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Technical Specification

Intelligent Transport Systems (ITS);
Vehicular Communications;
GeoNetworking;
Part 4: Geographical addressing and forwarding for point-to-point and point-to-multipoint communications;
Sub-part 2: Media-dependent functionalities for ITS-G5

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Foreword

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

The present document is part 4, sub-part 2 of a multi-part deliverable. Full details of the entire series can be found in part 1 [i.1].

Introduction

The GeoNetworking protocol is a network layer protocol that provides packet routing in an ad hoc network. It makes use of geographical positions for packet transport. GeoNetworking supports the communication among individual ITS-Ss as well as the distribution of packets in geographical areas.

GeoNetworking can be executed over different ITS access technologies for short-range wireless technologies, such as ITS-G5. In order to reuse the GeoNetworking protocol specification for multiple ITS access technologies, the specification is separated into media-independent and media-dependent functionalities. Media-independent GeoNetworking functionalities are those which are common to all ITS access technologies for short-range wireless communication and are specified in EN 302 636-4-1 [1]. The present document specifies media-dependent functionalities for GeoNetworking when using the ITS access technology ITS-G5 [2]. It covers an information sharing strategy for the decentralized congestion control (which is situated in the ITS access layer) and it provides multichannel operation.

The specification in the present document should be regarded as ITS-G5 specific extensions of the GeoNetworking protocol specified in [1] and does not represent a distinct protocol entity.

1 Scope

The present document specifies the media-dependent functionalities for GeoNetworking [1] over ITS-G5 [2] as a network protocol for ad hoc routing in vehicular environments.

2 References

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

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2.1 Normative references

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

[1] ETSI EN 302 636-4-1 (V1.2.0): "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".

[2] ETSI EN 302 663 (V1.2.1): "Intelligent Transport Systems (ITS); Access layer specification for Intelligent Transport Systems operating in the 5 GHz frequency band".

[3] ETSI TS 102 687: "Intelligent Transport Systems (ITS); Decentralized Congestion Control Mechanisms for Intelligent Transport Systems operating in the 5 GHz range; Access layer part".

[4] ETSI TS 102 792 (V1.1.1): "Intelligent Transport Systems (ITS); Mitigation techniques to avoid interference between European CEN Dedicated Short Range Communication (CEN DSRC) equipment and Intelligent Transport Systems (ITS) operating in the 5 GHz frequency range".

[5] ETSI TS 102 724: "Intelligent Transport Systems (ITS); Harmonized Channel Specifications for Intelligent Transport Systems operating in the 5 GHz frequency band".

2.2 Informative references

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 EN 302 636-1 (V1.2.0): "Intelligent Transport Systems (ITS); Vehicular Communications; GeoNetworking; Part 1: Requirements".

[i.2] ETSI EN 302 665 (V1.1.1): "Intelligent Transport Systems (ITS); Communications Architecture".

[i.3] ETSI EN 302 571 (V1.2.1): "Intelligent Transport Systems (ITS); Radio communications equipment operating in the 5 855 MHz to 5 925 MHz frequency band; Harmonized EN covering the essential requirements of article 3.2 of the R&TTE directive".

[i.4] IEEE Vehicular Networking Conference (VNC) (2011): "Design Methodology and Evaluation of Rate Adaptation Based Congestion Control for Vehicle Safety Communications", pp. 116 -123, T. Tielert, D. Jiang, Q. Chen, L. Delgrossi and H. Hartenstein.

[i.5] IEEE Std. 802.11-2012: "Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications", March 2012.

[i.6] IEEE 1609.4-2010: "IEEE Standard for Wireless Access in Vehicular Environments (WAVE)-- Multi-channel Operation".

3 Definitions, symbols and abbreviations

3.1 Definitions

For the purposes of the present document, the terms and definitions given in EN 302 636-4-1 [1], EN 302 663 [2], TS 102 687 [3], TS 102 792 [4], TS 102 724 [5] and the following apply:

channel busy ratio: time-dependent value between zero and one (both inclusive) representing the fraction of time that the channel was busy

local channel busy ratio: time-dependent value between zero and one (both inclusive) representing the channel busy ratio as perceived locally by a specific ITS station

1-hop channel busy ratio: highest local channel busy ratio that the ego ITS station has received from its 1-hop neighbourhood over a certain time

2-hop channel busy ratio: highest 1-hop channel busy ratio that the ego ITS station has received from its 1-hop neighbourhood over a certain time

global channel busy ratio: maximum of the local channel busy ratio, the 1-hop channel busy ratio and the 2-hop channel busy ratio

3.2 Symbols

For the purposes of the present document, the symbols given in EN 302 636-4-1 [1], EN 302 663 [2], TS 102 687 [3], TS 102 792 [4], TS 102 724 [5] and the following apply:

CBR_L_0_Hop	Local channel busy ratio for a specific frequency channel for ego ITS station
CBR_L_1_Hop	Highest received value of *CBR_R_0_Hop*
CBR_L_2_Hop	Highest received value of *CBR_R_1_Hop*
CBR_R_0_Hop	Local channel busy ratio *CBR_L_0_Hop* disseminated in single-hop broadcast packets
CBR_R_1_Hop	Highest received *CBR_L_1_Hop* disseminated in single-hop broadcast packets
CBR_target	Intended global channel busy ratio
CBR_G	Global Channel Busy Ratio for a specific frequency channel
PHY-S	ITS-S tuned on SCHs and operating in non-safety-related context
PHY-C	ITS-S tuned on CCH and operative in safety-related context
T_cbr	Lifetime of the channel busy ratio
T_trig	Trigger interval
T_duty	Multi-channel switching duty cycle
T_SCH1	Reference channel returning period
T_Safety	Phase, where an MCO-capable ITS-S is on PHY-C
T_Service	Phase, where an MCO-capable ITS-S is on PHY-S
T_mon	Minimum CBR monitoring interval as specified in [3]
t_offset	Offset time for the reference channel returning period

3.3 Abbreviations

For the purposes of the present document, the abbreviations given in EN 302 636-4-1 [1], EN 302 663 [2], TS 102 687 [3], TS 102 792 [4], TS 102 724 [5] and the following apply:

AC	Access Category
AC_BE	AC Best Effort
AC_BK	AC BacKground
AC_VI	AC VIdeo
AC_VO	AC VOice

