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Intelligent Transport Systems (ITS);
Cross Layer DCC Management Entity
for operation in the ITS G5A and ITS G5B medium

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Contents

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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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1 Scope

The present document specifies the functionality of the decentralized congestion control (DCC) entity residing in the management plane for the ITS-G5A, ITS-G5B, and ITS-G5D radio interfaces, collectively known as the 5 GHz ITS frequency band.

The purpose of the DCC operation is to evaluate the load of the active radio channels and to optimize the radio channel usage by managing the ITS-S DCC parameters. Another purpose is to keep track and help the exchange of DCC parameters which cannot be conveyed via the data plane between the different layers.

The present document specifies:

- The necessary support functions of DCC that needs to be in the management plane, i.e. cross-layer DCC operations.
- The required interface parameters between the DCC management entity and the DCC entities in the facilities, the networking & transport and the access layers.
- The testing procedures and corresponding test cases.

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 reference document (including any amendments) applies.

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

[1] IEEE 802.11-2012: "IEEE Standard for Information technology -- Telecommunications and information exchange between systems Local and metropolitan area networks -- Specific requirements Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications".

[2] 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".

[3] ETSI EN 302 636-4-1: "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".

[4] ETSI TS 102 636-4-2: "Intelligent Transport Systems (ITS); Vehicular Communications; GeoNetworking; Part 4: Geographical addressing and forwarding for point-to-point and point-to-multipoint communications; Sub-part 2: Media-dependent functionalities for ITS-G5".

[5] ETSI TS 102 723-1: "Intelligent Transport Systems (ITS); OSI cross-layer topics; Part 1: Architecture and addressing schemes".

[6] ETSI EN 302 665: "Intelligent Transport Systems (ITS); Communications Architecture".

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

[8] ETSI EN 302 571: "Intelligent Transport Systems (ITS); Radiocommunications 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".

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

2.2 Informative references

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

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 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 101 612: "Intelligent Transport Systems (ITS); Cross Layer DCC Management Entity for operation in the ITS G5A and ITS G5B medium; Report on Cross layer DCC algorithms and performance evaluation".

[i.2] G. Bansal, J. Kenney, and C. Rohrs, "LIMERIC: A Linear Adaptive Message Rate Algorithm for DSRC Congestion Control", IEEE Trans. Vehicular Technology, Vol. 62, No. 9, Nov. 2013.

[i.3] B. Cheng, M. Gruteser, J. Kenney, G. Bansal, K. Sjoberg, "Performance Evaluation of a Mixed Vehicular Network with CAM-DCC and LIMERIC Vehicles", Proceedings of the IEEE World of Wireless, Mobile and Multimedia Networks (IEEE WoWMoM'15), Boston, USA, 2015.

3 Definitions, symbols and abbreviations

3.1 Definitions

For the purposes of the present document, the terms and definitions given in IEEE 802.11-2012 [1], ETSI EN 302 665 [6], ETSI EN 302 663 [7], ETSI EN 302 571 [8] and the following apply:

burst of messages: set of one or more messages that the gatekeeper transfers to the ITS-G5 radio at one time

CBR target value: value used in GN as discriminator for the evaluation of the global CBR

NOTE: In the present document it is set to a fixed value and equal to the congestion threshold C_{TH}

channel busy ratio: time-dependent value between zero and one (both inclusive) representing the fraction of time that an individual radio channel used by an ITS-S was busy

NOTE: This is one possible implementation of the channel load metric.

channel resource limit: maximum amount of available resources of an individual radio channel used by an ITS-S

NOTE: It corresponds to a trade-off between the maximum usage of the channel for periodic safety-related messages, maximizing the performance of the ITS-G5 technology and allowing any event-based emergency packet to be reliably transmitted.

chipset channel load: chipset data type that the DCC_ACC entity will transform into a local channel specific CBR value

cross-layer DCC: cooperation mechanisms based on entities distributed over several layers of the protocol stack which jointly work together to fulfil the operational requirements of DCC

DCC_ACC: DCC entity located at the Access Layer that acts as a gatekeeper and also provides the local CBR values for all ITS-G5 radio channels used by a certain ITS-S

DCC_CROSS: DCC cross-layer entity located in the management plane

DCC_CROSS_Access: function in the DCC_CROSS entity that exchanges DCC control parameters with DCC_ACC

DCC_CROSS_Facilities: function in the DCC_CROSS entity that provides DCC control parameters to the facilities layer and to the applications

