S may make use of the relevance zone information in order to perform actions such as giving input to the vehicle´s Human Machine Interface or driving automation functions.

According to the event type and the event location, the size and the shape of the relevance zone varies. The relevance zone may be defined as:

- A point-based relevance zone, i.e. a degenerate circle with radius zero located at the centre position. This option can be used for use cases where the event is with high certainty located in a certain position, such as the Hazardous Location Notification - Accident Zone, Stationary Vehicle or Traffic Jam (dangerous end of queue) use cases or the Road Works Warning - Lane Closure and Road Closure use cases, e.g. providing the start of the closure of the lane, without extension information defined in [i.4].

- A single linear relevance zone, as a polyline from a start position. This option can be used for use cases where the event extends with high certainty over an entire stretch of road, such as the Hazardous Location Notification - Traffic Jam use case or the Road Works Warning - Lane Closure and Road Closure use cases, providing extension information, defined in [i.4].

- A single linear relevance zone, as a part of the road that starts at a start position and ends at an end position along that road.

One or more of the following information shall be used as longitudinal relevance zone information as defined in Table 10:

- *eventPosition*: the event reference position, i.e. the centre position of the point-based relevance zone or the start position of the linear relevance zone.

- *awarenessDistance*: always absent in case of relevance zone information.

- *trafficDirection*: the traffic direction along which the receiving ITS-S will encounter the event.

- *eventZone*:
  - option with *eventDeltaTime* ABSENT: a list of waypoints that, incl. the *eventPosition*, represents a linear relevance zone polyline: this is for example the case of an extended event detected by a roadside ITS-S or by a central entity, where each waypoint corresponds to a point in the linear relevance zone.
- *eventEnd*: the end position of the relevance zone, specified as a distance from the start position along that road.

Table 10: Longitudinal relevance zone information

Relevance zone type	*eventPosition*	*awareness Distance*	*trafficDirection*	*eventZone*	*eventEnd*
Point based relevance zone	Present	Absent	Optional	Absent	Absent
Single linear relevance zone – polyline	Present	Absent	Optional	Present, with eventDeltaTime ABSENT	Absent
Single linear relevance zone – start & end	Present	Absent	Optional	Absent	Present

The *eventPosition*, *awarenessDistance*, *trafficDirection*, *eventZone* and *eventEnd* shall be as specified in Annex A.

The lateral extension of the relevance zone is optionally provided by the components *lanePositions* and/or *occupiedLanes* of the Location container, see clause 7.1.5.

6.1.3.3 Detection zone

Complementary to the awareness area / relevance zone, a DENM provides detection zone information. A receiving ITS-S may compare its own trajectory with the detection zone information in order to detect the entering into an awareness area / a relevance zone.

If the Location container is present, the component *detectionZonesToEventPosition* of type *Traces*, shall contain up to 7 paths, which each represents a list of well-ordered waypoints that forms a path or trajectory approaching towards the event reference position, using the Data Frame *Path*.

The optional component *detectionZonesToSpecifiedEventPoint* of type *TracesExtended*, if present, shall contain up to 7 paths, which each represent a list of well-ordered waypoints that forms a path approaching towards a specific point of the *eventZone*, using the Data Frame *PathExtended*.

NOTE 1: The present document specifies the data formatting rules for paths or trajectories to be included in DENM, as specified in Annex A. However, the total length covered by a trace or density of waypoints in a trace may vary depending on ITS application needs.

NOTE 2: Details of the usage of *detectionZonesToEventPosition* and *detectionZonesToSpecifiedEventPoint* at receiving ITS-Ss are out of scope of the present document.

A DENM of type New or Update shall include at least one path or trajectory inside the component *detectionZonesToEventPosition* . Multiple paths may be included in DENM, e.g. in case there are more than one possible paths in which a detected event may be approached, e.g. in an intersection area.

The components *detectionZonesToEventPosition* and *detectionZonesToSpecifiedEventPoint* are defined and provided by the ITS-S application of the originating ITS-S and shall be included in DENM.

The components *detectionZonesToEventPosition* and *detectionZonesToSpecifiedEventPoint* shall be as specified in Annex A.

6.1.3.4 Destination area

The destination area is used by the ITS networking & transport layer for the DENM transmission. According to ETSI TS 103 899 [4], three geometric shapes are defined, each shape being represented by the combination of one or several geographical point and distance information:

- circular shape;

- rectangular shape;
- elliptical shape.

The DEN service of the originating ITS-S shall provide the destination area information to the ITS networking & transport layer.

The size and the shape of the awareness area and/or relevance zone are not necessarily identical to the destination area. The DEN service shall provide the destination area in the format compliant to the one as specified in ETSI TS 103 899 [4] to the ITS networking & transport layer.

The destination area should be selected in a way that receivers are sufficiently informed in advance. As an example, for an accident on a motorway, the component *trafficDirection* of a DENM related to the event may indicate the upstream portion of the traffic affect by the accident location. In such cases, the destination area should cover more of the upstream area than of the downstream area. For an accident that occurred on rural two-way roads, the component *trafficDirection* may indicate both traffic directions (also including the opposite direction). For such case, the destination area should be centred at the event to cover upstream and downstream parts equally.

6.1.4 DENM forwarding

6.1.4.1 Packet centric forwarding

DENM forwarding may be realized by the ITS networking & transport layer or the facilities layer.

The packet centric forwarding function refers to the ITS networking & transport layer functionality that forwards a DENM from the originating ITS-S to the destination area.

NOTE: The specification of this function is out of scope of the present document. When GeoNetworking/BTP stack is used, this functionality is specified in ETSI TS 103 836-4-1 [1].

6.1.4.2 Keep-alive forwarding

The Keep-Alive Forwarding (KAF) functionality is optional for the DEN service.

The KAF refers to the ITS facilities layer forwarding scheme, represented as a sub-function of DEN service in Figure 3. The main objective of KAF is to store a received DENM in the DEN service and to forward it to other ITS-Ss when necessary.

The KAF may be triggered by the DEN service or by an ITS application for one or several *actionId*s. Once triggered, the KAF may store the received DENM of the relevant *actionId* as long as all the below conditions are met:

- the validity duration of the received DENM is not expired;
- the ITS-S is located within the destination area or the awareness area / relevance zone of the received DENM;
- the event is not cancelled by the originating ITS-S;
- the event is not negated by any originating ITS-S.

The KAF may redeliver a DENM being stored in the DEN service to the ITS networking & transport layer if necessary. In one possible forwarding protocol, the KAF may forward a DENM if the DEN service has received neither DENM of the same *actionId* forwarded by any other ITS-S nor DENM of the same *actionId* transmitted from the originating ITS-S within a certain period of time. Only DENMs with the most recent *referenceTime* will be forwarded by the KAF.

KAF and packet centric forwarding functions may be complementary with each other. The KAF is able to maintain the dissemination of most updated DENM in the awareness area / relevance zone or in the destination area before the *validityDuratio*n expires, even though the originating ITS-S has lost the capacity to transmit the DENM by itself. For example, if the originating ITS-S is a broken down vehicle, it may stop transmitting DENM unexpectedly due to the failed operation of the vehicle ITS-S. In this case, KAF function of an ITS-S may be used to continue the transmission of DENM that it has received before.

The operation of one possible KAF protocol is specified in clause 8.3.

6.2 DENM dissemination constraints

6.2.1 General confidence constraints

Special data confidence constraints may apply to some data provided in the DENM, depending on the detection capabilities of the ITS-S, such as position accuracy constraint, time accuracy constraint and event detection quality constraint.

These confidence constraints are presented in the data element and data frame definitions as specified in Annex A of the present document and in ETSI TS 102 894-2 [5].

NOTE: According to the requirements of specific ITS-S application, data contained in a DENM may be obtained from different sources, e.g. from the in vehicle network or from ITS-S users via specific Human Machine Interface (HMI). Corresponding requirements are defined in ITS applications, ITS service and use case specifications such as the C2C-CC Basic System Profile [i.2] and the C-Roads Release [i.4].

6.2.2 General security constraints

6.2.2.1 Introduction

Clause 6.2.2 is applicable to ITS stations that are part of an ecosystem that uses the trust model according to ETSI TS 102 940 [9] and ITS certificates according to ETSI TS 103 097 [8]. The security mechanisms for ITS consider the authentication of messages transferred between ITS-Ss with certificates. A certificate indicates its holder's permissions, i.e. what statements the holder is allowed to make or privileges it is allowed to assert in a message signed by that certificate. The format for the certificates is specified in ETSI TS 103 097 [8]. Permissions are indicated by a pair of identifiers within the certificate, the ITS-AID and the SSP.

The ITS-Application Identifier (ITS-AID) indicates the overall type of permissions being granted: for example, there is an ITS-AID that indicates that the originating ITS-S is entitled to send DENMs, see ETSI TS 102 965 [3].

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 DENM that indicates the originating ITS-S is entitled to send DENMs with a cause code value (defined in clause 7.1.4) set.

ITS-S provides SSP information in its certificate for all generated, signed DENMs. This applies to new DENM, update DENM, cancellation DENM, and negation DENM. A received signed DENM is accepted by the receiving ITS-S if the DENM is consistent with the ITS-AID and SSP in its certificate.

6.2.2.2 Service Specific Permissions (SSP)

DENMs shall be signed using private keys associated to Authorization Tickets of type explicit that contain SSPs of type *BitmapSsp* as specified in ETSI TS 103 097 [8]. The *BitmapSsp* for DENMs shall conform to the DENM SSP octet scheme defined below.

The DENM SSP octet scheme allows the SSP format to flexibly accommodate the needs of the present document and of future versions of the present document. The octet scheme for DENM SSP is constructed out of a variable number of octets as illustrated in Figure 4, with SSP length $N \leq 31$.

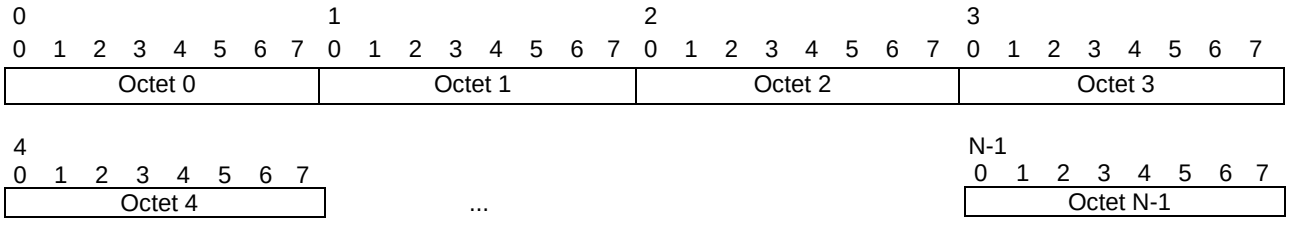

Figure 4: Format for the Octets

EXAMPLE of bit order: The decimal value 199 shall be represented as shown in Figure 5.

0	1	2	3	4	5	6	7
1	1	0	0	0	1	1	1

Figure 5: Example of octet presentation

For each octet, the most significant bit (MSB) shall be the leftmost bit. The transmission order shall always be the MSB first.

The length information of the SSP is indicated by the length indicator of the type BitmapSsp which is an Octet String according to ETSI TS 103 097 [8].

The octet scheme for DENM SSP is specified in Table 11.

The first octet (octet 0 in Figure 4) shall indicate the SSP version in the following way:

0: Null version, corresponding to an SSP length of 1 octet; this value shall only be used for testing purposes.

1: First version, corresponding to an SSP length of 4 octets, as specified in [i.9].

2: Second version, corresponding to an SSP length of 5 octets, as specified in Table 11.

3 to 255: Reserved for future usage.

As future versions of the present document are published, the SSP version will be incremented each time the length of the service-specific parameter is increased.

The second to fifth octet (octet 1 to octet 4 in Figure 4) represent the service-specific parameter and are based on the cause code values described in the clause 7.1.4, as defined in Table 12.

Table 11: Octet scheme for DENM SSP

Octet #	Description
0	SSP version control
1 to 3	Service-specific parameter - Release 1 (already specified in [i.9]), as specified in Table 12.
4	Service-specific parameter - Extension for Release 2, as specified in Table 12.
5 to 30	Reserved for Future Usage (not included for this SSP version)

Table 12: DENM SSP service-specific parameter

Octet position	Bit position	Cause code value	Bit value
1	0 (0x80) (MSBit)	trafficCondition1	0: certificate not allowed to sign
			1: certificate allowed to sign
1	1 (0x40)	accident2	0: certificate not allowed to sign
			1: certificate allowed to sign
1	2 (0x20)	roadworks3	0: certificate not allowed to sign
			1: certificate allowed to sign
1	3 (0x10)	adverseWeatherCondition-Adhesion6	0: certificate not allowed to sign
			1: certificate allowed to sign
1	4 (0x08)	hazardousLocation-SurfaceCondition9	0: certificate not allowed to sign
			1: certificate allowed to sign
1	5 (0x04)	hazardousLocation-ObstacleOnTheRoad10	0: certificate not allowed to sign
			1: certificate allowed to sign
1	6 (0x02h)	hazardousLocation-AnimalOnTheRoad11	0: certificate not allowed to sign
			1: certificate allowed to sign
1	7 (0x01) (LSBit)	humanPresenceOnTheRoad12	0: certificate not allowed to sign
			1: certificate allowed to sign
2	0 (0x80) (MSBit)	wrongWayDriving14	0: certificate not allowed to sign
			1: certificate allowed to sign
2	1 (0x40)	rescueAndRecoveryWorkInProgress15	0: certificate not allowed to sign
			1: certificate allowed to sign
2	2 (0x20)	adverseWeatherCondition-ExtremeWeatherCondition17	0: certificate not allowed to sign
			1: certificate allowed to sign

Octet position	Bit position	Cause code value	Bit value
2	3 (0x10)	adverseWeatherCondition-Visibility18	0: certificate not allowed to sign
			1: certificate allowed to sign
2	4 (0x08)	adverseWeatherCondition-Precipitation19	0: certificate not allowed to sign
			1: certificate allowed to sign
2	5 (0x04)	slowVehicle26	0: certificate not allowed to sign
			1: certificate allowed to sign
2	6 (0x02)	dangerousEndOfQueue27	0: certificate not allowed to sign
			1: certificate allowed to sign
2	7 (0x01) (LSBit)	vehicleBreakdown91	0: certificate not allowed to sign
			1: certificate allowed to sign
3	0 (0x80) (MSBit)	postCrash92	0: certificate not allowed to sign
			1: certificate allowed to sign
3	1 (0x40)	humanProblem93	0: certificate not allowed to sign
			1: certificate allowed to sign
3	2 (0x20)	stationaryVehicle94	0: certificate not allowed to sign
			1: certificate allowed to sign
3	3 (0x10)	emergencyVehicleApproaching95	0: certificate not allowed to sign
			1: certificate allowed to sign
3	4 (0x08)	hazardousLocation-DangerousCurve96	0: certificate not allowed to sign
			1: certificate allowed to sign
3	5 (0x04)	collisionRisk97	0: certificate not allowed to sign
			1: certificate allowed to sign
3	6 (0x02)	signalViolation98	0: certificate not allowed to sign
			1: certificate allowed to sign
3	7 (0x01) (LSBit)	dangerousSituation99	0: certificate not allowed to sign
			1: certificate allowed to sign
4	0 (0x80) (MSBit)	impassability5	0: certificate not allowed to sign
			1: certificate allowed to sign
4	1 (0x40)	aquaplaning7	0: certificate not allowed to sign
			1: certificate allowed to sign
4	2 (0x20)	publicTransportVehicleApproaching28	0: certificate not allowed to sign
			1: certificate allowed to sign
4	3 (0x10)	railwayLevelCrossing100	0: certificate not allowed to sign
			1: certificate allowed to sign
4	4 (0x08)	reserved for future usage	0: certificate not allowed to sign
4	5 (0x04)	reserved for future usage	0: certificate not allowed to sign
4	6 (0x02)	reserved for future usage	0: certificate not allowed to sign
4	7 (0x01) (LSBit)	reserved for future usage	0: certificate not allowed to sign

NOTE 1: The setting of the (sub) cause code and the related triggering conditions are out of scope of the SSP.