AIFS	Arbitration InterFrame Space
BUSY	Busy Mode
CAM	Cooperative Awareness Message
CBR	Channel Busy Ratio
CCF	Channel Configuration Function
CCH	Control CHannel
CEN	Comité Européen de Normalisation
C-ITS	Cooperative ITS
CSF	Channel Switching Function
CW	Contention Window
DCC	Decentralized Congestion Control
DENM	Decentralized Environmental Notification Message
DSRC	Dedicated Short Range Communication
ETC	Electronic Toll Collection
GN	GeoNetworking
HST	Header Sub-Type
HT	Header Type
IN-SAP	interface between access layer and network & transport layer
ITS	Intelligent Transport Systems
ITS-S	ITS Station
LocTE	Location Table Entry
LocTEX	Location Table Entry Extension
MAC	Medium Access Control
MAP	road map message
MCO	Multi Channel Operations
MCS	Modulation and Coding Scheme
MHL	Maximum Hop Limit
MIB	Management Information Base
MN-SAP	Interface between management and network & transport layer
NDL	Network Design Limits (DCC management information base)
NF-SAP	Interface between networking & transport and facilities layer
NH	Next Header
OBU	On-Board Unit
PHY	PHYsical layer
PHY-C	ITS G5 transceiver tuned on CCH
PHY-S	ITS-G5 transceiver tuned on any channel
PL	Payload Length
POS	Position
PV	Position Vector
RSSI	Received Signal Strength Indicator
RSU	Road Side Unit
RX	Receiver
SAM	Service Announcement Message
SAP	Service Access Point
SCF	Store Carry Forward
SCH	Service CHannel
SHB	Single-Hop Broadcast
SO	Source
SW	Switching mode
TC	Traffic Class
TC ID	Traffic Class IDentity
TOPO	road topology message
TST	Time STamp
TX	Transmitter
TX/RX	transmit / receive

4 Overview

The present document specifies the media-dependent functionalities necessary to run the GeoNetworking protocol [1] over ITS-G5 media [2]. The functionalities are:

- information sharing for Decentralized Congestion Control (DCC) (clause 5);
- support for multi-channel operation (annex A);
- interference mitigation techniques for co-existence between CEN DSRC and cooperative ITS (annex B).

Additionally, the present document specifies extensions to the GeoNetworking location table (clause 6), to the GeoNetworking header (clause 7) and to the GeoNetworking MIB (clause 9). Clause 8 specifies the traffic classes (TC) used for ITS-G5.

Figure 1 illustrates the ITS reference architecture as specified in [i.2]. The present document specifies ITS-G5 specific, media-dependent functionalities for the GeoNetworking protocol, which are found in the ITS networking & transport layer.

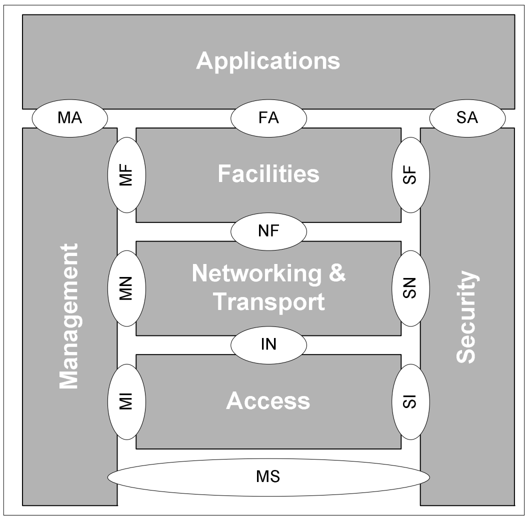

Figure 1: ITS-S reference architecture as specified in [i.2]

DCC is a necessity to control the load on a specific frequency channel and to avoid unstable behaviour. As specified in [i.3], several different frequency channels are available for Cooperative ITS (C-ITS) in Europe. Figure 2 illustrates the frequency channels together with their maximum allowed output power levels [i.3]. The spectrum comprises of four service channels (SCHx) and one control channel (CCH). The frequency band ITS-G5A contains frequency channels CCH, SCH1, and SCH2, which are intended for ITS road safety related applications. SCH3 and SCH4 are contained in the frequency band ITS-G5B and are intended for ITS non-safety applications. ITS-G5D is for future use and not yet allocated for C-ITS. The present document addresses information sharing to be used in the DCC algorithm for the access layer technology ITS-G5, which primarily uses the frequency bands ITS-G5A, ITS-G5B, and ITS-G5D.

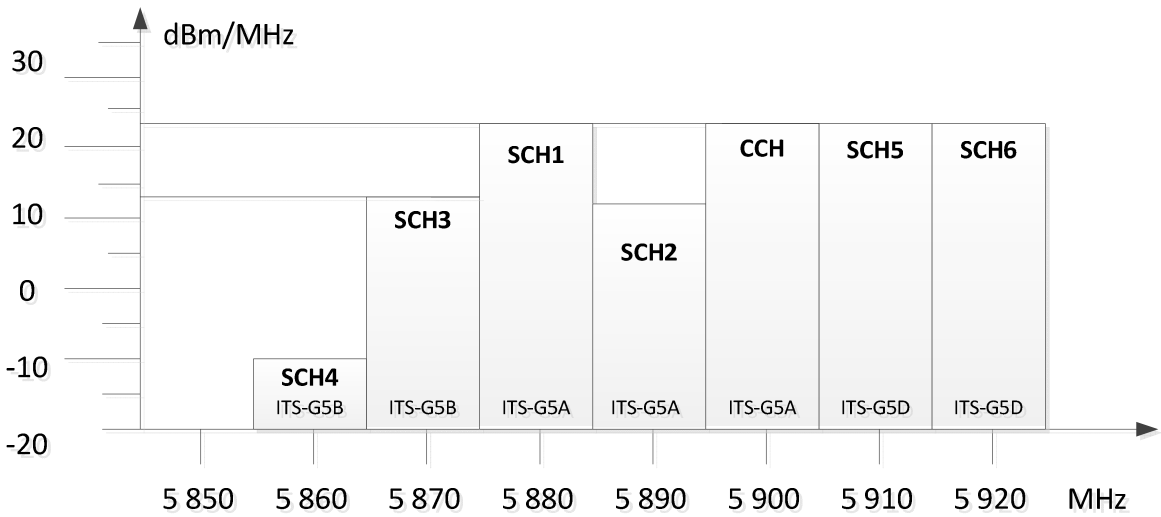

Figure 2: Maximum limit of mean spectral power density for each channel in ITS-G5A, ITS-G5B, and ITS-G5D as specified in [i.3]