DCC_CROSS_Net: function in the DCC_CROSS entity that provides DCC channel resources parameters to the networking and transport layer

DCC_FAC: DCC entity located at the facilities layer

DCC fairness: concept where any ITS-S under the same channel conditions has an equal opportunity of accessing the radio channel for periodic messages, while maintaining a channel access margin to always allow the exchange of safety-critical event-based messages

DCC flow control: function that retrieves the messages from the DCC queues according to their priorities and transfers them for transmission to the ITS-G5 radio interface

DCC flow control parameters: DCC parameters generated by the DCC_CROSS_Access that indicate to the DCC flow control the amount of available resources available for transmission on the radio

DCC_NET: DCC entity located in the networking & transport layer

DCC parameter evaluation: function that takes the local CBR and the global DCC RX parameters as input and evaluates them to obtain the internal DCC parameters and the global DCC TX parameters

DCC power control: optional function that sets the ITS-G5 TX power level according to the DCC power control parameters per radio channel

DCC power control parameters: DCC parameters generated by the DCC_CROSS_Access function to set the ITS-G5 TX power level limits per radio channel

DCC prioritization: function that routes messages per channel to DCC queues according to the IEEE 802.11 [1] EDCA access category indicated in the traffic class field

DCC queues: set of buffer space in the DCC_ACC entity in the access layer that temporarily stores the transmission requests per given radio channel sorted according to their priority and time of arrival

NOTE: A DCC queue retains a message, if a message in a DCC queue with higher priority is present.

decentralized congestion control: set of mechanisms for ITS-S to maintain network stability, throughput efficiency and fair resource allocation to ITS-S using ITS-G5 access technology

global channel busy ratio: maximum value of the local channel busy ratio, the 1-hop channel busy ratio and the 2-hop channel busy ratio for a given radio channel

NOTE: The evaluation of the global channel busy ratio, the 1-hop channel busy ratio and the 2-hop channel busy ratio is specified in ETSI TS 102 636-4-2 [4].

global DCC RX parameters: DCC parameters received from neighbouring ITS-S (e.g. their local CBR measurement) and locally determined parameters (e.g. number of neighbours) that are used to derive the currently available channel resources and the global DCC TX parameters

NOTE: These parameters comprehend the basic metrics to derive the current level of resource usage in order to classify the congestion. Metrics based on local knowledge are used in a first step, such as the Channel Busy Ratio (CBR) and the number of neighbouring ITS-S. To avoid channel congestion, it is appropriate to also use cooperatively determined metrics that can be retrieved by exchanging the local metrics.

global DCC TX parameters: DCC parameters per given radio channel broadcasted to neighbouring ITS-S using the same channel

idle time: time interval between the end of transmission of a first burst and the start of transmission of the next burst by the ego ITS-S on a given radio channel, considering the inter-frame spacing and inter-leaving transmissions from other senders

internal DCC parameters: management parameters that are used to disseminate the DCC parameter evaluation result to DCC_CROSS_Facilities, to DCC_CROSS_Net and to DCC_CROSS_Access

NOTE: Internal DCC parameters are derived by the DCC parameter evaluation function based on the global DCC RX parameters and the local CBR value. These parameters define how much channel resources an ITS-S is allowed to use on each individual radio channel used by the ITS-S.

inter-reception rate: receiver-based metric representing the time between the successful reception of two messages from the same ITS-S on the same given radio channel

NOTE: If the receiver knows the time between two CAM messages, the inter-reception rate indicates message losses impacting the ITS-S safety applications.

ITS-G5A: frequency band ranging from 5 875 MHz to 5 905 MHz

ITS-G5B: frequency band ranging from 5 855 MHz to 5 875 MHz

ITS-G5D: frequency band ranging from 5 905 MHz to 5 925 MHz

local channel busy ratio: time-dependent value between zero and one (both inclusive), representing the channel busy ratio (CBR) as perceived locally by a specific ITS-S for each individual radio channel

message generation parameters: parameters that inform the components in the facilities layer and in the applications layer about the available channel resources

transmission duration: total time during which the ITS-S own messages are sent on the target radio channel as a burst, not considering the inter-frame spacing or inter-leaving transmissions from other senders

NOTE: It is also considered to be the transmit duration for the DCC flow control function.

transmit ratio: contribution to the CBR on a given radio channel caused by the transmissions of the ego ITS-S