NOTE 2: From security point of view, enabling one cause code value by setting the corresponding SSP bit automatically enables all corresponding sub cause code value. However, the triggering conditions of the sub cause code value are defined by ITS application requirements. As consequence, if the SSP for a cause code value is set to 1, it does not imply that the ITS-S is able to detect all events of the corresponding sub cause code values.

EXAMPLE: The application Electronic Emergency Break Light (EEBL) requires the SSP bit for dangerousSituation(99) to be set to 1 because emergencyElectronicBrakeEngaged(1) is part of DangerousSituationSubCauseCode. However, this does not mean that aebEngaged(5) can be detected.

NOTE 3: an implementation of the DEN service conformant to the present document should be able to correctly receive and decode both DENMs including an Authorization Ticket with SSP version 2 and DENMs including an Authorization Ticket with SSP version 1. The DEN service should be also prepared to correctly receive and (partly) decode DENMs conformant to future Release 2 versions of the present document, i.e. DENMs including an Authorization Ticket with SPP version higher than 2.

6.2.3 General priority constraints

The DENM priority is defined by the related use case specified in the C2C-CC Basic System Profile [i.2] and the C-Roads Release [i.4].

Priority information is provided in the PCI across the OSI layers and/or transmitted by lower layers as specified as Traffic Class in ETSI TS 103 836-4-1 [1]. Therefore, it is not included in a DENM.

7 DENM specification

7.1 DENM structure

7.1.1 General structure of a DENM

A DENM is a PDU composed of a common ITS PDU header and multiple containers, which constitutes the DENM payload.

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

The component *denmPayload* represents the DENM payload and consists of four fixed order components:

- The component *management* represents the Management container and contains information related to the DENM management and the DENM protocol.
- The component *situation* represents the Situation container and contains information related to the type of the detected event.
- The component *location* represents the Location container and contains further information about the event location, and the detection zone information.
- The component *alacarte* represents the À La Carte container and contains information specific to the use case which requires the transmission of additional information that is not included in the three previous containers.

For all types of DENM, the ITS PDU header and the Management container shall always be present. The Situation container, the Location container and the À La Carte container are optional containers:

- For a Cancellation DENM or a Negation DENM, the Situation container, Location container and À La Carte container shall not be present.
- For a New or Update DENM, the Situation container and the Location container shall be present. The À La Carte container is present only when applicable as specified in application specifications, such as the C2C-CC Basic System Profile [i.2] and the C-Roads Release [i.4].

The general structure of a DENM is illustrated in Figure 6. 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 DENM Format. If not specified as optional in Annex A of the present document, a component is considered as mandatory. Components that are optional shall be present if the information is provided by the ITS-S application of the originating ITS-S.

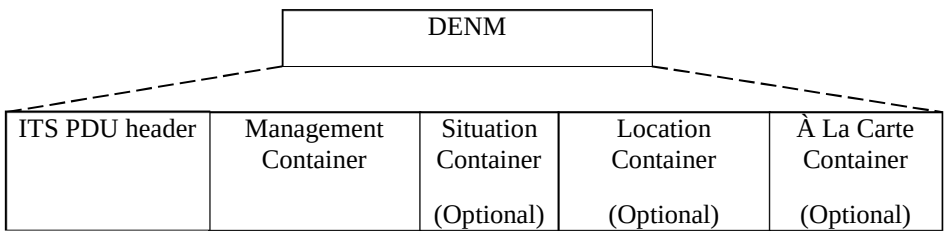

Figure 6: General structure of a DENM

7.1.2 ITS PDU header

The ITS PDU header shall be as specified in ETSI TS 102 894-2 [5] and as constraint in Annex A.

7.1.3 DENM Management container

The Management container shall include the components: *actionId*, *detectionTime*, *referenceTime*, *eventPosition*, *validityDuration* and *stationType* and may include the components *termination*, *awarenessDistance*, *trafficDirection* and *transmissionInterval*:

- *actionId*: This component shall be used as defined in clause 6.1.1 and Annex A. The actionId differs from the actionIds generated by other ITS-Ss and from the actionIds generated by the same ITS-S for other detected events. It is used by a receiving ITS-S to process information for DENMs that are multiply received. The actionId is maintained by the originating ITS-S.

- *detectionTime*: This component shall be used as defined in clause 6.1.2 and Annex A. For the DENM repetition, *detectionTime* shall remain unchanged. For the DENM update, this component shall be the time at which the event update is detected. For the DENM termination, this component shall be the time at which the termination of the event is detected.

- *referenceTime*: This component shall be used as defined in clause 6.1.2 and Annex A.

- *termination*: This component shall be used as defined in clause 6.1.2 and Annex A. It shall be present only if the generated DENM is a cancellation DENM or negation DENM as requested by the ITS-S application of the originating ITS-S.

- *eventPosition*: This component shall be used as defined in clause 6.1.3. When the event reference position corresponds to the position of a vehicle ITS-S (i.e. the component stationType is set to one of the values in the range 3 to 9), the component *eventPosition* shall be set to the reference position of the vehicle ITS-S at *detectionTime* as defined in clause 6.2 of ETSI EN 302 890-2 [7].

- *awarenessDistance*: This component shall be used as specified in clause 6.1.3, with the centre at the *eventPosition* or at any of the *eventZone* points.

- *trafficDirection:* This component shall be used as specified in clause 6.1.3 and indicate:

  - The traffic direction along which the receiving ITS-S may/will encounter the event, with respect to the reference direction. The reference direction shall be the direction of the component *eventPositionHeading* if present, otherwise it shall be the direction of the vector connecting the first point in the first *Path* instance inside the component *detectionZonesToEventPosition* to the *eventPosition* in the management container.

  - For a traffic direction that corresponds to the reference direction, the upstream or downstream portion of that traffic, with respect to the reference position given in the component *eventPosition.*

- *validityDuration*: This component shall represent an estimation of how long the event may persist. It implies the duration over which the DENM should be kept at the DEN service of the receiving ITS-S and the DENM dissemination be maintained, until the expiration of *validityDuration*. In case the expiry time of the event cannot be estimated at the originating ITS S, a default value is used for the DENM protocol operation. This component may be renewed by the originating ITS-S, if the pre-set expiry time has reached to its limit and the originating ITS-S detects that the event persists.

- *transmissionInterval:* This component shall be used as specified in Annex A. If the ITS-S application of the originating ITS-S does not provide this information to the DEN service, the component shall not be included in DENM. In this case, the DENM shall not be forwarded by the forwarding ITS S.

- *stationType*: This component shall be used as specified in Annex A.

7.1.4 DENM Situation container

The Situation container includes information that describes the detected event. It shall include the components: *informationQuality* and *eventType*, and may include the components *linkedCause, eventZone, linkedDenms* and *eventEnd* as follows:

- *informationQuality*: This component shall be used as specified in Annex A. If the information is unknown, the component shall be set to the value 0.

- *eventType*: This component shall provide a description of the event type being detected: the cause code value and associated sub cause code value of a traffic event. It shall be used as defined in clause 6.1.3 and Annex A.

- *linkedCause*: This component shall indicate an event which is linked to the event indicated in the component *eventType*. It shall be used as specified in Annex A.

NOTE 1: Traffic events can be the result of the combination of situations that are causally connected and happening at the same time and place, for example, an accident due to the bad weather conditions, a broken down vehicle resulting in people on the road. In that case, the *linkedCause* component can be used.

- *eventZone*: This component shall be used as specified in clause 6.1.3 and Annex A and comply with the following rules:

  - In case of all *EventPoint* with *eventDeltaTime* PRESENT, the *EventPoint* closest in time to the *eventPosition* following the course of the zone, shall be put as the first point. It represents an offset delta position and an offset delta detection time with regards to the *eventPosition*. Other *EventPoint* shall be structured in ascending order according to the travel time to the *eventPosition* along the course of the zone. Each *EventPoint* represents an offset delta position and an offset travel time with respect to the previous *EventPoint*.

  - In case of all *EventPoint* with *eventDeltaTime* ABSENT, the *EventPoint* closest in distance to the *eventPosition* following the course of the zone, shall be put as the first point. It represents an offset delta position with regards to the *eventPosition*. Other *EventPoint* shall be structured in ascending order, according to the distance to the *eventPosition* along the course of the zone. Each EventPoint represents an offset delta position with respect to the previous *EventPoint*.

- *linkedDenms*: This component shall provide information about other DENMs that are relevant with respect to the event. It shall be used as specified in Annex A.

NOTE 2: Traffic events can be causally connected and happening at the same time but consecutively to each other, for example a congestion or traffic jam that happens because of an accident or a broken-down vehicle. In that case, the *linkedDenms* component can be used.

- *eventEnd*: This component shall be used as specified in clause 6.1.3.2 and Annex A. The reference direction shall be the direction of the component *eventPositionHeading* if present, otherwise it shall be the direction of the vector connecting the first point in the first *Path* inside the component *detectionZonesToEventPosition* to the *eventPosition* in the management container.

7.1.5 DENM Location container

The Location container describes the location of the detected event. It shall include *detectionZonesToEventPosition* and may include *eventSpeed, eventPositionHeading, roadType, lanePositions, occupiedLanes, linkedIvims, linkedMapem, detectionZonesToSpecifiedEventPoint* and *predictedPaths* as follows:

- *eventSpeed*: This component shall be used as specified in Annex A. When the *eventPosition* corresponds to the position of a vehicle ITS-S, the *eventSpeed* shall be set to the vehicle speed at *detectionTime*.

- *eventPositionHeading:* This component shall be used as specified in Annex A. When the *eventPosition* corresponds to the position of a vehicle ITS-S, the *eventPositionHeading* shall be set to the vehicle heading, i.e. to the orientation of the horizontal velocity vector of the vehicle at *detectionTime*.

- *detectionZonesToEventPosition*: This component shall be used as specified in clauses 6.1.3.3 and Annex A to represent a path or a trajectory and shall comply with the following rules:

  - When the *eventPosition* corresponds to the position of the vehicle ITS-S originating the DENM, the first *Path* shall represent the vehicle's recent trajectory over some past time and/or distance and shall have all *PathPoint* with *pathDeltaTime* PRESENT.

  - For each *Path*, in case of all *PathPoint* with *pathDeltaTime* PRESENT: the *PathPoint* closest in time to the *eventPosition* with respect to the *detectionTime* following the trajectory shall be put as the first waypoint: it presents an offset delta position with regards to the *eventPosition*. Other *PathPoints* shall be structured in ascending order according to the travel time to the *eventPosition* along the trajectory: each *PathPoint* presents an offset delta position and an offset travel time with regards to the previous *PathPoint*.

  - For each *Path*, in case of all *PathPoint* with *pathDeltaTime* ABSENT: the *PathPoint* closest in distance to the *eventPosition* following the course of the path shall be put as the first waypoint: it presents an offset delta position with regards to the *eventPosition*. Other *PathPoints* shall be structured in ascending order according to the distance to the *eventPosition* following the course of the path: Each *PathPoint* presents an offset delta position with regards to the previous *PathPoint*.

NOTE 3: This component was called *traces* in previous versions of the present document. The corresponding DF is still called *Traces* in ETSI TS 102 894-2 [5].

- *roadType*: This component shall be used as specified in Annex A.

- *lanePositions*: This component shall be used as specified in Annex A. The reference direction shall be the direction of the component *eventPositionHeading* if present, otherwise it shall be the direction of the vector connecting the first point in the first *Path* inside the component *detectionZonesToEventPosition* to the *eventPosition* in the management container. If a MAPEM (see ETSI TS 103 301 [i.10]) is available, the lane(s) may additionally be described in the scope of that MAPEM as a synonym, by addressing the same lane(s) but with the lane identification used in the MAPEM.

- *occupiedLanes*: This component shall be used as specified in Annex A. The reference direction shall be the direction of the component *eventPositionHeading* if present, otherwise it shall be the direction of the vector connecting the first point in the first *Path* inside the component *detectionZonesToEventPosition* to the *eventPosition* in the management container. If a MAPEM (see ETSI TS 103 301 [i.10]) is available, the occupied lane(s) may additionally be described in the scope of that MAPEM as a synonym, by addressing the same lane(s) but with the lane identification used in the MAPEM.