5 Information sharing for decentralized congestion control

5.1 Introduction

This clause specifies an information sharing concept for the DCC algorithm situated in the ITS access layer [3]. The DCC algorithm controls the network load and thereby avoids unstable behaviour of the system due to its *ad hoc* topology [3]. The information sharing is based on dissemination of channel busy ratio (CBR) values among the ITS-Ss. This dissemination of CBR values makes the ITS-S aware of a possible channel congestion at neighbouring ITS-Ss that the ego ITS-S can contribute to (even though the ego ITS-Ss does not perceive a local congested channel status). More information about the CBR information dissemination and motivation of thereof is found in [i.4]. The obvious place for CBR dissemination is at the network & transport layer due to its network wide view. The dissemination of CBR values are conducted in every transmitted Single Hop Broadcast (SHB) packet assembled at the networking & transport layer, see clause 7. For every entry of an ITS-S in the location table [1], there will also be information about its transmitted CBR values.

Additionally, the algorithm to ensure coexistence between CEN DSRC equipment used for Electronic Toll Collection (ETC) and ITS described in TS 102 792 [4] belongs to the networking & transport layer (due to the network wide view and the placement of the location table). Depending on whether the placement of the CEN DSRC equipment on the roadside is known or unknown, the combination of the DCC concept and the coexistence algorithm looks different. Proposed implementation details for coexistence methods are given in informative annex B.

The information sharing shall provide a parameter called *CBR_G* to the management entity. This parameter is used by the DCC algorithm in the ITS access layer when calculating the current allowed time between packets [3]. The information sharing shall read the local CBR from the management via a parameter called *CBR_L_0_Hop*. The value of *CBR_L_0_Hop* is disseminated in SHB packets. More information about the inclusion of CBR values at the networking & transport layer can be found in clause 5.2.3. A schematic overview of the information sharing together with DCC in the protocol stack is depicted in figure 3. The exchange of *CBR_G* and *CBR_L_0_Hop* could also be performed via the service access point (SAP) between the access and networking & transport layers.

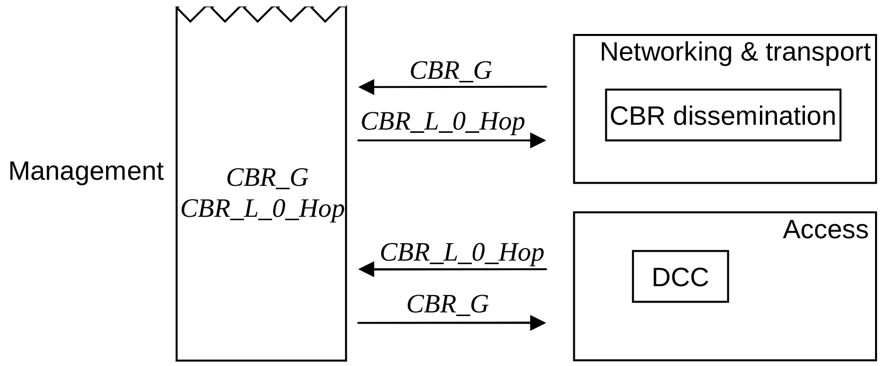

Figure 3: Overview of the information sharing together with the placement of DCC in the protocol stack

5.2 Information sharing

5.2.1 General rules

The information sharing is subject to the following general rules:

- The inclusion of CBR values shall be performed in each GN SHB packet.
- The calculation of *CBR_G* shall be activated at every trigger interval, *T_trig*.

5.2.2 CBR aggregation

The CBR dissemination and aggregation are central in DCC since this is regarded as the best feedback that can be used in C-ITS, where broadcast is the prevalent transmission mode (see also [i.4]).

The CBR aggregation is dependent upon the following CBR parameters:

- CBR_L_0_Hop,
- CBR_L_1_Hop,
- CBR_L_2_Hop,
- CBR_R_0_Hop,
- CBR_R_1_Hop, and
- CBR_G.

The CBR parameters are described in detail in table 1.

Table 1: Description of necessary CBR parameters for DCC algorithm

Parameter	Description
CBR_L_0_Hop	Local (measured) channel busy ratio, disseminated to neighbouring ITS-S as *CBR_R_0_Hop*.The local CBR measurement is performed in the access layer and specified in [3].
CBR_L_1_Hop	*CBR_L_1_Hop* is the maximum *CBR_R_0_Hop* value received from a neighbouring ITS-S in a given *T_cbr* interval, i.e. it is the 1-hop channel busy ratio. It is subsequently disseminated to neighbours as *CBR_R_1_Hop.*
CBR_L_2_Hop	*CBR_L_2_Hop* is the maximum *CBR_R_1_Hop* value received from a neighbouring ITS-S in a given *T_cbr* interval, i.e. it is the 2-hop channel busy ratio. It is never disseminated by ego ITS-S.
CBR_R_0_Hop	Disseminated local (measured) channel busy ratio (*CBR_L_0_Hop*), i.e. *CBR_L_0_Hop* becomes *CBR_R_0_Hop* when disseminated. At receiving ITS-S it becomes *CBR_L_1_Hop.*
CBR_R_1_Hop	Disseminated 1-hop channel busy ratio (*CBR_L_1_Hop*), i.e. *CBR_L_1_Hop* becomes *CBR_R_1_Hop* when disseminated. At receiving ITS-S it becomes *CBR_L_2_Hop.*
CBR_G	Global channel busy ratio at ego ITS-S, used in the DCC algorithm (maximum over *CBR_L_0_Hop*, *CBR_L_1_Hop* and *CBR_L_2_Hop*).
CBR_target	In control theory called reference value. It is the intended global channel busy ratio that DCC tries to achieve. The *CBR_target* shall be one common parameter for both the access layer and the network and transport layer DCC algorithm (e.g. shared as constant MIB parameter – see Annex C).

For every ITS-S, *i*, in the location table:

- *CBR_R_0_Hop*(*i*) is the remote *CBR_L_0_Hop* received from *i*,
- *CBR_R_1_Hop*(*i*) is the remote *CBR_L_1_Hop* received from *i*.