3.2 Symbols

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

α	Parameter of the linear adaptive algorithm
β	Parameter of the linear adaptive algorithm
CBR	Channel Busy Ratio
CBR_a	Available CBR percentage per radio channel and per ITS-S (output of DCC algorithm)
CBR^{target}	Target CBR in the linear adaptive algorithm
C_{TH}	Congestion threshold
C_w	Weight factor
NDL_timeUp	Inertia control parameter in the state-based DCC algorithm (upwards direction)
NDL_timeDown	Inertia control parameter in the state-based DCC algorithm (downwards direction)
N_{Sta}	Number of ITS-S
P_{RX}	Received Power
P_{TX}	Transmit Power
R_M	Message Rate
T_{off}	Idle time
$T_{off\ Limit}$	Idle Time Limit
T_{offm}	Measured equilibrium of the DUT idle time
T_{on}	Transmission duration

NOTE: All channel specific values refer to an individual radio channel used by an ITS-S.

3.3 Abbreviations

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

ASN	Abstract Syntrax Notation
AWGN	Additive White Gaussian Noise
CA	Cooperative Awareness (basic service)
CAM	Cooperative Awareness Message

CBR	Channel Busy Ratio
CEN	Comité Européen de Normalisation
CL	Channel Load
DCC	Decentralized Congestion Control
DEN	Decentralized Environmental Notification (basic service)
DENM	Decentralized Environmental Notification Message
DSRC	Dedicated Short Range Communication
DUT	Device Under Test
E.I.R.P	Equivalent Isotropically Radiated Power
EDCA	Enhanced Distributed Channel Access
FAC-ID	Facilities interface Identifier
GN	GeoNetworking
IP	Internet Protocol
ITS	Intelligent Transportation System
ITS-S	ITS StationMAC Medium Access Control
MAC-ID	Medium Access Control interface Identifier
MF-SAP	Management-Facilities SAP
MI-SAP	Management-Interface SAP
MN-SAP	Management-Networking and Transport SAP
NDL	Network Design Limits
NT	Networking and Transport
NT-ID	Networking and Transport interface Identifier
OFDM	Orthogonal Frequency Division Multiplexing
R/W	Read/Write
RX	Receiver
SAP	Service Access Point
TC	Traffic Class
TR	Technical Report
TS	Technical Specification
TX	Transmitter

4 Introduction

The aim with the Decentralized Congestion Control (DCC) is to adapt the transmit parameters of the ITS station (ITS-S) given the present radio channel conditions, in order to maximize the probability of a successful reception at intended receivers.

The DCC attempts to provide equal access to the channel resources among neighbouring ITS-S. The channel resources allotted by the DCC to the ITS-S should be distributed between the applications according to their needs. The ITS-S determines priorities between different messages and discards messages if application requirements exceed allotted resources (with the ITS-S applications' consent). In case of a situation of road traffic emergency even during a high network utilization period, where every ITS-S has very few resources (e.g. CAM period at 1 Hz or 2 Hz), the ITS-S may still transmit a burst of messages during a short period of time to maintain a safe road traffic environment. However, this exception shall occur rarely and the messages transmitted for this purpose are only those of uttermost importance.

The present document describes the cross-layer operation of the DCC mechanisms for ITS-S operating in the ITS-G5 band. It focuses on the DCC management functions in the DCC_CROSS entity and the corresponding internal functions related to the different layers in the management entity as defined in ETSI TR 101 612 [i.1].

The present document specifies the functional behaviour and the interfaces of the DCC_CROSS component to control the load on the active radio channels. Channel load limits are provided to accommodate this.

5 DCC architecture

5.1 Overview

ETSI EN 302 665 [6] provides the ITS reference architecture for an ITS-S. The present document provides details of the DCC_CROSS entity residing in the management plane.

The DCC functionality, including interfaces mapped to the ITS-S architecture, is shown in Figure 1. It is distributed between the following entities:

- DCC_FAC located in the facilities layer;
- DCC_NET located in the networking and transport layer as specified in ETSI TS 102 636-4-2 [4];
- DCC_ACC located in the access layer as specified in ETSI TS 102 687 [2];
- DCC_CROSS located in the management plane as specified in the present document.

The components are connected through the DCC interface 1 to interface 4 as shown in Figure 1. These interfaces are compliant with ETSI TS 102 723-1 [5].