NOTE 4: If the components *lanePositions* and / or *occupiedLanes* are present and the event covers a certain part of a road which is made of different road sections with different characteristics, the receiving ITS-S can apply this information to the entire road section containing the position indicated in the *eventPosition* in the management container and, if needed, transform the information to correctly apply to the subsequent affected sections of the road. Those following road sections could have a different lane layout: therefore, the receiver could use local map information or information of the component *roadConfiguration* of the À La Carte container, if present.

- *linkedIvims:* This component shall provide information about IVIMs (see ETSI TS 103 301 [i.10]) that are relevant with respect to the event, as specified in Annex A.

- *linkedMapem:* This component shall provide information about MAPEMs that are relevant with respect to the event, as specified in Annex A.

- *detectionZonesToSpecifiedEventPoint*: This component shall be used as specified in clause 6.1.3.3 and comply with the following rules:

  - within one *Path*, the *PathPoint* closest to the *EventPoint* specified in the component *pointOfEventZone* following the course of the zone, shall be put as the first point. It represents an offset delta position with regards to that *EventPoint*. Other *PathPoint* shall be structured in ascending order according to the distance to the *EventPoint* along the course of the zone. Each *PathPoint* represents an offset delta position with respect to the previous *PathPoint*. The component *pathDeltaTime* of *PathPoint* shall always be absent.

- *predictedPaths*: This component shall describe a list of future trajectories or paths that the event may move along or zones that the event may occupy. It shall be used as specified in Annex A and comply with the following rules:

  - For each instance of P*athPredicted2*, in case of all *PathPointPredicted* with *pathDeltaTime* PRESENT: the *PathPointPredicted* closest in time to the *eventPosition* with respect to the *detectionTime* following the trajectory or zone shall be put as the first waypoint: it presents an offset delta position with regards to the *eventPosition*. Other *PathPointPredicted* shall be structured in ascending order according to the estimated travel time to the *eventPosition* along the trajectory or zone: each *PathPointPredicted* presents an offset delta position and an offset travel time with regards to the previous *PathPointPredicted*. Additionally, the following conditions apply:

    - In case of all *PathPointPredicted* with *symmetricAreaOffset* ABSENT, *pathPredicted2* represents a trajectory that the event may move along.

    - In case of all *PathPointPredicted* with *symmetricAreaOffset* PRESENT: *pathPredicted2* represents a zone that the event may occupy. The zone is further divided into smaller sections between every pair of *PathPointPredicted*. *pathDeltaTime* then indicates the point in time when *usageIndication* applies to the area after one *PathPointPredicted* to the next *PathPointPredicted*.

  - For each instance of P*athPredicted2*, in case of all *PathPointPredicted* with *pathDeltaTime* ABSENT: the *PathPointPredicted* closest in distance to the *eventPosition* following the course of the path or zone shall be put as the first waypoint; it presents an offset delta position with regards to the *eventPosition*. Other *PathPointPredicted* shall be structured in ascending order according to the distance to the *eventPosition* following the course of the path or zone. Each *PathPointPredicted* presents an offset delta position with regards to the previous *PathPointPredicted*. Additionally, the following conditions apply:

    - In case of all *PathPointPredicted* with *symmetricAreaOffset* ABSENT, *PathPredicted2* represents a path that the event may move along.

    - In case of all *PathPointPredicted* with *symmetricAreaOffset* PRESENT, *PathPredicted2* represents a zone that the event may occupy.

7.1.6 DENM À La Carte container

The À La Carte container contains additional information that is not provided by other containers. This container provides the possibility for ITS-S application to include application specific data in a DENM.

All information included in the À La Carte container is optional. It shall be present when the data is provided by the ITS-S application.

The present document defines the following use case specific components of the À La Carte container:

- *lanePosition:* This component may be added to indicate the corresponding lane position of the event. If this component is present, it shall indicate the lane position as specified in Annex A with a predefined confidence level as defined by the ITS application (e.g. 95 %).

- *impactReduction:* This component may be added when a potential collision is detected. If this component is present, it shall include vehicle data for the collision mitigation as specified in Annex A and the component *requestResponseIndication* within this component set to 0. Alternatively, on reception of a DENM where the component *requestResponseIndication* within this component is set to 0, the receiving ITS-S may in turn transmit a DENM with its *impactReduction* component present, and the component *requestResponseIndication* within this component set to 1, as response to the request.

- *externalTemperature:* This component may be added for the adverse weather condition use case. If this component is present, it shall indicate the ambient temperature at the *eventPosition* as specified in Annex A.

- *roadWorks:* This component may be added for the roadwork use case. If this component is present, it shall include optional information about the roadwork zone and specific access conditions as specified in Annex A.

- *positioningSolution:* This component may be added for the emergency vehicle approaching, slow vehicle and stationary vehicle use cases. Typically, this component may be included for events that are caused by vehicle ITS-S. If this component is present, it shall indicate the type of positioning solution being used for the resolution of the *eventPosition* as specified in Annex A.

- *stationaryVehicle:* This component may be added for the stationary vehicle use case. If this component is present, it shall include one or more of the optional information about the stationary vehicle, as specified in Annex A.

- *roadConfiguration:* This component may be added to indicate a simple description of the configuration of the road, see Annex C for further explanations. If this component is present, it shall indicate basic information about the lanes of one or more road sections as specified in Annex A. These road sections shall be geographically related to the event such as the sections that include:

  - the reference position of the event (see the component *eventPosition* in the DENM Management container);

  - the zone where the event is detected (see the component *eventZone* in the DENM Situation container);

  - the zone(s) in approach of the event (see the components *detectionZonesToEventPosition* and *detectionZonesToSpecifiedEventPoint* in the DENM Location container).

- *preCrash*: This component may be added for hazardous location notification uses cases [i.4] that aim at warning the approaching traffic of a hazardous event such as an object, person, or stationary vehicle on the road, or for pre-crash use cases [i.2] and ETSI TR 103 832 [i.11] that support performing crash mitigation actions at the affected vehicle(s) in those situations in which a collision is imminent and unavoidable. If this component is present, it shall be used as specified in Annex A:

  - *perceivedPreCrashObject*: this component is mandatory and shall be used to indicate the following information:

    - hazardous location notification uses cases: additional information about a perceived object located at the position indicated in the component *eventPosition* that is endangering the traffic;

    - pre-crash use cases: information about a vehicle with which the vehicle located at the position indicated in the component *eventPosition* is likely to collide.

  - *objectStationId*: the optional identifier of an ITS Station mounted in the vehicle described in the component *perceivedPreCrashObject.*

  - *timeToCollision*:

    - pre-crash use cases only: the optional time to collision of the vehicle located at the position indicated in the component *eventPosition* with the object.

  - impactSection:

    - pre-crash use cases only: the optional impact section where the collision of the vehicle located at the position indicated in the component *eventPosition* with the object will occur.

  - estimatedBrakingDistance:

    - pre-crash use cases only: the optional braking distance of the vehicle located at the position indicated in the component *eventPosition*.

7.2 DENM format specification

The DENM syntax and semantics 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 [5] as specified in Annex A

Detailed specifications of all components of DENM are provided in the normative Annex A and presented in readable format in the informative Annex B.

Unaligned Packed Encoding Rules (PER) as defined in Recommendation ITU-T X.691/ISO/IEC 8825-2 [6] shall be used for DENM encoding and decoding.

8 Protocol operation of the DEN service

8.1 Introduction

This clause specifies the protocol operations of the DEN service for three main roles:

- originating ITS-S operation (clause 8.2);
- forwarding ITS-S operation (clause 8.3); and
- receiving ITS-S operation (clause 8.4).

The specification of the protocol operation is organized in three parts:

1) Protocol data setting rules specify the setting of the relevant parameters used by the protocol.
2) The general protocol operation specifies the sequence of protocol operations.
3) Exception handling specifies additional protocol operations that extend the general protocol operation. They are applied when special conditions, referred to exceptions (for example inconsistent data) occur.

An ITS-S shall maintain a local data structure, referred to as "ITS-S message table". This data structure holds information about sent or received DENM messages.

It is out of the scope of the present document to describe how this data structure is implemented.

8.2 Originating ITS-S operation

8.2.1 Protocol data setting rules

8.2.1.1 General requirements

The data setting for the originating ITS-S operation shall be as specified in Annex A and shall follow the rules defined in this clause.

8.2.1.2 *actionId*

For the application request type AppDENM_trigger, actionId shall be assigned as defined in clause 6.1.1.1.

For the application request type *AppDENM_update*, the application may pass *actionId* to the DEN service in the application request. For update DENM, the *actionId* shall remain unchanged, as long as the originating ITS-S *stationId* is unchanged.

For the application request type *AppDENM_termination*, the application may pass *actionId* to the DEN service in the application request. For cancellation DENM, the *actionId* shall remain unchanged, as long as the originating ITS-S *stationId* is unchanged. For negation DENM, the *actionId* shall be set to the *actionId* for which the negation DENM refers to.

In case ITS application requests the DENM repetition, the *actionId* shall remain unchanged during DENM repetition, as long as the originating ITS-S *stationId* is unchanged.

8.2.1.3 *referenceTime*

For the application request type *AppDENM_trigger*, the *referenceTime* shall be set to the time at which the new DENM is generated by the DEN service.

For the application request type *AppDENM_update*, the *referenceTime* shall be set to the time at which update DENM is generated by the DEN service for each update.

For the application request type *AppDENM_termination*, DEN service shall generate a cancellation DENM if the originating ITS-S message table as defined in clause 8.2.1.6 contains a DENM of the same *actionId*. The DEN service shall generate a negation DENM if the receiving ITS-S message table as defined in clause 8.4.1.6 contains a DENM of the same *actionId*. Otherwise, the DEN service shall ignore the application request and sends a failure notification to the ITS-S application. For cancellation DENM, the *referenceTime* shall be set to the time at which cancellation DENM is generated. For negation DENM, the *referenceTime* shall be set to the latest value of the DENM of the same *actionId* in the receiving ITS-S message table. This is to enable receiving ITS-Ss to match to which event update the negation DENM is referring to (see clause 6.1.2.4).

In case application requests the DENM repetition, the *referenceTime* shall remain unchanged during the DENM repetition.

8.2.1.4 *termination*

For the application request type *AppDENM_trigger*, the *termination* component shall not be included in DENM.

For the application request type *AppDENM_update*, the *termination* component may be present, depending on the DENM type for which the update is requested by the ITS-S application.

For the application request type *AppDENM_termination*, the *termination* shall be set to 1 if a negation DENM is to be generated. The *termination* shall be set to 0 if a cancellation DENM is to be generated.

8.2.1.5 *T_O_Validity*, *T_RepetitionDuration* and *T_Repetition*

The timer *T_O_Validity* is the time that indicates the end of the DENM validity for the originating ITS-S protocol operation. Its expiration time shall be set to:

- the offset of the *validityDuration* starting from the *detectionTime*, if the *validityDuration* is provided by the application;
- the default offset of 600 s starting from the *detectionTime*, if the *validityDuration* is not provided by the application.

The timer *T_RepetitionDuration* is the time that indicates the end of the DENM repetition by the DEN service of the originating ITS-S. Its expiration time shall be set to:

- the offset of the *repetitionDuration* starting from the *referenceTime*, if the *repetitionDuration* is provided by the application;
- an invalid value, if the *repetitionDuration* is not provided by the application.

NOTE 1: *repetitionDuration* is not included in DENM.

The timer *T_Repetition* schedules the DENM repetition. Its timeout value shall be set to:

- the *repetitionInterval*, if the parameter is provided by the ITS-S application;
- an invalid value, if the *repetitionInterval* is not provided by the ITS-S application.

NOTE 2: If the *T_Repetition* is set to invalid, the DENM is transmitted only once.

NOTE 3: *repetitionInterval* is not included in DENM.

For all application request types, the *T_Repetition* and *T_RepetitionDuration* shall not be greater than the *validityDuration.*

8.2.1.6 Originating ITS-S message table

The DEN service shall maintain at least all data as defined in the present clause in the originating ITS-S message table.

At a point in time, any DENM entry in the originating ITS-S message table may be associated with one of three states:

- ACTIVE state: The *termination* data is not set for DENM entry of the *actionId*.
- CANCELLED state: The *termination* value is set to 0 for DENM entry of the *actionId*.
- NEGATED state: The *termination* value is set to 1 for DENM entry of the *actionId*.

The state of a DENM indicates the most updated status of a DENM entry of the same *actionId*.

NOTE: For application that requests the DENM repetition, the DENM is stored in the originating ITS-S message table.

8.2.2 General protocol operation

Upon reception of a request from ITS-S application via the interface IF.DEN.1, the DEN service shall execute the following operations:

For application request type *appDENM_trigger:*

1) Calculate expiration time for timer *T_O_Validity* (clause 8.2.1.5):
   a) If expiration time of timer *T_O_Validity* is in the past, send a failure notification to the ITS-S application and omit the execution of further steps.
   b) Otherwise, continue the operation.
2) Assign unused *actionId* value (clause 8.2.1.2).
3) If *transmissionInterval* is provided by the application request:
   a) Set transmissionInterval.
   b) Otherwise, continue the operation.
4) Set other fields of DENM management container, situation container, location container and À La Carte container (Annex A).
5) Set *referenceTime* to the current time.
6) Generate the DENM.
7) Pass the DENM to the ITS networking & transport layer.
8) Create an entry in the originating ITS-S message table and set the state to ACTIVE.
9) Start/restart timer *T_O_Validity*.
10) If *repetitionDuration* > 0 and *repetitionInterval* > 0:
    a) Calculate and start timer T_RepetitionDuration and T_Repetition.
    b) Otherwise, continue the operation.
11) Send *actionId* to the requesting ITS-S application.

12) End.

For application request type *appDENM_update:*

1) Calculate expiration time for timer *T_O_Validity* (clause 8.2.1.5):

   a) If expiration time of timer *T_O_Validity is* in the past, send a failure notification to the ITS-S application and omit the execution of further steps.

   b) Otherwise, continue the operation.

2) Compare *actionId* in the application request with entries in the originating ITS-S message table:

   a) If *actionId* provided by the ITS-S application request does not exist in the originating ITS-S message table, send a failure notification to the ITS-S application and omit the execution of further steps.

   b) Otherwise, continue the operation.