A plausibility check shall be performed when calculating *CBR_L_1_Hop* and *CBR_L_2_Hop* from the maximum value of *CBR_R_0_Hop*(*i*) and *CBR_R_1_Hop*(*i*), since the highest received value could come from a faulty chipset or malicious sources. The plausibility check shall be performed as follows:

- If the *CBR_L_1_Hop* is larger than *CBR_target* and the average of all *CBR_R_0_Hop*(*i*) is smaller than *CBR_target*, take the second largest entry found for *CBR_R_0_Hop*(*i*); otherwise take the largest entry.
- If the *CBR_L_2_Hop* is larger than *CBR_target* and the average of all *CBR_R_1_Hop*(*i*) is smaller than *CBR_target*, take the second largest entry found for *CBR_R_1_Hop*(*i*); otherwise take the largest entry.

Following this procedure the 1-hop channel busy ratio *CBR_L_1_Hop* shall be calculated according to equation (2) when the average of *CBR_R_0_Hop*(*i*), i.e. $\overline{CBR\_R\_0\_Hop}$, from equation (1) is bigger than *CBR_target*.

$$\overline{CBR\_R\_0\_Hop} = \frac{1}{n_0}\sum_i CBR\_R\_0\_Hop(i)\ \forall i \text{ where } CBR\_R\_0\_Hop(i) \text{ is not older than } T\_cbr \qquad (1)$$

In equation (1), n_0 is the total number of the *CBR_R_0_Hop* entries that are not outdated (older than *T_cbr).*

When $\overline{CBR\_R\_0\_Hop} > CBR\_target$

$$CBR\_L\_1\_Hop := \max_i \{ CBR\_R\_0\_Hop(i) \} \text{ during the last CBR lifetime } T\_cbr, \qquad (2)$$

otherwise *CBR_L_1_Hop* shall be set to the second largest *CBR_R_0_Hop* (i) during the last CBR lifetime *T_cbr*.

Accordingly, the 2-hop channel busy ratio *CBR_L_2_Hop* shall be calculated by equation (4) when the average of *CBR_L_1_Hop*, i.e. $\overline{CBR\_R\_1\_Hop}$, from equation (3) is bigger than *CBR_target*.

$$\overline{CBR\_R\_1\_Hop} = \frac{1}{n_1}\sum_i CBR\_R\_1\_Hop(i)\ \forall i \text{ where } CBR\_R\_1\_Hop(i) \text{ is not older than } T\_cbr \qquad (3)$$

In equation (3), n_1 is the total number of the *CBR_R_1_Hop* entries that are not outdated (older than *T_cbr).*

When $\overline{CBR\_R\_1\_Hop} > CBR\_target$, *CBR_L_2_Hop* shall be calculated by

$$CBR\_L\_2\_Hop := \max_i \{ CBR\_R\_1\_Hop(i) \} \text{ during the last CBR lifetime } T\_cbr \qquad (4)$$

otherwise *CBR_L_2_Hop* shall be set to the second largest *CBR_R_1_Hop* (i) during the last CBR lifetime *T_cbr*.

The global channel busy ratio *CBR_G(n)* after the *n*th trigger interval, *T_trig*, is calculated as specified in equation (5).

$$CBR\_G\ (n) = \max\left(CBR\_L\_0\_Hop\ (n\text{-}1),\ CBR\_L\_1\_Hop\ (n),\ CBR\_L\_2\_Hop\ (n) \right) \quad (5)$$

The initial values are *CBR_L_1_Hop(0) = 0* and *CBR_L_2_Hop(0) = 0*.

The *CBR_G* value is the input to the DCC algorithm running at the access layer as specified in [3].

5.2.3 Sending process

ITS-Ss executing the GeoNetworking protocol over ITS-G5 shall include the following DCC information in every transmitted SHB packet:

- the most recently obtained value *CBR_L_0_Hop*;
- the most recently calculated value *CBR_L_1_Hop*.

Further details are specified in clauses 6 and 7 of the present document.

5.2.4 Receiving process

Upon reception of a SHB packet from a remote ITS-S, an ITS-S shall update the location table entry fields *CBR_R_0_Hop* and *CBR_R_1_Hop* for the remote ITS-S entry.

5.2.5 Algorithm for CBR information sharing

The calculation of *CBR_G* is triggered every *T_trig*. When triggered the algorithm shall collect and update the following CBR parameters:

- CBR_L_0_Hop,
- CBR_L_1_Hop,
- CBR_L_2_Hop,
- CBR_R_0_Hop,
- CBR_R_1_Hop, and
- CBR_G.

Upon calculation of the *CBR_G*, it shall be passed over to the DCC algorithm running on the access layer described in [3]. This can be done via the Network Design Limits (NDL) table in the management plane.

NOTE 1: The DCC algorithm in the access layer updates the values of the parameters *Target_bit_rate* and *T_GenCam_Dcc*. They are provided to higher layers (e.g. by use of the NDL) for data traffic shaping and they are used by the access layer to control the data traffic (see [3] and [5]).

The DCC algorithm shall be performed for each channel in the frequency bands ITS-G5A, ITS-G5B, and ITS-G5D that is used by the ITS-S for packet transmissions.

NOTE 2: On channels where no SHB packets were received within the CBR lifetime *T_cbr*, the *CBR_G* value will result in the local CBR value of the previous trigger interval *CBR_L_0_Hop* (*n*-1) (see equation (5)).

The default value of *T_trig* shall be set to 100 ms. Within the trigger interval *T_trig*, all ITS-S shall start randomly (e.g. a *T_trig* shall not be based on the GPS time signal, thereby causing all ITS-Ss to trigger the calculation of *CBR_G* at the same time).

6 Location table extensions for ITS-G5

6.1 Location table entry extensions

This clause specifies the media-dependent extension to the Location Table Entry (LocTE) for GN over ITS-G5, following the structure of as specified in clause 7.1 of [1].

A GeoAdhoc router supporting ITS-G5 shall maintain additional parameters required for the evaluation and dissemination of the network-wide congestion level. The additional data elements to the location table entry and their specific maintenance are specified in clauses 6.1.1 and 6.1.2, respectively.