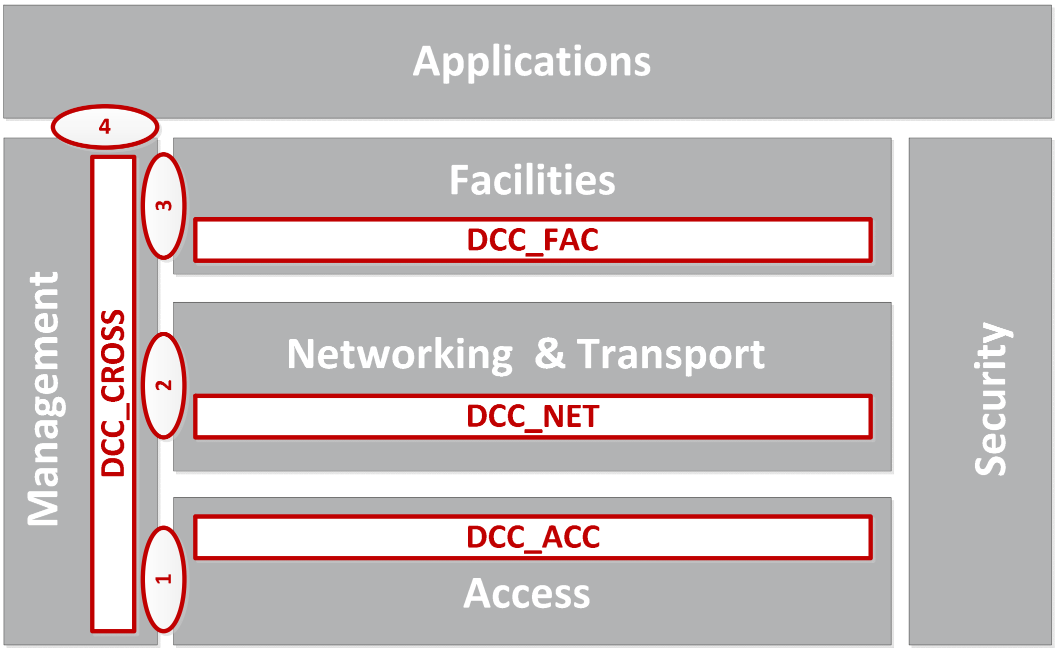

Figure 1: DCC Architecture

The DCC management entity (DCC_CROSS) in the management plane contains for each layer a function that is connected to the interface towards the corresponding DCC entity in the communication stack.

In clauses 5.2 to 5.5, an overview of the four DCC entities is given. The corresponding cross-layer functionalities in the management plane are addressed in clause 6 of the present document.

5.2 DCC_ACC

REQ001: The access layer of an ITS-S that transmits on an ITS-G5 radio channel shall include a DCC_ACC entity, as specified in ETSI TS 102 687 [2], containing the access layer specific DCC functionalities such as those described in Annex B.

5.3 DCC_NET

REQ002: If GeoNetworking over ITS-G5 is in place, as described in ETSI EN 302 636-4-1 [3], the network and transport layer of an ITS-S that transmits on an ITS-G5 radio channel shall include the DCC_NET entity, specified in ETSI TS 102 636-4-2 [4], which contains the networking & transport layer specific DCC functionalities such as those described in Annex B. Otherwise, the usage of the DCC_NET entity is optional.

5.4 DCC_FAC

The facilities layer of an ITS-S optionally includes a DCC_FAC entity containing the facilities layer specific DCC functionalities such as those described in Annex B.

5.5 DCC_CROSS

REQ003: The management plane of an ITS-S that transmits on an ITS-G5 radio channel shall include a DCC_CROSS entity.

It contains the management specific DCC functionalities:

- DCC parameter evaluation. It computes the DCC internal parameters which indicate the available channel resources based on CBR values collected by the CBR evaluation function (local CBR) and received by the DCC_NET (highest global CBR value).
- DCC_CROSS_Access. It determines the DCC flow control and the DCC power control parameters for each used radio channel based on the internal DCC parameters computed by the DCC parameter evaluation function and provide them to the DCC_ACC entity.
- DCC_CROSS_Net. It returns to the DCC_NET the available resources per radio channel used.
- DCC_CROSS_Facilities. It uses internal DCC parameters from the DCC parameter evaluation function to determine the available channel resource limit for the registered applications and basic facilities services. This value is provided to the DCC_FAC entity.