3) Stop T_O_Validity, T_RepetitionDuration and T_Repetition if applicable.

4) If *transmissionInterval* is provided by the application request:

   a) Set transmissionInterval.

   b) Otherwise, continue the operation.

5) Set other fields of DENM management container, situation container, location container and À La Carte container (Annex A).

6) Set *referenceTime* to the current time.

7) Generate the DENM.

8) Pass the DENM to the ITS networking & transport layer.

9) Update the entry in the originating ITS-S message table.

10) Start/restart timer *T_O_Validity*.

11) If repetitionDuration > 0 and repetitionInterval > 0:

   a) Calculate and restart timer *T_RepetitionDuration* and *T_Repetition.*

   b) Otherwise, continue the operation.

12) Send *actionId* to the requesting ITS-S application.

13) End.

For application request type *appDENM_termination:*

1) Set expiration time for timer *T_O_Validity* (clause 8.2.1.5):

   a) If expiration time of timer *T_O_Validity* is in the past, send a failure notification to the ITS-S application and omit the execution of further steps.

   b) Otherwise, continue the operation.

2) Compare *actionId* in the application request with entries in the originating ITS-S message table and the receiving ITS-S message table:

   a) If *actionId* exists in the originating ITS-S message table and the entry state is ACTIVE, then set *termination* to *isCancellation*.

   b) If *actionId* exists in the receiving ITS-S message table and, if applicable, the SSP is valid for that cause code value; the entry state is ACTIVE, then set *termination* to *isNegation*.

   c) Otherwise, send a failure notification to the ITS-S application and omit the execution of further steps.

3) Set *referenceTime:*

   a) If *termination* is set to 0, set *referenceTime* to the current time.

   b) If *termination* is set to 1, set *referenceTime* to the *referenceTime* value of receiving ITS-S message table DENM entry.

4) Stop T_O_Validity, T_RepetitionDuration and T_Repetition if applicable.

5) If *transmissionInterval* is provided by the application request:

   a) Set transmissionInterval.

   b) Otherwise, continue the operation.

6) Set other fields of the DENM management container (Annex A).

7) Generate the DENM.

8) Pass the DENM to the ITS networking & transport layer.

9) Update the entry:

   a) If *termination* is set to 0, update the entry in the originating ITS-S message table and set the state to CANCELLED.

   b) If *termination* is set to 1, create an entry in the originating ITS-S message table and set the state to NEGATED.

10) Start/restart timer *T_O_Validity*.

11) If *repetitionDuration* > 0 and *repetitionInterval* > 0:

   a) Calculate and restart timer *T_RepetitionDuration* and *T_Repetition.*

   b) Otherwise, continue the operation.

12) Send *actionId* to the requesting ITS-S application.

13) End.

When the timer *T_O_Validity* expires, the DEN service shall execute the following operations:

1) Stop timer *T_Repetition* if exists.

2) Stop timer *T_RepetitionDuration* if exists.

3) Discard the expired DENM entry from the originating ITS-S message table.

When the timer *T_RepetitionDuration* expires, DEN service shall execute the following operations:

1) Stop timer *T_Repetition*.

When the timer *T_Repetition* expires, DEN service shall execute the following operations:

1) Pass the DENM to ITS networking & transport layer.

2) Restart timer *T_Repetition*.

The protocol operation is illustrated in Figure 7, Figure 8, Figure 9 and Figure 10.