6.1.1 Additional data elements for the location table entry

In addition to the data elements in the LocTE as specified in clause 7.1 of [1], a LocTE for a GeoAdhoc router supporting ITS-G5 shall contain media-dependent extensions. These extensions are named Location Table Entry Extension for ITS-G5 (LocTEX-G5). The following data elements shall be present in the LocTEX-G5 for GN neighbours on ITS-G5 interfaces:

- Timestamp (local to ego station) of the last update of the LocTEX-G5, *TST_G5(GN_ADDR).*
- Timestamp in the SO PV of the SHB packet header as per clause 8.8.4 of [1], *TST_SO_PV_G5(GN_ADDR).*

NOTE: The TST_SO_PV_G5 is only updated when a received packet updates the LocTEX-G5; therefore it is not necessarily equal to the media-independent counterpart TST (POS, GN_ADDR) as per clause 7.1.2 in [1].

- The transmit power for the packet used as per clause 7.3, *TX_POWER_G5(GN_ADDR).*
- The received signal-strength indicator for the packet that updated the LocTEX-G5 entry, RSSI_G5(GN_ADDR).
- *CBR_R_0_Hop* as per clause 5.2.2, *CBR_R_0_HOP(GN_ADDR).*
- *CBR_R_1_Hop* as per clause 5.2.2, *CBR_R_1_HOP(GN_ADDR).*

6.1.2 Specific maintenance of the location table entry

The data elements in the LocTEX-G5 shall be updated as specified in [1] clause 7.1, with the following additions:

- The media-dependent extension of the LocTE shall only be updated for received GeoNetworking SHB packets as specified in clause 8.8.4 in [1].
- The media-dependent extension of the LocTE shall **not** be updated if the packet causing the update is a duplicate packet or a packet received on an interface that is not of ITS-G5 type.
- The media-dependent extension of the LocTE shall **not** be updated if the packet causing the update does **not** contain the optional media-dependent header field as specified in clause 7 of the present document.
- Upon an update of the LocTE, the media-dependent extensions for ITS-G5 shall be determined as follows:
  - *TST_G5* shall be determined from the local time source, details of this process are beyond the scope of the present document.
  - *TST_SO_PV_G5* shall be copied from the SHB packet header SO PV field in the SHB packet header as per clause 8.8.4 in [1], using the TST subfield of the Long Position Vector as per clause 8.5.2 in [1].
  - *TX_POWER_G5*, *CBR_R_0_Hop*, *CBR_R_1_Hop*, *STA_MCO_G5*, *GN_T_DUTY_G5* and *GN_T_SCH1_G5* shall be copied from the media-dependent header field as specified in clause 7 of the present document.
- The media-dependent extensions of the LocTE shall be discarded following the same procedure as for the media-independent fields specified in [1], clause 7.13.

- The LocTEX-G5 shall also be soft-state, i.e. entries are added with a lifetime *T(LocTEX)* set to the value of the MIB attribute *itsGnLifetimeLocTEX*. The complete LocTEX-G5 shall be removed when the lifetimes expires.

NOTE: The expiration of the itsGnLifetimeLocTE lifetime also triggers the removal of the LocTEX-G5, but not the opposite.

- *GN_T_DUTY_G5(GN_ADDR)* and *GN_T_SCH1_G5(GN_ADDR)* when Multi Channel Operations (MCO) as described in annex A is used, these parameters shall be updated continuously at a minimum rate of *1 / T_mon* and latest before the occurrence of the next MCO duty cycle.

7 Field settings in the GeoNetworking header for ITS-G5 usage

7.1 Overview

As specified in EN 302 636-4-1 [1], clause 8, the GeoNetworking header consists of a *Basic Header*, a *Common Header* and an optional *Extended Header* (figure 4).

Basic header	Common header	Extended header (optional)

Figure 4: The header structure of GeoNetworking [1]

The *Basic Header* and the *Common Header* are transmitted in all transmitted GeoNetworking packets, irrespective of the GeoNetworking header type. The *Common Header* carries a traffic class (TC) field of 8 bits length that is used by the GeoNetworking protocol to differentiate between incoming data traffic types. Setting and encoding of the TC field are specified in clause 7.2. For the transmission of media-dependent parameters, SHB packet header has a reserved 32-bit field [1]. This field is further specified in clause 7.3.

7.2 Field settings in the Common Header

As specified in EN 302 636-4-1 [1], the GeoNetworking *Common Header* consists of the fields shown in figure 5. The traffic class identity (TC ID) is transmitted in the TC field.

<table>
<tr><td colspan="8">0</td><td colspan="8">1</td><td colspan="8">2</td><td colspan="8">3</td></tr>
<tr><td>0</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>0</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>0</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>0</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td></tr>
<tr><td colspan="4">NH</td><td colspan="4">Reserved</td><td colspan="4">HT</td><td colspan="4">HST</td><td colspan="8">TC</td><td colspan="8">Flags</td></tr>
<tr><td colspan="16">PL</td><td colspan="8">MHL</td><td colspan="8">Reserved</td></tr>
</table>

Figure 5: GeoNetworking Common Header format as specified [1]

As specified in EN 302 636-4-1 [1], clause 8.7.2, the TC field consists of three sub-fields, SCF, channel offload and TC ID (table 2). The present document specifies the TC ID in clause 8.

Table 2: *TC* field in the Common Header

Field #	Field name	Octet/bit position		Type	Unit	Description
		First	Last			
1-4	See table 4 [1].					
5	*TC*	Octet 2 Bit 0	Octet 2 Bit 7	Three sub-fields: 1 bit selector, 1 bit selector, 6 bit selector	n/a	Traffic class represents facility layer requirements on packet transport. Bit 0: **SCF** Flag indicating whether the packet shall be buffered when no neighbour exists (store-carry-forward). Bit 1: **Channel Offload** Flag indicating whether the packet can be offloaded to another channel. Bit 2 to Bit 7: **TC ID** TC ID as specified in the present document.
6-9	See table 4 in [1].					

7.3 Field settings in the Extended Header

As specified in EN 302 636-4-1 [1], clause 8.8.4, the SHB packet header carries a 4-byte, reserved field for media-dependent functionality (figure 6).

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

Basic Header
Common Header
SO PV
Reserved by EN 302 636-4-1 and specified in the present document

Figure 6: The SHB packet header format [1]

The present document replaces the field Reserved in [1], table 3 by the field *DCC-MCO* (see table 3). Further, as specified in table 3 the DCC-MCO field consists of several sub-fields.