6 DCC management entity

6.1 Overview

The DCC_CROSS entity is illustrated in the left side of Figure 2, configured for multi-channel operation and global DCC information, as described in ETSI TR 101 612 [i.1]. The right part illustrates the functions in the data layers interacting with the DCC_CROSS. For simplification of the figure, the DCC_ACC, DCC_NET, and DCC_FAC entities introduced in clause 5 and located in the data plane are not pictured here.

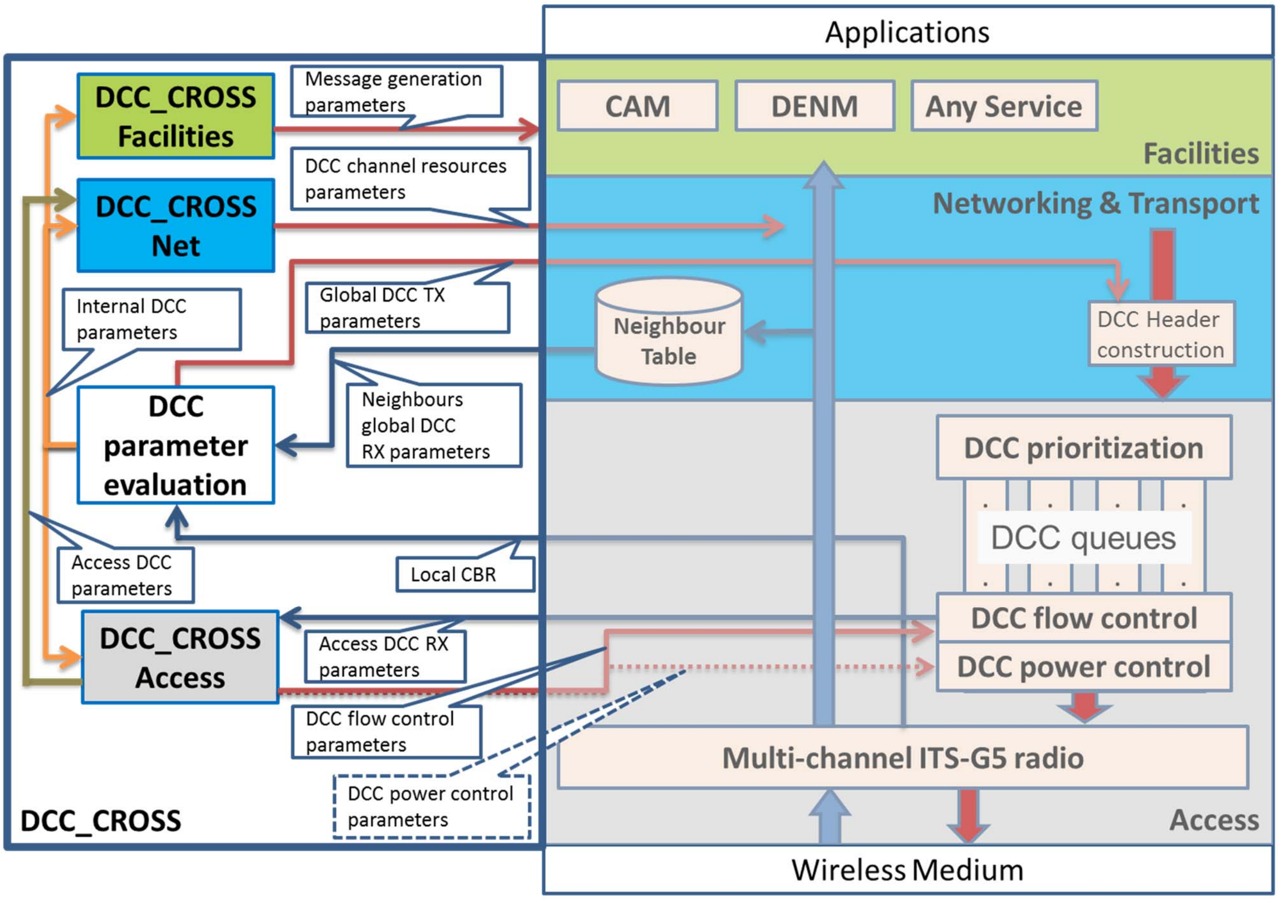

Figure 2: Overview of the DCC in an ITS-S

Clause 6 provides functional requirements on the sub-components of the DCC_CROSS entity and a high level description of its interfaces. The interfaces are described in more details in clause 8. The sub-components found in DCC_CROSS are DCC parameter evaluation, DCC_CROSS_Access, DCC_CROSS_Net and DCC_CROSS_Facilities.