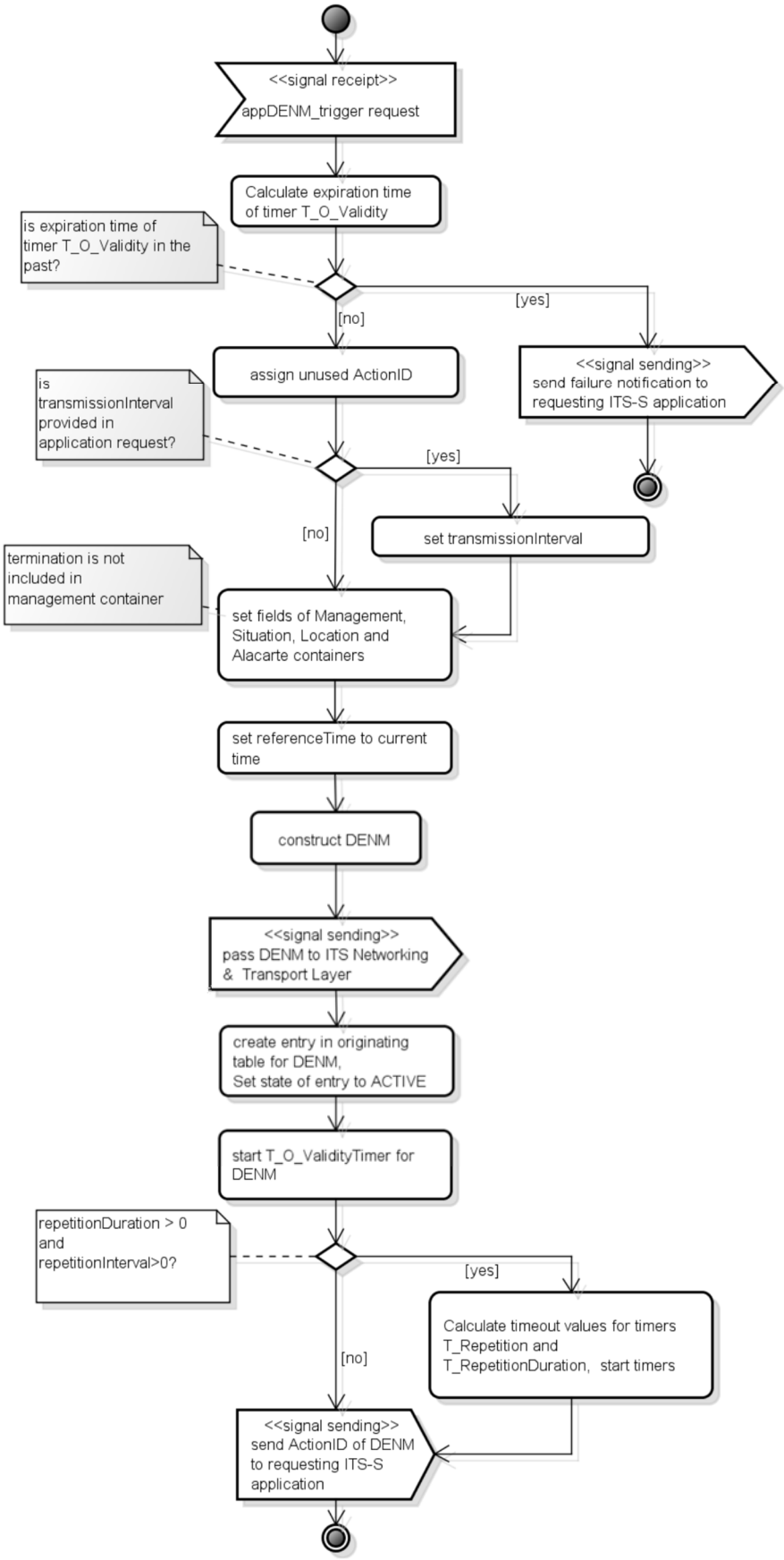

Figure 7: Originating ITS-S activity diagram: appDENM_trigger request

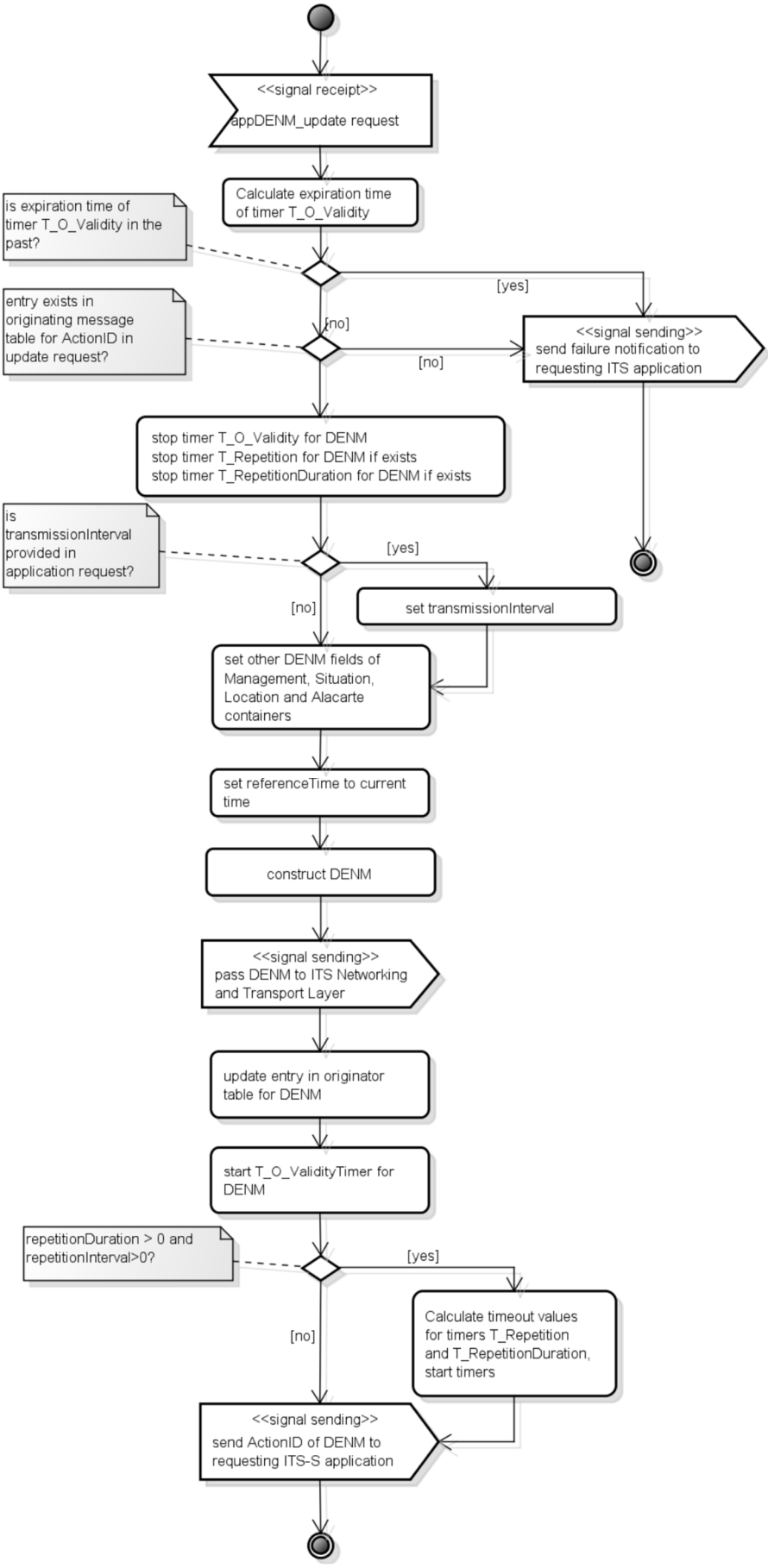

Figure 8: Originating ITS-S activity diagram: appDENM_update request

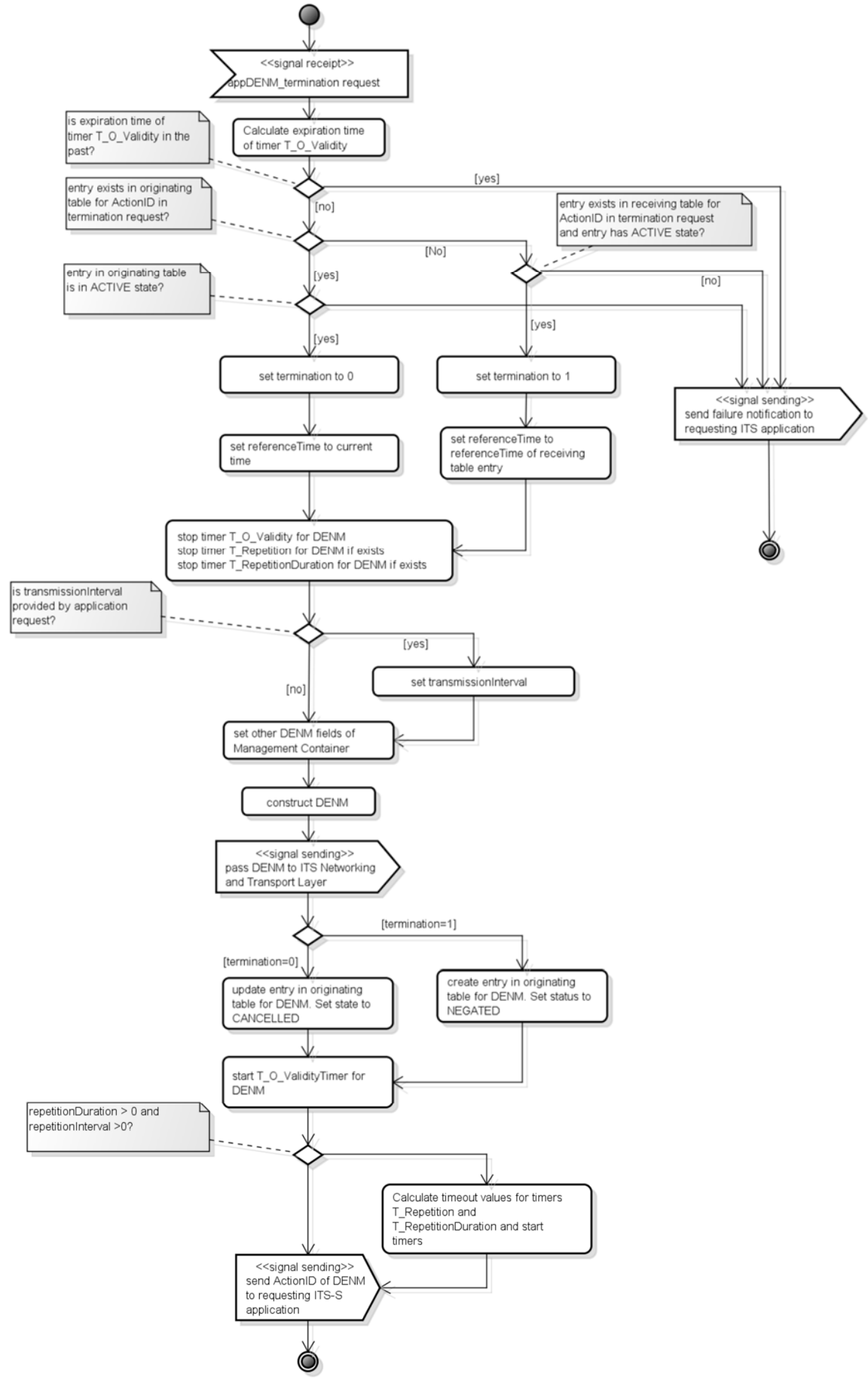

Figure 9: Originating ITS-S activity diagram: appDENM_termination request

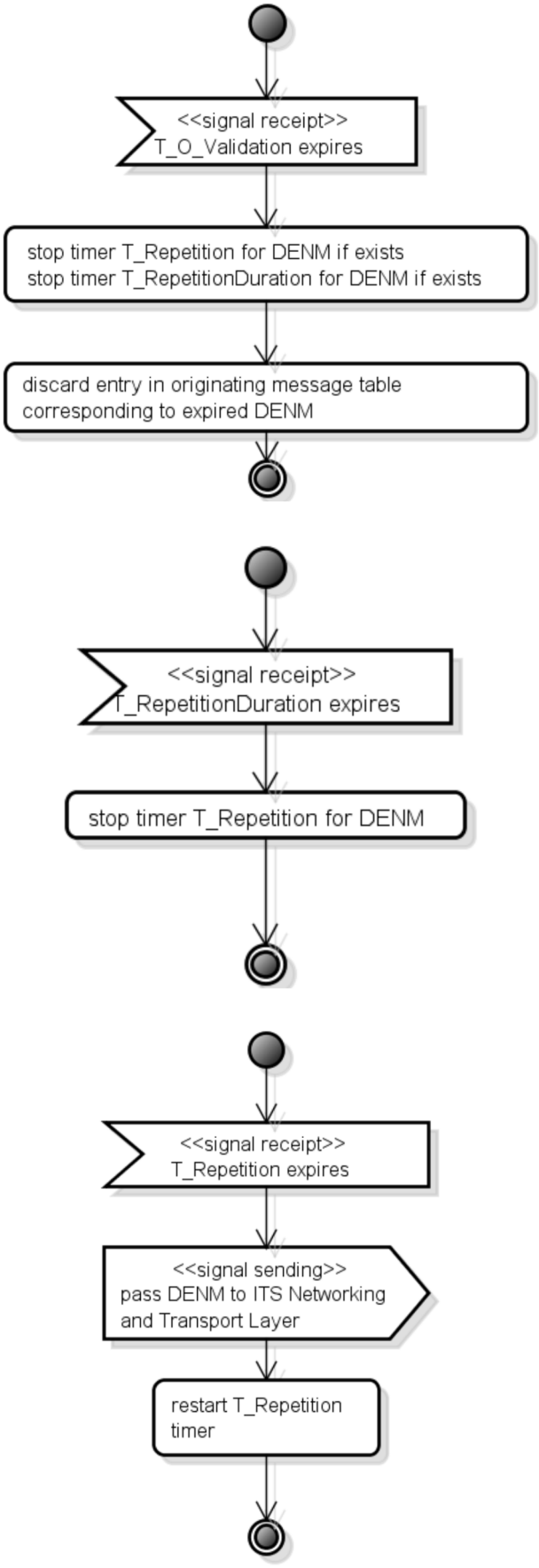

Figure 10: Originating ITS-S activity diagram: timeout management

8.2.3 Exception handling

8.2.3.1 General requirements

The originating ITS-S shall apply the exception handling rules specified in this clause.

8.2.3.2 DENM generation exception

If the DEN service cannot generate a DENM successfully, the DEN service shall send a failure notification to the ITS-S application.

NOTE 1: This exception is valid for all application request types.

NOTE 2: The failure of the DENM generation may happen, if the DEN service was not able to collect all required data for the DENM generation, or the collected data are not compliant to the DENM format as specified in Annex A (e.g. the value of a data is out of authorized range of the ASN.1 definition).

8.2.3.3 *actionId* non-existence exception

This exception applies to the application request types *AppDENM_update* and *AppDENM_termination*.

For the application request type *AppDENM_update*, if the corresponding *actionId* does not exist in the originating ITS-S message table, the DEN service shall send a failure notification to the ITS-S application.

For the application request type *AppDENM_termination*, if the corresponding *actionId* exists neither in the originating ITS-S message table (defined in clause 8.2.1.6), nor in the receiving ITS-S message table (defined in clause 8.4.1.6), the DEN service shall send a failure notification to the ITS-S application.

8.2.3.4 Time operation exception

If the expiration time of the timer *T_O_Validity* lies in the past when the application request is processed, the DEN service shall send a failure notification to the ITS-S application.

NOTE: This may happen, if the DEN service is not able to process the application request in time, due to the processing delay of the ITS-S system.

8.3 Forwarding ITS-S operation

8.3.1 Introduction

The following clauses describe the protocol operation of a one possible KAF protocol as introduced in clause 6.1.4.2. The KAF is a sub-function of the DEN service that forwards a received DENM from the facilities layer to the ITS networking & transport layer when necessary. This sub-function is optional. It may be deactivated either by the ITS-S application, the ITS-S configuration, the management layer or the DEN service itself.

NOTE: The triggering of the KAF may be useful for some applications or some event types. This means that among the received DENM, it can be the case that only DENMs with certain *actionIds* will be forwarded by the KAF protocol. An ITS-S may also deactivate the KAF protocol for all DENMs.

8.3.2 Protocol data setting rules

8.3.2.1 General requirements

The data setting for the forwarding ITS-S operation shall be as specified in Annex A and shall follow the rules defined in this clause.

8.3.2.2 *actionId*

The forwarding ITS-S shall not set the *actionId*.

8.3.2.3 referenceTime

The forwarding ITS-S shall not set the *referenceTime*.

8.3.2.4 termination

The forwarding ITS-S shall not set the *termination*.

8.3.2.5 *T_F_Validity* and *T_Forwarding*

The timer *T_F_Validity* schedules the end of the DENM validity for the KAF protocol operation. Its expiration time shall be set to:

- the offset of the *validityDuration* starting from the *detectionTime*, if the *validityDuration* is included in the received DENM;
- an invalid value, if the *validityDuration* is not included in the received DENM.

NOTE 1: If the timer *T_F_Validity* is set to an invalid value, the DENM is not forwarded and the KAF is deactivated.

The timer *T_Forwarding* schedules the DENM forwarding from the DEN service to the ITS networking & transport layer. Its timeout value shall be set to:

- two times of the received *transmissionInterval* plus a random delay in the range of 0 ms to 150 ms, if the *transmissionInterval* and *validityDuration* are present in the received DENM and the resulting timeout value is not greater than the *validityDuration*;

NOTE 2: The random delay addresses the potential synchronization of the keep-alive forwarding functionality among multiple ITS-S.

- *validityDuration*, if *transmissionInterval* and *validityDuration* are present in the received DENM and two times of the *transmissionInterval* plus a random delay in the range 0 ms to 150 ms is greater than the *validityDuration*;
- an invalid value, if the *transmissionInterval* is not present in the received DENM;
- an invalid value, if the timeout of the timer *T_F_Validity* is set to an invalid value.

NOTE 3: If the timer *T_F_Validity* is set to an invalid value, the DENM is not forwarded. Therefore there is no need to set the timeout value and start/stop the timer *T_Forwarding*.

NOTE 4: If the *transmissionInterval* is not present in the DENM, the originating ITS-S does not require the DENM to be kept alive and to be forwarded by an intermediate ITS-S.

8.3.2.6 Forwarding ITS-S message table

The DEN service shall maintain a forwarding ITS-S message table. This message table shall at least store the DENMs for which the KAF is activated. The forwarding ITS-S message table shall store the received DENM payload.

The update of the forwarding ITS-S message table shall follow the rules as defined in the receiving ITS-S operation specified in clause 8.4.

NOTE: The update of the forwarding ITS-S message table allows forwarding of the latest update DENM.

8.3.2.7 DENM regeneration

When a DENM is being forwarded, the DEN service shall regenerate the DENM before forwarding it to the ITS networking & transport layer. For this regeneration, the management container, situation container, location container and À La Carte container of the DENM shall not be modified. The ITS PDU header shall be replaced by the ITS PDU header generated by the forwarding ITS-S.

NOTE: Especially for DENMs with an eventZone component, it is recommended to buffer the original DENM's destination area for possible reuse in KAF forwarding.

8.3.3 General protocol operation

Upon reception of a DENM with an *actionId* for which the KAF is activated, the DEN service shall execute the following operations:

1) Check if the *termination* exists in received DENM:
   a) If yes, continue the operation.
   b) Otherwise, omit execution of further steps.
2) Check if the *referenceTime* of the received DENM is equal or greater than the *referenceTime* value of the DENM entry in the forwarding ITS-S message table of the same *actionId*:
   a) If the received *referenceTime* is equal to the entry *referenceTime*, start/restart *T_F_Forwarding* and omit execution of further steps.
   b) If the received *referenceTime* is less than the entry *referenceTime*, discard the received DENM and omit execution of further steps.
   c) Otherwise, continue the operation.
3) Calculate expiration time of timer *T_F_Validity* (clause 8.3.2.5):
   a) If timer *T_F_Validity* is set to invalid value, omit execution of further steps.
   b) Otherwise, continue operation.
4) Calculate timeout value for timer *T_ Forwarding* (clause 8.3.2.5):
   a) If timer *T_ Forwarding* is set to invalid value, omit execution of further steps.
   b) Otherwise, continue operation.
5) Start/restart timer *T_F_Validity* and *T_ Forwarding*.
6) Regenerate DENM by replacing the ITS PDU header.
7) Update DENM entry in forwarding ITS-S message table.
8) End.

When the timer *T_F_Validity* expires, the DEN service shall execute the following operations:

1) Stop *T_Forwarding* timer.
2) delete DENM entry from the forwarding message table.

When the timer *T_Forwarding* expires, the DEN service shall execute the following operations:

1) Check if the forwarding ITS-S is located in the awareness area / relevance zone or the destination area:
   a) If not, omit execution of further steps.
   b) Otherwise, continue operation.
2) Pass the regenerated DENM to ITS networking & transport layer.

3) Restart timer *T_Forwarding*.

The protocol operation is illustrated in Figure 11 and Figure 12.