Table 3: Fields of the SHB packet header

Field #	Field name	Octet/bit position		Type	Unit	Description
		First	Last			
1-3	See [1], table 13.					
4	*DCC-MCO (was Reserved)*	Octet 40	Octet 43	32-bit unsigned integer	n/a	**Octet: 40** Bit 0 to Bit 7: Current *CBR_L_0_Hop* **Octet 41** Bit 0 to Bit 7: Current *CBR_L_1_Hop* **Octet 42** Bit 0 to Bit 4: Output power of the current packet, E.I.R.P [0 dBm to 31 dBm, unit 1 dBm, values higher than 31 dBm shall be set to 31 dBm] Bit 5 to Bit 7: Reserved for future use **Octet 43** Reserved for MCO see annex A

The *CBR_L_0_Hop* and *CRB_L_1_Hop* shall be encoded as *floor(CBR_L_0_Hop x 255)* and *floor(CBR_L_1_Hop x 255)*, respectively.

NOTE: This is consistent with CBR encoding in [i.5].

8 Traffic classes for ITS-G5

The traffic class identification (TC ID) provides a way to prioritize between data traffic at the networking & transport layer, which is based on the four different queues found in the access protocol entity [2] for each frequency channel. For each frequency channel, there is one access layer. This access layer contains the medium access control (MAC) method with the ability to prioritize between data traffic using four different queues with different listening periods (arbitration inter-frame space, AIFS) and contention window (CW) settings. For details around the MAC method and how the prioritizing of data traffic is performed, see [i.5] and annex B in [2]. In table 4, the default values for AIFS and CW are depicted for the different access categories (AC) [2].

Table 4: Default values for AIFS and CW for each frequency channel at the access layer

AC	CW_{min}	CW_{max}	*AIFS*
AC_VO	3	7	58 µs
AC_VI	7	15	71 µs
AC_BE	15	1 023	110 µs
AC_BK	15	1 023	149 µs

Table 5 specifies the mapping of TC IDs (clause 7) onto transmission parameters for ITS-G5 [2]. The corresponding AC is shown in table 4.

Table 5: Traffic classes for ITS-G5

TC ID	AC	Channel	Maximum Transmit Power Level [dBm]	MCS	Intended Use
0	AC_VO	CCH	+33	6 Mbit/s	High-priority DENM
1	AC_VI	CCH	+23	6 Mbit/s	DENM
2	AC_BE	CCH	+23	6 Mbit/s	CAM
3	AC_BK	CCH	+23	6 Mbit/s	Multihop DENM, other data traffic

Annex A (informative): Multichannel operation

A.1 Introduction

This clause describes the Multi-Channel Operation (MCO) for GeoNetworking over ITS-G5.

The MCO has three objectives:

- to efficiently use the resources of all available channels;
- to provide the mechanisms to listen to services announcements and switch to an announced service channel, and
- finally, to provide support mechanisms for MCO capable stations, to protect the receiver(s) from transmissions on an adjacent channel done by the transmitter in the same station.

TS 102 724 [5] provides a channel specification for ITS-G5. The CCH is the reference channel of all ITS-S operating in a safety-related context, where CAM, DENM, TOPO and MAP are transmitted. Other types of messages may be sent arbitrarily on other service channels (SCH).

Any ITS-S transmitting messages on a SCH is expected to operate them though a "Service". Any service is expected to be announced with a Service Announcement Message (SAM) sent on a well-known reference channel, where ITS-Ss interested in getting them are tuned.

Operating services is optional in GeoNetworking media-dependent functionalities.

As indicated in [5], for ITS-G5A and ITS-G5B the CCH is the reference channel for the SAM. SCH1 and SCH5 are an alternate reference channel for ITS-G5A and ITS-G5B respectively. The SAM is transmitted using a TC that refers to SCH1 and SCH5 as alternative channels. All SAM transmissions are done under the control of DCC.

TS 102 724 [5] also specifies alternate channels for transmitting some safety-related message outside of CCH (e.g. SCH1 for some traffic classes) under the control of DCC.

Accordingly, clauses A.2 and A.3 differentiate between two multi-channel operations:

1) Supporting service management on one or more SCH.
2) Supporting the reception and relaying of safety-related messages on SCHs.

Both operations are optional.

NOTE: As mentioned in [5], the SAM may be transmitted on the CCH. But due to the safety-critical aspects of the transmissions on the CCH, services should not be transmitted on the CCH.

A.2 Single transceiver ITS-S on ITS-G5

A.2.1 Safety-related context

Any ITS-S operating in a safety-related context and having a single transceiver (single PHY interface) should be constantly be tuned to the CCH.

NOTE: The specification of safety related context is out of scope of the present document.

Although not capable of being tuned to a SCH, ITS-S operating in safety-related context may offer and consume services on alternate communication interfaces (cellular, Wi-Fi, etc.). Services available or offered to these devices are announced by SAMs that are transmitted on the CCH, as long as the DCC can accommodate them.

A.2.2 Non safety-related context

An ITS-S operating outside a safety-critical context does not need to be tuned to the CCH. It may implement the functionality of the PHY-S ITS-S as described in clause A.3.2, where the default operation channel may either be the CCH or the first reference SCH of its class of operation as specified in [5].

As such PHY-S ITS-S would spontaneously and asynchronously switch away from CCH, such a ITS-S should not be used in a safety-related context, even while tuned to CCH.

A.3 Multi-transceiver ITS-S on ITS-G5

A.3.1 General

This clause A.3 relates to multi-channel access of an ITS-S that is capable of switching several transceivers between multiple SCHs. The first ITS-S transceiver, called PHY-C is assumed to remain tuned to CCH. Any other ITS-S transceiver, called PHY-S, may be tuned to any other SCH upon request.

A.3.2 Multi-Channel Operation for service management

Considering that a PHY-C ITS-S remains tuned to the CCH and may receive SAMs, any other PHY-S ITS-S is expected to operate by default on the first reference SCH of its class of operation as specified in [5]. Any PHY-S ITS-S is capable of switching to any alternate SCH upon request and for the duration of the service as indicated in SAMs or other GeoNetworking messages. After expiration of the service, any PHY-S transceiver of an ITS-S returns to its default operation channel.