6.2 DCC parameter evaluation

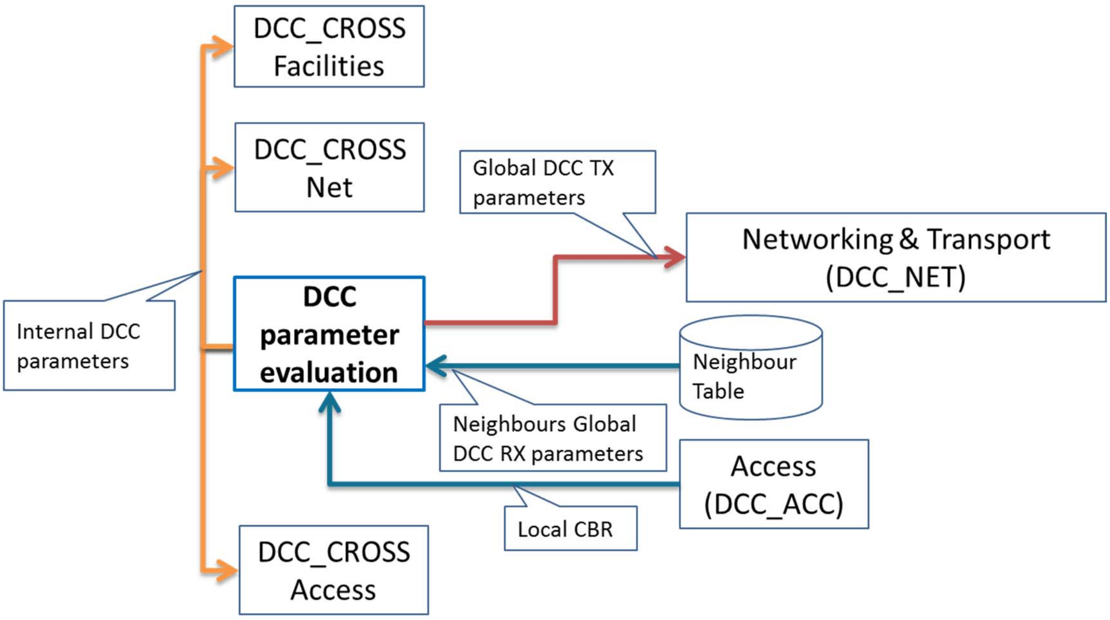

Figure 3: DCC parameter evaluation function

REQ004: The DCC parameter evaluation function shall calculate the available channel resources to meet the requirements as specified in clause 7.

REQ005: The DCC parameter evaluation function shall obtain the local CBR from the DCC_ACC entity specified in ETSI TS 102 687 [2], and optionally obtain the global CBR from DCC_NET, for each radio channel used by the ITS-S.

REQ006: The local CBR value shall be provided by the DCC_ACC as a value between 0 and 1 for each given radio channel used by the ITS-S. It shall represent the ratio between the channel active time and the measurement period of 100 ms. The channel active time is specified in ETSI TS 102 687 [2].

The local CBR is derived by the DCC_ACC from the measured CL value, as specified in ETSI TS 102 687 [2].

REQ007: When the global CBR is available, the DCC parameter evaluation function shall use the global CBR as input for the DCC limits evaluation, as the measured local CBR is already taken into account in the global CBR described in ETSI TS 102 636-4-2 [4]. Otherwise, the DCC parameter evaluation shall use the measured local CBR.

REQ008: The DCC parameter evaluation function shall provide the local CBR value, the CBR target value, and optionally the TX power level upper limit of each individual used radio channel to the DCC_NET as described in ETSI TS 102 636-4-2 [4].

REQ009: The CBR target value passed to the DCC_NET for the global CBR evaluation shall be set to 0,62. This is the same value as the congestion threshold C_{TH} used in Equation 1 in clause 7.2.

REQ010: The DCC parameter evaluation function (DCC algorithm) shall provide as part of the internal DCC parameters, the available CBR percentage per radio channel CBR_a. This value represents the upper limit of the time fraction the ego ITS-S is allowed to transmit on the radio channel.

The output of the DCC parameter evaluation function is transferred to the DCC_CROSS Facilities, DCC_CROSS_Net and DCC_CROSS_Access functions.