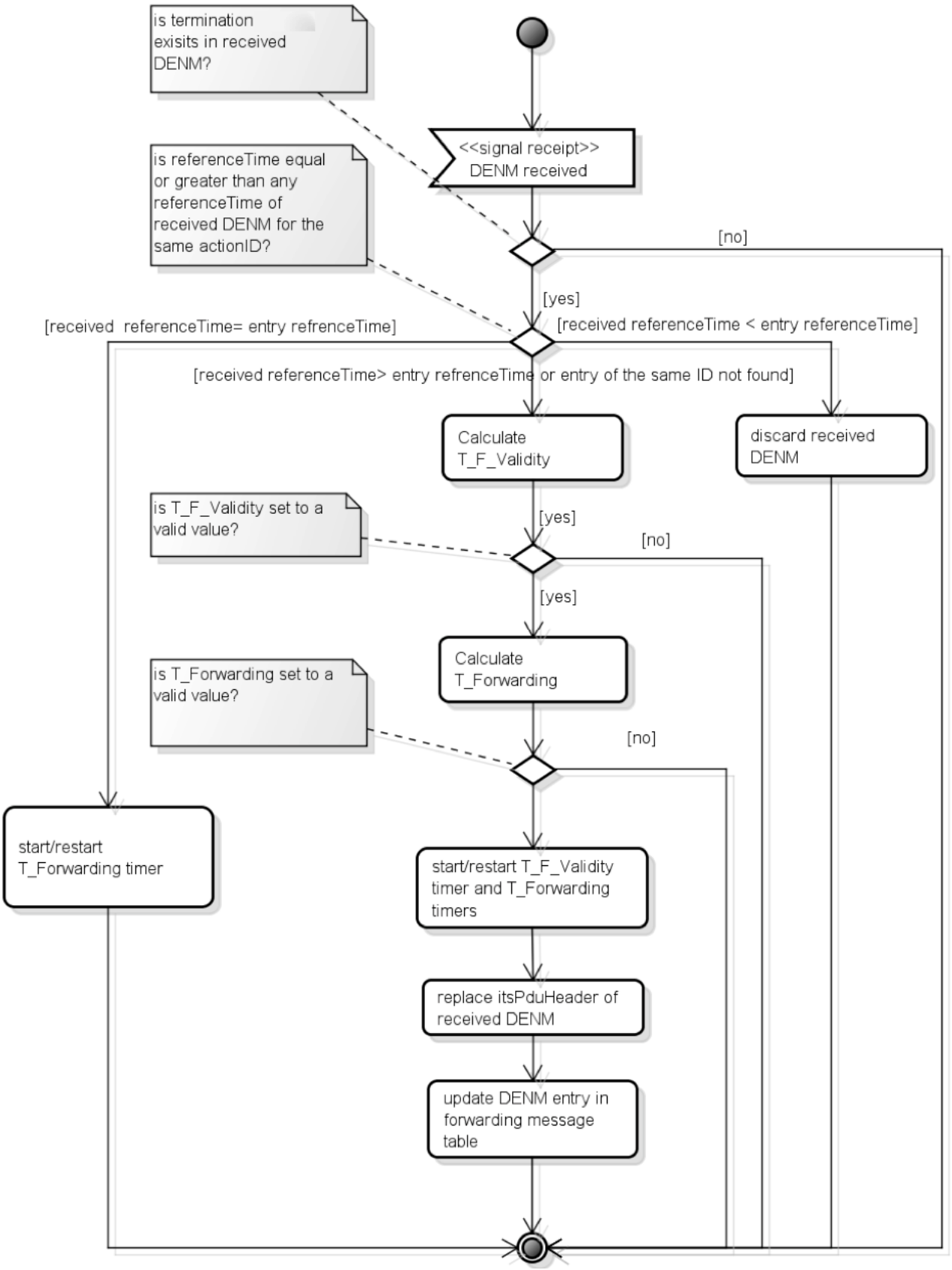

Figure 11: Forwarding ITS-S activity diagram

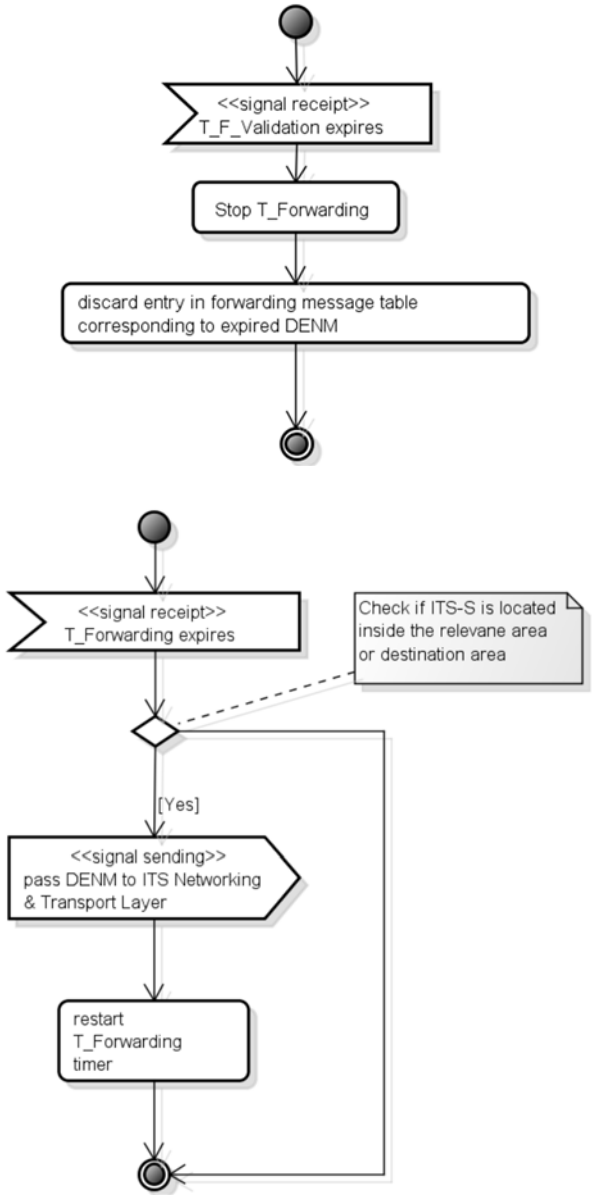

Figure 12: Forwarding ITS-S activity diagram: timeout management

8.3.4 Exception handling

8.3.4.1 General requirements

The forwarding ITS-S shall apply the exception handling rule specified in this clause.

8.3.4.2 DENM generation exception

If the DEN service cannot generate a DENM successfully, the DEN service shall stop executing further operations of the forwarding.

NOTE: The failure of the DENM regeneration may happen, if the DEN service was not able to collect all required data for the DENM regeneration, or the collected data are not compliant to the DENM format as specified in Annex A (e.g. the value of a data is out of range of the ASN.1 definition).

8.4 Receiving ITS-S operation

8.4.1 Protocol data setting rules

8.4.1.1 General requirements

The data setting for the receiving ITS-S operation shall be as specified in Annex B and may follow the rules defined in this clause.

8.4.1.2 *actionId*

The receiving ITS-S shall not set the *actionId*.

8.4.1.3 referenceTime

The receiving ITS-S shall not set the *referenceTime*.

8.4.1.4 termination

The receiving ITS-S shall not set the *termination*.

8.4.1.5 T_R_Validity

T_R_Validity is the time that indicates the end of DENM validity. It is used in the receiving ITS-S message table for keeping up-to-date DENM information. Its expiration time may be set to:

- the offset of the *validityDuration* starting from the *detectionTime*, if the *validityDuration* is present in the received DENM;
- the default offset of the *validityDuration* of 600 s starting from the *detectionTime*, if the *validityDuration* is not present in the received DENM.

8.4.1.6 Receiving ITS-S message table

The DEN service may maintain an ITS-S message table with at least the following data for the receiving protocol operation:

- *actionId*: *actionId* value of the received DENMs until the *T_R_Validity* is expired.
- *referenceTime*: The value of the *referenceTime* refers to the most recent value of received DENMs of the same *actionId*.
- *termination*: The value of the *termination* refers to the most recent value of received DENMs of the same *actionId*.
- *detectionTime*: The value of the *detectionTime* refers to the most recent value of received DENMs of the same *actionId*.

NOTE: DENMs stored in the receiving ITS-S message table are indexed with *actionId*.

A DENM with a specific *actionId* may be stored in the receiving ITS-S message table as long as the timer *T_R_Validity* is not expired. When the timer *T_R_Validity* expires, all data related to the corresponding *actionId* (including the *actionId* entry) may be deleted from the receiving ITS-S message table.

At a point in time, any stored DENM in the receiving ITS-S message table may be associated with one of three states:

- ACTIVE state: Receiving ITS-S has not received the *termination* data from all received DENMs of the *actionId*.
- CANCELLED state: The *termination* value of DENM stored in the receiving ITS-S message table is 0.

- NEGATED state: The *termination* value of DENM stored in the receiving ITS-S message table is 1.

The state of a DENM indicates the most updated status of received DENMs of the same *actionId*.

The receiving ITS-S message table may be updated upon the reception of a DENM, under the following conditions:

- the *referenceTime* of a received DENM is greater than the latest value stored in the receiving message table;
- the state of the DENM is changed due to a received DENM when the *referenceTime* or *detectionTime* of a received DENM is equal or greater than the latest values stored in the receiving message table; or
- the DENM entry with the *actionId* is deleted when the timer *T_R_Validity* expires.

If a received DENM does not satisfy any of the above conditions, the received DENM is considered to be outdated and may be discarded by the receiving ITS-S. The receiving ITS-S message table is not updated with this received DENM.

8.4.2 General protocol operation

Upon reception of a DENM, the DEN service may execute the following operations:

1) Decode DENM; Calculate expiration time for timer *T_R_Validity* (clause 8.4.1.5):
    a) If expiration time is in the past, discard the received DENM and omit execution of further steps.
    b) Otherwise, continue the operation.
2) Lookup entries in the receiving ITS-S message table with the received *actionId:*
    a) If entry does not exist in the receiving ITS-S message table, check if *termination* data exists in the received DENM:
        i) If yes, discard the received DENM and omit execution of further steps.
        ii) Otherwise, check SSP and cause code value if available:
            1) If SSP value is not consistent with the cause code value in *eventType*, discard the received DENM and omit execution of further steps.
            2) Otherwise, create an entry in the receiving ITS-S message table with the received DENM and set the state to ACTIVE.
    b) If entry does exist in the receiving ITS-S message table, check if the received *referenceTime* is less than the entry *referenceTime*, or the received *detectionTime* is less than the entry *detectionTime*:
        i) If yes, discard the received DENM and omit execution of further steps.
        ii) Otherwise, check if the received DENM is a repeated DENM of the entry, i.e. the received *referenceTime* equals to the entry *referenceTime*, the received *detectionTime* equals to the entry *detectionTime*, and the received *termination* value equals to the entry state:
            1) If yes, discard received DENM and omit execution of further steps.
            2) Otherwise, check SSP and the cause code value if available:
                a) If SSP value is not consistent with the cause code value in *eventType*, discard the received DENM and omit execution of further steps.
                b) Otherwise, update the entry in receiving ITS-S message table, set entry state according to the *termination* value of the received DENM.
3) Start/restart *T_R_Validity* timer.
4) Inform ITS-S applications of the DENM entry and state if applicable.
5) End.

When the timer *T_R_Validity* expires, the DEN service may execute the following operations:

1) Delete DENM entry from the receiving ITS-S message table.
2) Notify application if necessary (clause 5.4.1).

The protocol operation is illustrated in Figure 13 and Figure 14.

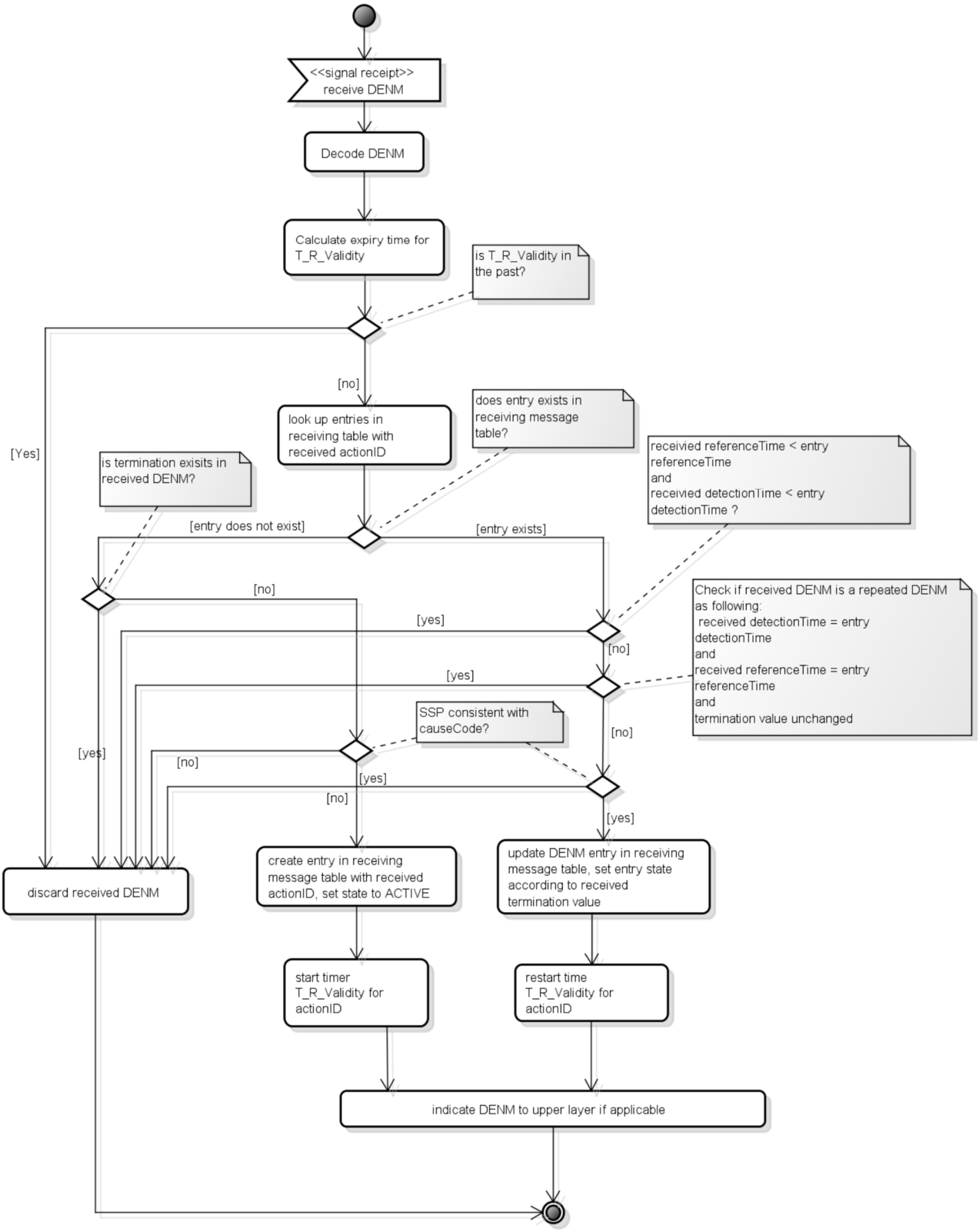

Figure 13: Receiving ITS-S activity diagram

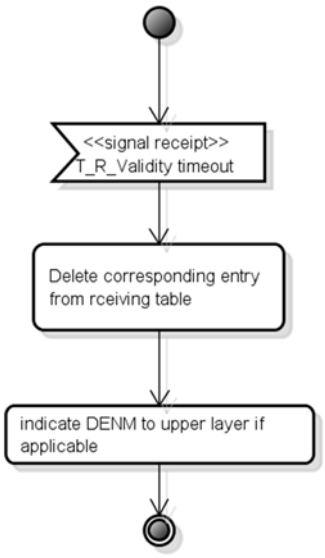

Figure 14: Receiving ITS-S activity diagram: timeout management

8.4.3 Exception handling

8.4.3.1 General requirements

The receiving ITS-S may apply the exception handling rules specified in this clause.

8.4.3.2 DENM decoding exception

If the received DENM cannot be decoded by the DEN service, the operation may stop, and the received DENMs may be discarded.

Annex A (normative): ASN.1 module

This clause provides the normative ASN.1 module containing the syntactical specification of the DENM PDU, its containers, and the data frames, and data elements defined in the present document.

The semantical specification of the DENM 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 DENM-PDU-Descriptions module is identified by the Object Identifier {itu-t (0) identified-organization (4) etsi (0) itsDomain (5) wg1 (1) denmPduRelease2 (103831) major-version-2 (2) minor-version-2 (2)}. 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: ETSI TS 103 831 ASN.1 module information

Module name	DENM-PDU-Descriptions
OID	{itu-t (0) identified-organization (4) etsi (0) itsDomain (5) wg1 (1) denmPduRelease2 (103831) major-version-2 (2) minor-version-2 (2)}
Link	https://forge.etsi.org/rep/ITS/asn1/denm_ts103831/-/raw/v2.2.1/DENM-PDU-Descriptions.asn
SHA-256 hash	2c4dffa03abe29c5ff3b91599149f6cbddc037c2c5c91bcd9f2386bfc23b2989

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

The specification of DENM PDU components is available at the following URL:

https://forge.etsi.org/rep/ITS/asn1/denm_ts103831/-/blob/v2.2.1/docs/DENM-PDU-Description.md.