NOTE 1: As services are not transmitted on CCH, the default service channel should not be the CCH.

The Multi-Channel Operation is controlled by the traffic class of a message received from the NF-SAP. It is based on the same Channel Configuration Function (CCF) indicated in clause 8 to map a TC to the PHY parameters (radio channel, data rate, AC queue, transmit power level) of a selected ITS-G5 interface.

The Multi-Channel Operation is established with an interaction between the CCF and a Channel Switching Function (CSF) by the management entity over the MN-SAP.

NOTE 2: The specification of the functionality of a Channel Switching Function (CSF) at the management entity is out of scope of the present document.

In the same process that performs a mapping between a TC to a channel configuration (PHY parameters), the CCF also receives the authorization or rejection of the switching of the given channel from the CSF. The CCF triggers the service primitive MN-SAP-req with the following parameters

- *TC* - TC of the packet as indicated by the MN-SAP.
- *Duration* - Service or switching duration as specified in the SAM or GeoNetworking header. If this field is empty or unavailable, the management assumes a minimum switching duration of *T_mon*.

Based on the level of priority and other parameters of the request, the CSF will decide if the channel switching is allowed and may accept or reject the channel switch request.

In case the CSF accepts the channel switch, it will trigger a service primitive PLME-SET-req to the ITS-G5 interface to trigger the channel switching and will return the requested channel configuration (channel, data rate and priority) to the CCF over a service primitive MN-SAP-cfm.

Upon reception of a service primitive MN-SAP-cfm from the management entity, the CCF does:

- If *MN-SAP.cfm* includes the channel specification (accept):
  ... transmit the packet to the IN-SAP on the channel, at the given data rate and on the indicated priority queue.
- If *MN-SAP.cfm* does not include the channel specification *(reject)*:
  ... drop the packet and send an indication to the higher layer on the NF-SAP.

Optionally, the management entity may answer with *wait* (empty channel configuration) in order to indicate to the CCF to wait until the PHY-S switches back from a higher priority service and becomes available. In that case, the CCF will buffer the packet and renew its request after the waiting time, without notifying the higher layer.

A.3.3 Multichannel in safety-related context for ITS-G5

The present clause only applies to PHY-S ITS-S, as PHY-C ITS-S is assumed to remain constantly tuned to CCH. The present clause also does not apply to single transceiver ITS-S station.

As indicated in [5], some safety-related messages may be transmitted under certain conditions on the SCH. As any critical safety-related messages are primarily transmitted on CCH, this function is optional. A PHY-S ITS-S implementing this functionality is assumed to be operating in a safety-related context and restrictions in channel switching as described in clause A.3.2 are required.

Considering the importance of safety-critical messages transmitted on SCH, they are expected to be transmitted outside the context of a service. Under the control of the DCC function, it is the responsibility of the management entity and the CSF to map the TC of a safety-related message to a channel outside of the CCH. This channel is assumed to be well known by any PHY-S ITS-S communicating in a safety-related context.

The critically of a message and the requirement from GeoNetworking [1] require all transmitters and receivers PHY-S ITS-S to be simultaneously tuned to the same SCH. Accordingly, a synchronous channel switching mechanism between SCH is expected to be specified.

The synchronous channel switching mechanism as specified in the present document is conceptually similar to [i.6], yet applied between SCH.

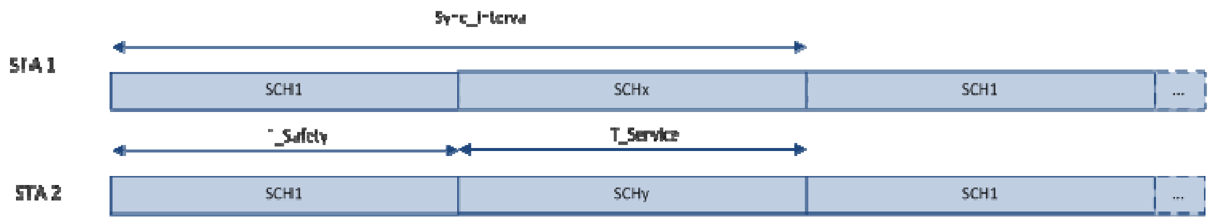

Figure A.1: Synchronous channel switching mechanism

As indicated in Figure A.1, the PHY-S ITS-S will alternate between a *safety phase* and a *service phase* following two intervals *T_safety* and *T_service*.

The CSF at the management entity has the responsibility to alternatively switch between the reference safety SCH during a *T_safety* phase, and the default SCH during the *T_service* phase during a *sync_interval*. At every beginning of each interval, the management entity will send a service primitive PLME-SET-req to the ITS-G5 interface at access layer with the indication of the respective channels. A guard interval will also be added for time synchronization reasons, during which both channels are unavailable.

The default values for the durations *T_Service* and *T_Safety* are given in table 1. Although similar to [i.6], the durations are longer, as safety-related messages on SCH do not have the same delay constraints, and services may suffer from regular interruptions for large packets.

Table A.1: System Characteristics

Parameter	Default Duration
T_Service	*T_mon*
T_Safety	*T_mon*

NOTE 1: The specification of the CSF extension at the management entity to support synchronous channel switching is out of the scope of the present document.
The specification of the synchronization function between ITS-S is out of the scope of the present document.

The *T_safety* and *T_service* phases should be known to the Facilities through the MF-SAP, so that safety-critical messages could not be generated when the PHY-S ITS-S is away from the safety SCH.

For safety-related messages being relayed by the GeoNetworking stack, the following rule is applied:

- Upon arrival of a message, which TC indicates a safety-related context, the CCF contacts the CSF to obtain a mapping between the TC and the channel configurations. Similarly to clause A.3.2, the CCF reacts as follows:
  - If *MN-SAP.cfm* includes the channel specification, send the packet on IN-SAP with the given channel specifications.
  - If *MN-SAP.cfm* does not include any channel specification, drop the message.

NOTE 2: The specification of the functionality of the CSF at the management entity is out of the scope of the present document. As indication, and considering the synchronous nature of the CSF, the CSF should not accept any safety packet while on *T_service* and service packet while in *T_safety*.

A.4 TX/RX synchronization

Due to hardware and radio limitations, single or dual transceiver ITS-S usually cannot transmit (TX) and receive (RX) at the same time. Accordingly, TX and RX restrictions apply due to physical limitations of the receivers.