Parameters

- External interface from DCC_ACC (IM_SAP): local CBR for each radio channel used.
- External interface to DCC_NET (NM_SAP): local CBR, CBR target value, and optionally TX power level upper limit (global DCC TX parameters shown in figure 3) for each radio channel used.
- External interface from DCC_NET (NM_SAP): global CBR for each used radio channel as described in ETSI TS 102 636-4-2 [4] (global DCC RX parameters shown in figure 3).
- Internal usage to other DCC_CROSS functions: available CBR percentage CBR_a per radio channel for one ITS-S (internal DCC parameters shown in figure 3).

6.3 DCC_CROSS_Access

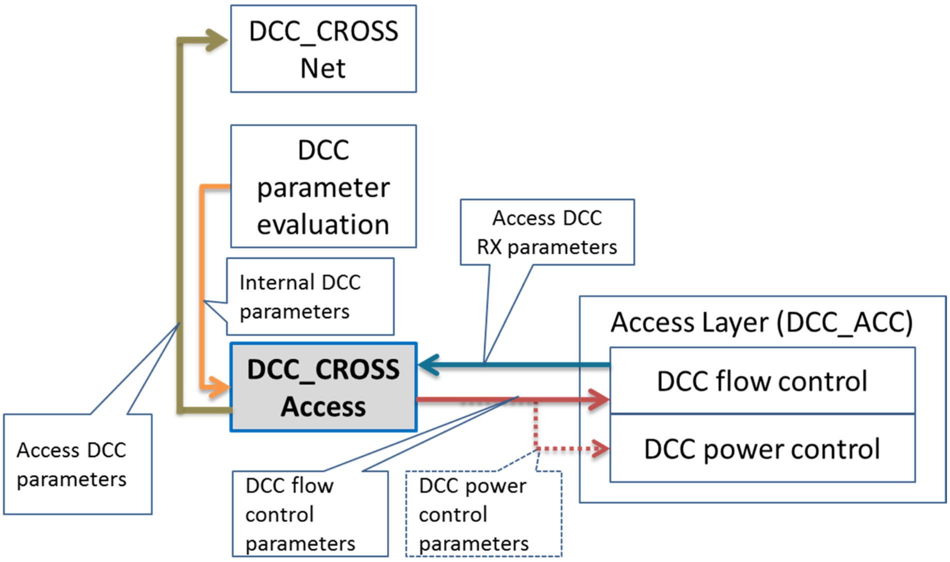

Figure 4: DCC_CROSS_Access function

REQ011: The specified DCC_CROSS_Access function shall be implemented in every ITS-S that is sending messages on an ITS-G5 radio channel.

REQ012: The DCC_CROSS_Access function shall provide the idle time T_{off} per radio channel to the DCC_ACC (DCC flow control parameters as shown in figure 4) and, if GeoNetworking over ITS-G5 [3] is used, within the management plane to the DCC_CROSS_Net function.

REQ013: DCC_ACC shall provide the length of all transmitted messages (air time per radio channel) T_{on} to the DCC_CROSS_Access function.

REQ014: The DCC_CROSS_Access function shall retrieve the available CBR percentage per radio channel CBR_a from the DCC parameter evaluation function (DCC algorithm) for each used radio channel as defined in clause 6.2.

REQ015: The value of T_{off} shall be calculated according to: $\mathrm{T_{off}} = \mathrm{T_{on}} \times ((1 - \mathrm{CBR_a}) / \mathrm{CBR_a})$

REQ016: When DCC power control is implemented, the DCC_CROSS_Access function shall provide the DCC power control parameters shown in figure 4 containing an upper TX power level limit to the DCC_ACC for each used radio channel.

REQ017: If GeoNetworking over ITS-G5 in accordance with ETSI EN 302 636-4-1 [3] is used, the DCC_CROSS_Access function shall receive from the DCC_ACC the time when the last message was forwarded to the ITS-G5 radio and provide it to the DCC_CROSS_Net function.

NOTE: This is a general requirement, supporting forwarding algorithms in ETSI EN 302 636-4-1 [3].

Once the system operates under high channel load conditions it may happen that some packets have to be dropped in the access layer queues. In the present document, there is no mandatory function to report back that packets have been dropped.