Annex C (informative): Road configuration description

C.1 Introduction

A simple description of the configuration (number and type of lanes) of the road where a hazardous event occurs would be highly beneficial to ITS-S applications based on DENM. Assuming it is easily accessible by road infrastructure managers and can be provided to vehicles via V2X in a reliable way, this information would allow:

- Contextualization of a hazardous event on an unambiguous road layout configuration with considerable added value to receiving ITS-S applications. Contextualization here is to be understood as being able to associate the position (*eventPosition*) or the zone (e.g. *eventZone*) where the event is detected, and optionally the lane(s) where the event occurrence is announced in the DENM (*alacarte.lanePosition*), to the actual road configuration. As shown in the following, associating other information contained in the DENM like detection zone information (in this annex called "traces") to the road layout configuration can be also useful for:
  - Improvement of Release 1 I2V applications implementations (e.g. via richer HMI visualization options, see Figure C.1: the driver knows on which of the existing lane(s) the hazard occurs and can better judge if a reaction like slowing down or changing lane is necessary)
  - Support for Release 2 use cases (e.g. more meaningful AD reactions thanks to detailed road configuration information. As an example, and similarly to what stated above for Release 1 applications, the AD system knows on which of the existing lane(s) the hazard occurs and can better judge if a reaction like slowing down or changing lane is necessary)
- Easier implementation of receiving ITS-S applications (no need to necessarily derive road configuration information from digital map databases or road sensing systems, etc.).

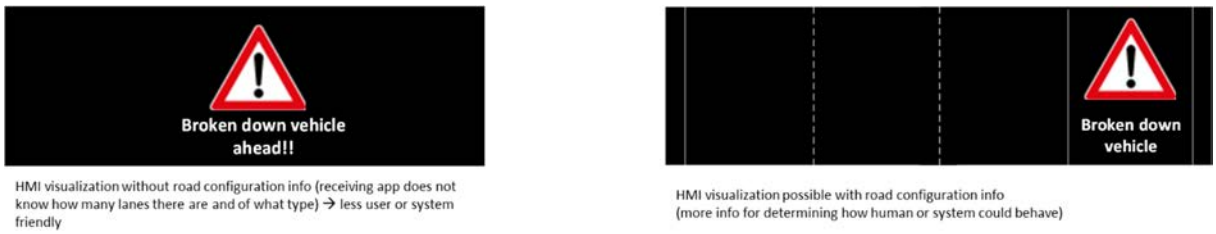

Figure C.1: New HMI options with road configuration information

If the road configuration information is available to road infrastructure managers, it can be I2V-shared as part of infrastructure-generated DENMs. Assuming it can be detected by vehicles via reliable on-board detection systems, the road configuration information can also be V2V-shared as part of vehicle-generated DENMs, and hence also adopted in V2V use cases.

C.2 Technical solution and scope of usage

The À La Carte container "Road Configuration Container" (RCC in the following) specified in the present document, can allow representing road configurations with different complexities. Targeted complexities go from highways and motorways (single driving direction with physical separation from the other direction) up to at least interurban roads (multi-directional and without physical separation between driving directions).

The RCC is not meant to be self-contained: on the contrary both originators and receivers of the RCC are expected to logically link (explicitly or implicitly) its contents to other components of the DENM (e.g. *eventPosition*, *eventZone*, *detectionZonesToEventPosition*, *detectionZonesToSpecifiedEventPoint*, *eventHeading*), if required for application purposes. In particular, the RCC definition is targeted at allowing mapping of the DENM *eventPosition* and, if present, optional fields like *lanePosition* of the event or its *eventZone* on the actual underlying road configuration to better characterize their relevance to receiving ITS-S applications. To allow this, the RCC:

- Describes the configuration of the road where the event exists (is detected), which means that it is specified at least at the *eventPosition* and along the *eventZone*, if existing.

Additionally, the RCC:

- Could specify the road configuration of given roads in a DENM detection zone. E.g. it could specify the configuration of road portions where the DENM traces are described (as described in clause C.3.2.1, this can help receiving ITS-S applications to determine whether an event downstream is located on the road where the vehicle is currently driving, and hence is relevant, or on a parallel road, hence not relevant).

The RCC is not meant to point to road configuration representations that might be available in concurrently transmitted IVIMs (see ETSI TS 103 301 [i.10]). Not being the IVIM an "always on" message, linking the DENM RCC to road configuration representations in IVIMs would require synchronization mechanisms making sure that the IVIM is always transmitted as long as the DENM event is valid. On the contrary, methods for linking the DENM RCC to a road configuration representation achieved from concurrently transmitted MAPEMs (see ETSI TS 103 301 [i.10]) are considered. Being the MAPEM an "always on" message, synchronization efforts would not be required. This link between a DENM RCC and a MAPEM permits associating the DENM *eventPosition* to specific couples (*IntersectionID+LaneID*) or (*RoadSegmentID+LaneID*) out of those described in detail in the MAPEM (see clause C.3.2.3).

C.3 Technical solution description

C.3.1 General definitions

The DENM RCC defines the configuration of "road sections" where key geo-referenceable information included in the DENM such as *eventPosition*, *eventZone*, *detectionZonesToEventPosition* and *detectionZonesToSpecifiedEventPoint*, etc. is described. A road section is defined as a portion of road where the number of lanes, their type and width are constant along its longitudinal direction. As an example, Figure C.2 represents a road that can be driven in only one direction (left to right) and with two road sections: one with 1 and one with 2 lanes (see note).

NOTE: It is not in the scope of the present document to define where exactly a road section starts or ends based on road topological characteristics (e.g. whether the tapered part of the most-right lane is part of the section with one or two lanes).

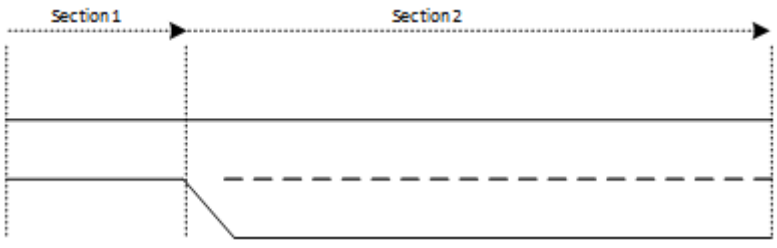

Figure C.2: Example of road with 2 different road sections

Depending on the capabilities of the DENM originator, the RCC can:

- Define the road configuration at the *eventPosition* only (in this case a road section corresponds to the very point of the *eventPosition* and does not define how far this configuration actually extends in up and downstream directions).

- Represent one or multiple subsequent road sections starting from the *eventPosition* up to the last point of the *eventZone* if the road configuration changes in that direction along the *eventZone*.

- Represent one or multiple subsequent road sections starting from the last point of the *eventZone* up to the *eventPosition* as the road configuration changes in that direction.

- Represent one or multiple subsequent road sections starting from the last point of a trace up to the *eventPosition* as the road configuration changes in that direction.

- Represent one or multiple subsequent road sections starting from the last point of a trace up to the last point of the *eventZone* as the road configuration changes in that direction (for I2V DENMs where the *eventZone* is on the other side of the trace).

For doing this, the RCC contains an extensible list of up to 8 data fields of type *RoadConfigurationSection* (see the ASN.1 definitions in Annex A). Each *RoadConfigurationSection* is used to represent the configuration of a single road section as "seen" along a specific direction. If a road can be driven in both directions, the configuration of the same road section can be described in both directions (see Figure C.3), if this can be useful for DENM-based receiving ITS-S applications (like for example when a hazard is relevant for both traffic directions). For describing the configuration of a road section as seen in a given direction, all the lanes are first classified as drivable in the same or opposite direction, and then numbered accordingly with the ETSI numbering scheme (see Figure C.3). The *RoadConfigurationSection* includes starting and ending points that, as mentioned above, may coincide with *eventPosition* or with start- and end points of traces and *eventZone* (see Figure C.3). Starting and ending points do not need to be necessarily placed on specific lanes of a given driving direction, but rather on representative positions along the longitudinal direction of the road. More precisely, the *RoadConfigurationSection* is an ordered list of the following components (see ETSI TS 102 894-2 [5] for details):

- *roadSectionDefinition* providing the basic topological definition of a road section in terms of:

  - *startingPointSection*, being the position of the starting point of the section.

  - *lengthOfSection*, as the optional length of the section along the road profile (i.e. including curves).

  - *endingPointSection*, being the optional position of the ending point of the section. If this component is absent, the ending position is implicitly defined by other means, e.g. the starting point of the next *RoadConfigurationSection*, or the section's length.

  - *connectedPaths*, which includes the identifiers of the paths having one or an ordered subset of waypoints located upstream of the *RoadConfigurationSection'* starting point.

  - *includedPaths*, which includes identifiers of the paths that cover (either with all its waypoints or with a part of it) a *RoadConfigurationSection*.

  - *isEventZoneConnected* indicating, if set to TRUE, that the *eventZone* has one or an ordered subset of waypoints located upstream of the *RoadConfigurationSection'* starting point.

  - *isEventZoneIncluded* indicating, if set to TRUE, that the *eventZone* (either one or an ordered subset of waypoints) covers a *RoadConfigurationSection*.

- *roadType*: the optional type of road on which the section is located.

- *laneConfiguration*: the optional configuration of the road section as seen in a specific traffic direction in terms of *BasicLaneConfiguration*. The *BasicLaneConfiguration* specifies how many lanes are available in each driving direction, and based on this, numbers them according to the ETSI ITS lane numbering scheme. If *laneConfiguration* is absent, a configuration of the road section in terms of *MapemConfiguration* needs to be provided.

- *mapemConfiguration*: the optional configuration of the road section in terms of *MapemConfiguration*. If absent, a configuration of the road section in terms of *BasicLaneConfiguration* needs to be provided.

Figure C.3 provides a visual explanation of the above components on a representative road layout where a DENM is described (here the RCC is provided in terms of *laneConfiguration*). The considered sample DENM is assumed to be relevant for both traffic directions. As a consequence, DENM-based receiving ITS-S applications would benefit from a road configuration description of the road where the event is detected (*eventZone*) which is consistent with the direction receiving vehicles enter the *eventZone* from (i.e. "as seen" by those vehicles). For this reason, road configurations for section 1 and section 2 are defined for the direction left to right, and road configurations for section 3 and section 4 are defined for the direction right to left.

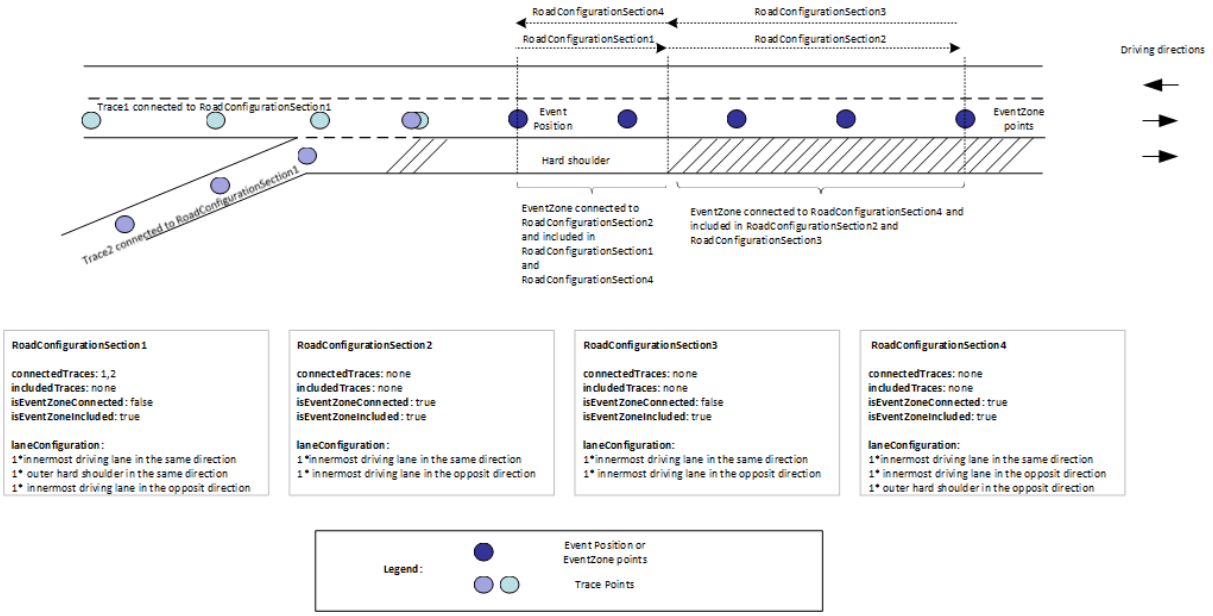

Figure C.3: Visual explanation of the RCC elements

C.3.2 Rationales

C.3.2.0 Introduction

This clause describes the rationales behind the definition of some of the elements included in the RCC. To a given extent, definition choices are explained referring to possible behaviours and needs of transmitting and receiving ITS-S applications using the RCC.

C.3.2.1 Connected and included traces and eventZone

Knowing which traces are connected to a given *RoadConfigurationSection* may be useful for receiving ITS-S applications when approaching the starting point of that *RoadConfigurationSection*. In general, a receiving ITS-S application implemented on a vehicle runs algorithms for determining if the vehicle is currently driving along one of the traces included in the DENM. If that is the case, the ITS-S application may check the *connectedPaths* element of the closest *RoadConfigurationSection* ahead to identify what road configuration would be considered next (i.e. from the *startingPointSection*). This situation is depicted in Figure C.4a). The vehicle is currently driving on the trace that is indicated to be connected to the RoadConfigurationSection1. The receiving application may use this feature e.g. to start informing the driver with a visualization of the road configuration applicable downstream before reaching the point where that configuration starts (similarly to what shown in the right picture of Figure C.1, as an example).

Similarly, a receiving ITS-S application can determine if the vehicle is currently driving along the *eventZone* of the DENM. As a consequence, the same mechanism can be applied using the *isEventZoneConnected* element: if an ITS-S application determines that it is driving along the *eventZone* indicated as connected to the closest *RoadConfigurationSection* ahead, then it may identify and use the road configuration of that *RoadConfigurationSection* as the one to be considered next. This situation is depicted in Figure C.4b). The vehicle is currently driving on the *eventZone*. By analysing the RCC, the receiving C-ITS application detects that the next road section it will encounter (RoadSection 2) is connected to the *eventZone*. Consequently, the application can start considering this road configuration before reaching that section.