A.4.1 Single transceiver (outside the safety-related context)

Usually, an ITS-S that is not capable of transmitting and receiving simultaneously on different channels, because the transmitted signal blocks the receiver. If this is the case, higher layers should be aware that the reception is stopped while transmitting (e.g. by a management indication).

A.4.2 Multi-transceiver

A multi-transceiver cannot transmit and expect reception on the second transceiver. Accordingly, provisions should be taken to protect the first transceiver in RX mode while the second transceiver is in TX mode.

NOTE: The provisions taken to protect the RX transceiver could impact the DCC channel load monitoring. Because DCC_NET might assume all transceivers in RX mode as BUSY while another one is in TX mode. In fact, no channel probing is possible while the ITS-S is transmitting on any channel.

Annex B (informative): DSRC Interference Mitigation

TS 102 792 [4] specifies mitigation techniques to avoid interference between the already deployed European CEN dedicated short-range communication (CEN DSRC) used for electronic toll collection (ETC) at 5,8 GHz and cooperative ITS equipment operating at the frequency bands ITS-G5A, ITS-G5B, and ITS-G5D. These mitigation techniques ensure co-existence between the two systems. If a CEN DSRC onboard unit (OBU) has a distance of at least 1,5 meter to the ITS-G5 installation, no harmful interference caused by ITS-G5 occurs, if the ITS-G5 output power level does not exceed 10 dBm E.I.R.P. If there is a shorter physical distance between them, the electrical field strength caused by a continuous 10 dBm signal should not exceed 0,11 V/m (-51,6 dBm) at the position of the CEN DSRC OBU [4]. In other words, if the output power level is set to a maximum of 10 dBm and the physical distance between the two systems is larger than 1,5 m, no other mitigation is required.

If higher output power levels are used, mitigation techniques are necessary to avoid harmful interference. There are two possible options described in [4] when these mitigation techniques should be applied:

1) Use an appropriate CEN DSRC detection system to switch the mitigation techniques on when necessary.

2) Apply the mitigation techniques always - no detection is needed.

Option 1 requires additional detection hardware at the ITS-G5 antenna, or a modified ITS-G5 radio frontend, whereas option 2 is purely software based.

TS 102 792 [4] specifies several applicable mitigation techniques and their combinations:

- Reduce the ITS-G5 output power level according to the distance to the CEN DSRC tolling station.
- Continuously keep track of the number of ITS-S in the vicinity and adjust the time between packet transmissions based on the output power level of the ITS-S.
- Combine the ITS-G5 output power adjustment with the inter packet time adjustment.

For the inter packet time (T_{off}) adjustment, the distance at which the ITS-Ss are to be counted depends on the output power level. Table B.1 lists the required circular area around an ITS-S (i.e. given by the radius of the circle) for the output power levels 15 dBm, 20 dBm, and 23 dBm [4]. The radius around the ITS-S increases with the output power level.

Table B.1: Radius of around the ITS-S required to include vehicles

Output power level [dBm]	Radius around the ITS-S [m]
15	26
20	41
23	55

For the number of ITS-Ss found within the radius, a minimum required time between consecutive transmissions is derived. In table B.2, the time between transmissions of consecutive packets is tabulated given the number of ITS-Ss within the radius.

Table B.2: Required time between transmissions depending on the number of ITS-S within a specific radius

Time between transmission (T_{off}) [ms]	Number of ITS-Ss within radius
50	2
100	4
200	6
500	12
1 000	24

Controlling the time T_{off} between transmissions needs additional resources to compute the distance to all other ITS-Ss in the location table. Since several applications anyhow need distance information, the computation can be reused for other purposes. In order to calculate the distance, the coexistence algorithm needs to know the positions of all ITS-Ss that are closer than the radius given in table B.1 to calculate the time T_{off} between transmissions. This T_{off} time applies to all frequency channels including ITS-G5A, ITS-G5B, and ITS-G5D, i.e. the time T_{off} between transmissions for one ITS-S is expected to be kept for all transmissions performed for all frequency channels. When the number of ITS-Ss in the radius given by table B.1is high and a shorter T_{off} time than the coexistence algorithm allows is needed, the output power can be reduced to e.g. 10 dBm (10 mW). This is the simplest way to combine a power level adjustment with a T_{off} adjustment.

Further, in order to count the number of ITS-Ss in the radius given by table B.1, the position is exchanged over a wireless channel (i.e. on the CCH by CAM messages or beacons). This implies that to ensure co-existence between CEN DSRC and ITS-G5, vehicle ITS-S transmitting with more than 10 dBm transmit power level cannot operate on a SCH only, they should be tuned additionally to the CCH to distribute their position information and to receive the position information of all ITS-S within a radius given by table B.1. Or they should send regularly GeoRouting SHB packets on the SCH that they are using (e.g. beacons).

For fixed ITS-S advertising a service on a SCH only, the position of the next tolling station is known, and the output power level can be adjusted according to the distance to the tolling station.

The major advantage of using a CEN DSRC RSU detector (option 1) is that the available frequency channels can be utilized more efficiently since the ITS-S knows exactly when it is close to a tolling zone and can then for example mute the ITS-G5 radio or decrease the output power level to 10 dBm. Since the protection area around a tolling station is relatively small (depending on the ITS output power level), typically the power level reduction is only required for some seconds of travelling time (depending on the driving speed).

NOTE: The generation of Decentralized Environmental Notification Message (DENM) with a TC ID of zero is not restricted by the CEN DSRC equipment, i.e. in a hazardous situation the DENM is always transmitted.

Annex C (informative): ITS-G5 extensions to GeoNetworking NDL parameters

Table C.1 lists the NDL parameters used by DCC on the network & transport layer.

Table C.1: Global parameters used by DCC on the network & transport layer

Name	Units	Range	Type	Description
CBR_G	%	0 to 100	numeric list	Global CBR value provided by DCC network & transport to DCC access as list entry in the NDL for each transmit channel in use. It will be updated periodically with a frequency of 1 / *T_trig.*
CBR_target	%	0 to 100	constant	Constant input parameter of the DCC algorithm provided by the NDL to both DCC network & transport and to DCC access. Specified in [3].

Annex D (informative): Bibliography

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