The elements *includedPaths* and *isEventZoneIncluded* can be used to identify the road configuration of the road where the vehicle is currently driving with more certainty. As an example, Figure C.4c) shows a situation with two parallel roads divided by a barrier. A DENM is applicable only on the upper road, hence only the configuration of the section of the upper road is intended to be described. A vehicle currently driving on the lower road and receiving the DENM with the RCC, might erroneously consider the road configuration of the upper road since it is currently located between the starting and ending point of that section. Nevertheless, the RCC specifies that the *eventZone* is included in the road configuration of Section1. Since the receiving C-ITS application does not locate the vehicle to be on the *eventZone* (based on lateral distance), then the erroneous road configuration will not be considered.

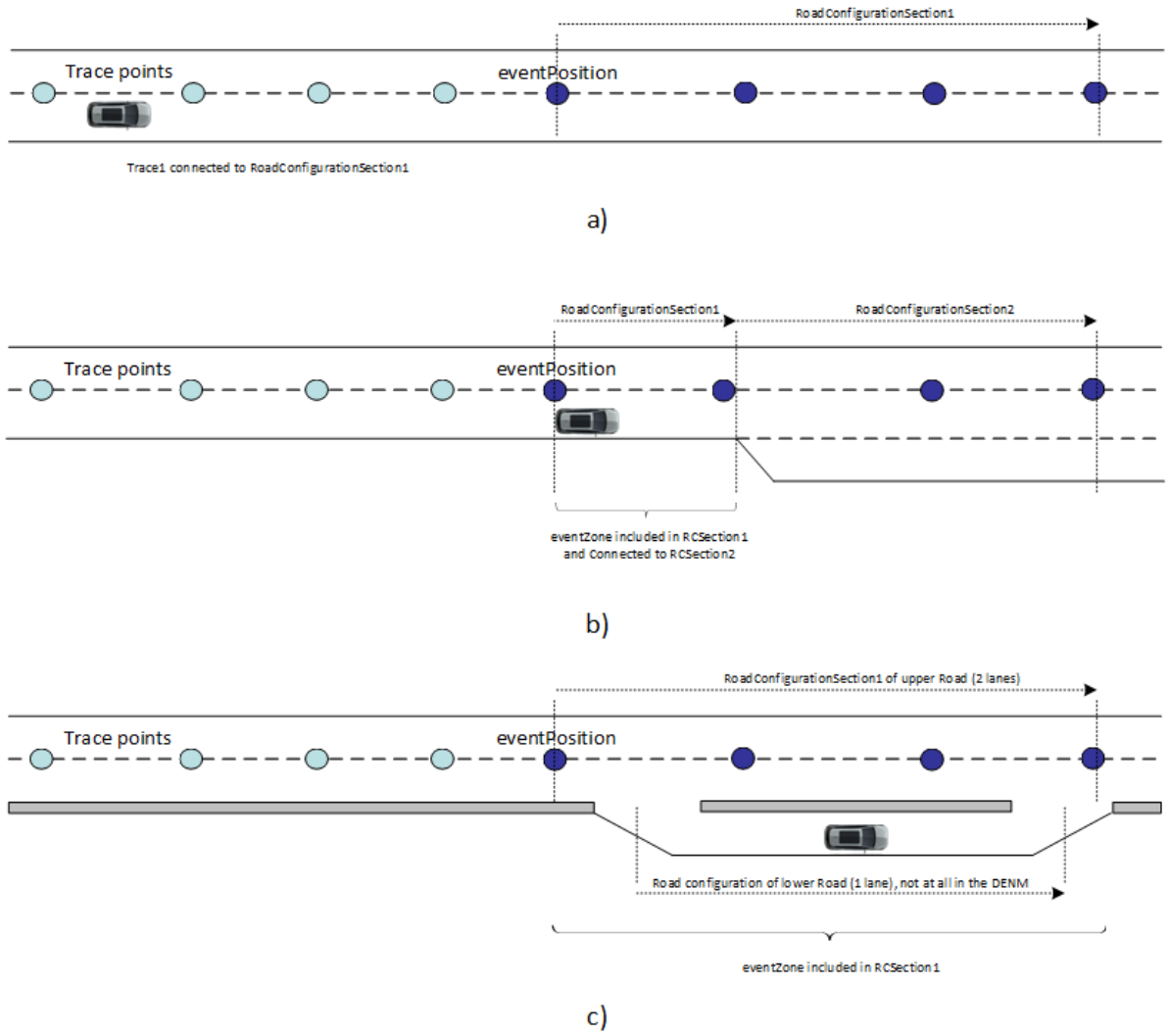

Figure C.4: examples of traces and *EventZone*, connected and included in *RoadConfigurationSections*

Explicitly informing that traces or *eventZone* are included in a *RoadConfigurationSection* also opens new possibilities for improving the relevance check of DENMs, which in turn helps preventing false positives and negatives at ITS-S application reactions. In the example of Figure C.5 where two unidirectional roads run in parallel with a physical separation in between, a DENM is described with *eventPosition* and trace on the upper road. By knowing that the DENM trace is included in a *roadConfigurationSection* having 2 driving lanes, the receiving ITS-S application can define a bounding box centred at the trace and as wide as two driving lanes to be used for DENM relevance checking: only if the current vehicle position falls within the box, the DENM is relevant. Without the additional RCC information, the ITS-S application might use wider bounding boxes possibly leading to false positives for vehicles driving towards the event on the lower road (they are not concerned by the hazard), or narrower ones that could generate false negatives for the vehicles driving on the upper road.

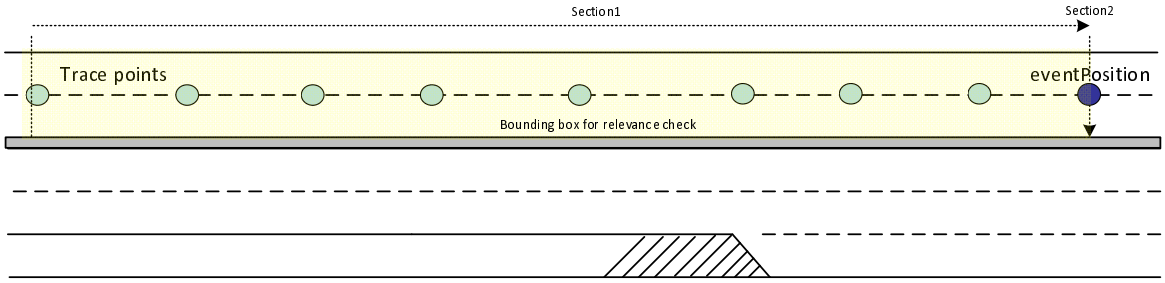

Figure C.5: example of trace included in a *RoadconfigurationSection*

C.3.2.2 Road configuration descriptions for both driving directions

The RCC can include separate *roadConfigurationSections* for expressing the road configuration of the same road portion in opposite driving directions. This is useful for DENMs relevant for all traffic directions on bidirectional roads as data elements like *connectedPaths*, *includedPaths*, *isEventZoneConnected isEventZoneIncluded* will have different values for different driving directions (see Figure C.3). A *roadConfigurationSection* provides *startingPointSection* and *endingPointSection* for receiving ITS-S applications to derive if the described road configuration applies to the currently driven direction or not, and makes use of the components *connectedPaths*, *includedPath*, *isEventZoneConnected* and *isEventZoneIncluded* accordingly. The components *startingPointSection* and *endingPointSection* can be also used to derive if a vehicle is before or inside a given *roadConfigurationSection*. The *laneConfiguration* included within a *roadConfigurationSection* lists each lane in that section with a lane number (in terms of CDD *LanePosition*), its width, and whether the lane is usable in the same or in the opposite direction. Alternatively, the *mapemConfiguration* can be used. In this case, the lane configuration of the road section is described by references to lanes described in pre-existing MAPEM messages and geographically placed at the same location as the DENM event or *eventZone* (see clause C.3.2.3).

C.3.2.3 Road configuration descriptions referring to MAPEM messages

MAPEM messages accurately describe the road topology of specific road segments or intersections using an explicit description of individual lanes (lane nodes, driving directions, usage, etc.). This accurate description can be reused in the RCC with the *mapemConfiguration* data field to enable an alternative road configuration definition. The *mapemConfiguration* only indicates references to specific MAPEM intersections, road segments, lanes, and their connections. As a consequence, DENM receiving ITS-S applications can extract the road configurations of specific road sections possibly reusing modules for handling of MAPEM information running in background.

Unfortunately, topological descriptions conveyed in MAPEM messages are often very localized (e.g. at an intersection and its ingress and egress approaches, 200~300m from an intersection centre) and might not be sufficient to describe the road configuration of the road sections where the event exists in its totality (e.g. in case of long *eventZone*). For this reason, the road configuration of the road sections in the RCC of a DENM would be suitable for representation in terms of *mapemConfiguration* only if MAPEM topological descriptions (received in one or separate MAPEM messages) cover the totality of the area where the event exists (see Figure C.6).

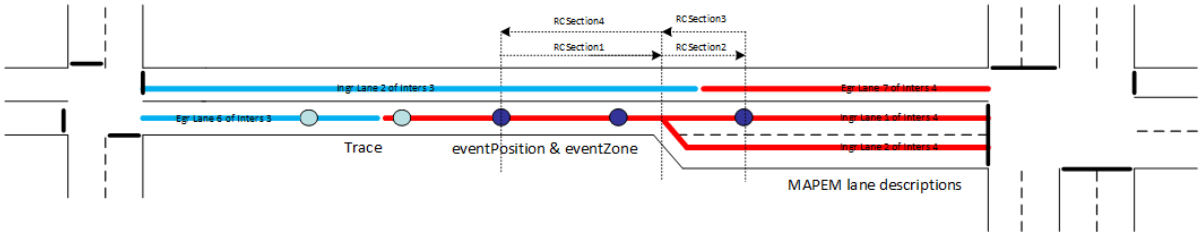

Figure C.6: Scenario where a road configuration description in terms of *mapemConfiguration* is viable

In particular cases, hazards occur in the intersection's conflict zone. In the example of Figure C.7, a bicyclist is going to cross an intersection when an incoming vehicle whose view is obstructed by a bus is about to make a right turn. The right turn is along the MAPEM connection 1, which in turn is in conflict with the bicyclist's crossing direction. In cases like this, it could be very helpful to generate DENMs to notify vehicles whose turning manoeuvres at the intersection are affected by the hazard. By receiving these DENMs, receiving ITS-S applications might determine whether such hazards are relevant via comparison with the intended crossing manoeuvre at the intersection (e.g. in the previous example, a warning would be generated only in case the receiving vehicle plans to turn right). The RCC container and its *MapemConnectionList* included in the *mapemConfiguration* description would allow the receiving application to know about all the possible turning connections, including "parallel" connections (besides those where the hazard is applicable). Knowing this additional information can be very useful as it might allow a better contextualization of the hazardous connections among all the possible connections for HMI- (e.g. visualization) or automated reactions' purposes (e.g. automatically brake or evade the hazard). In the example of Figure C.7, a right turning vehicle would be informed that connection 1 and connection 2 are to be considered in terms of road configuration when notifying an event applicable on connection 1.

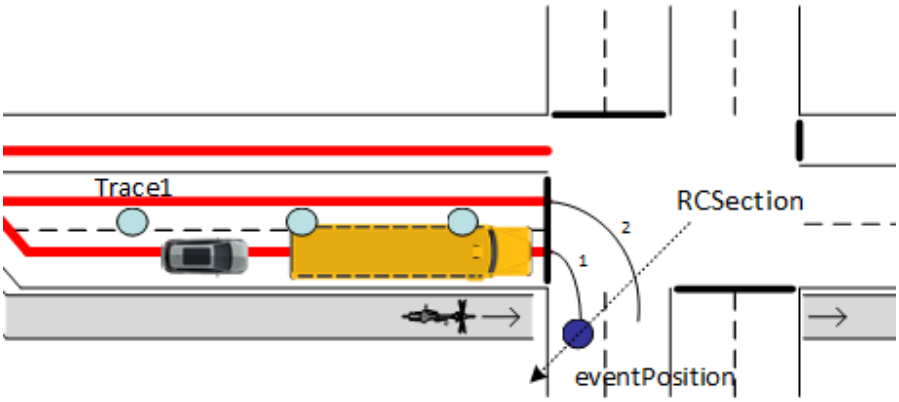

Figure C.7: Scenario where a road configuration description in terms of *mapemConfiguration* using MAPEM connections is useful

C.3.2.4 Lane numbering

When the lane configuration of a given road section is expressed in terms of *laneConfiguration*, the lane numbering refers always to a specific traffic direction. On bidirectional roads, lanes are counted from the central line of separation between two traffic directions to the outer board of the road (this implies that on a bidirectional road with one lane per direction, both lanes are numbered as "1"), see ETSI TS 102 894-2 [5] for details. Then, each lane is labelled as usable in the same, opposite or both directions with respect to the direction of the *roadConfigurationSection*. This definition choice is due to the fact that digital road databases used by both vehicles and road infrastructure ITS-S applications often adopt this representation.

C.3.2.4 Road configuration Confidence

The road configuration confidence of the RCC expresses the quality of the provided road configuration information and can be used at the receiving side to evaluate if this quality meets proprietary receiving application requirements for its adoption. This road configuration confidence is common for all the configurations expressed in the multiple *RoadConfigurationSection* elements listed in the RCC (see ASN.1 definitions in Annex A). The reason for this is that the originator of the RCC will presumably use the same road configuration detection means for all the road sections in the container. The road configuration confidence is composed of elements that describe how the road configuration is derived by the transmitter and elements that indicate the road configuration accuracy. The *usedDetectionInformation* element describes if and which sensors are used for detecting the road configuration. Additionally, the *usedStoredInformation* element describes if any kind of stored information helps deriving it. Finally, the data element *confidenceValue* expresses the road configuration quality by a quantitative value, whose calculation depends on the detection and stored information types reported by the former element. The calculation of the quantitative accuracy is based on algorithms that are assumed to be defined either in standard or profiling documents.

History

Document history		
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