Parameters

- External interface from DCC_ACC (IM_SAP): length of all transmitted messages (air time) T_{on}, time when the last message was forwarded to the ITS-G5 radio.
- External interface to DCC_ACC (IM_SAP): idle time T_{off} and upper TX power level limit per given channel used.
- Internal usage from DCC parameter evaluation function: available CBR percentage per radio channel, CBR_a (internal DCC parameters shown in figure 4, as defined in clause 6.2.

- Internal usage to DCC_CROSS_Net function: idle time T_{off} per radio channel and time when the last message was forwarded to the ITS-G5 radio.

6.4 DCC_CROSS_Net

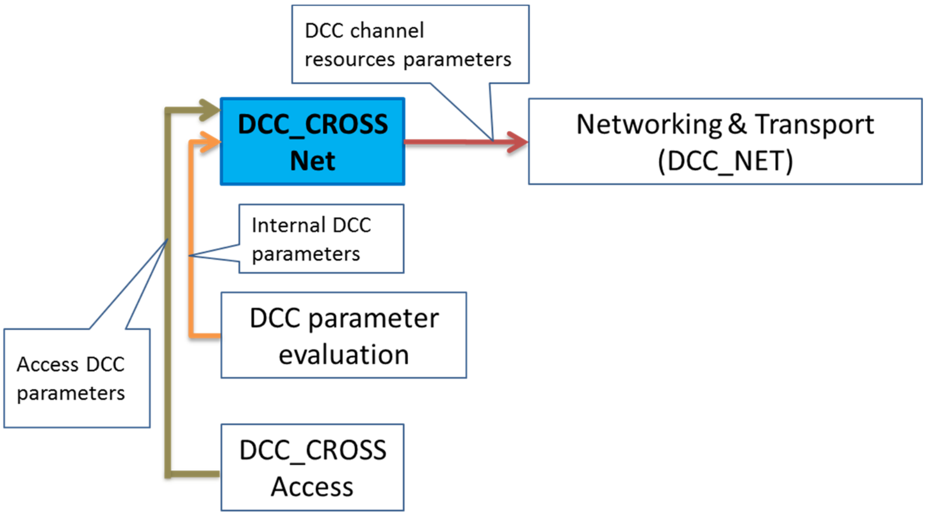

Figure 5: DCC_CROSS_Net function

REQ018: If GeoNetworking over ITS-G5 in accordance with ETSI EN 302 636-4-1 [3] is used at the networking and transport layer, then the implementation of DCC_CROSS_Net is mandatory. Otherwise, the implementation of the DCC_CROSS_Net function is optional.

REQ019: When present, the DCC_CROSS_Net shall disseminate to the DCC_NET the idle time T_{off} per radio channel and optionally, the CBR_a, i.e. the available resources that can be allocated per radio channel and, if available, the time when the last message was forwarded to the ITS-G5 radio.

Parameters

- External interface to DCC_NET (NM_SAP): idle time T_{off} per radio channel and optionally, CBR_a and time when the last message was forwarded to the ITS-G5 radio (DCC channel resources parameters shown in figure 5).
- Internal usage from DCC parameter evaluation function: available CBR percentage per radio channel CBR_a (internal DCC parameters shown in figure 5), as defined in clause 6.2.
- Internal usage from DCC_CROSS_Access function: idle time T_{off} per radio channel, time when the last message was forwarded to the ITS-G5 radio.

6.5 DCC_CROSS_Facilities

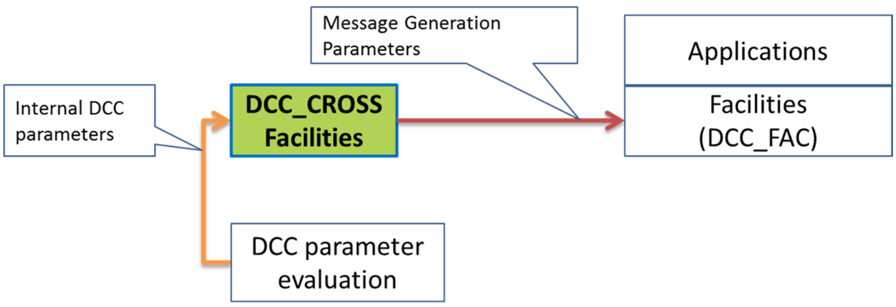

Figure 6: DCC_CROSS_Facilities function

The implementation of a DCC_CROSS_Facilities function is optional. When implemented, its purpose is the reduction of the message rate already at generation time.

REQ020: When present, the DCC_CROSS_Facilities function shall distribute the available CBR percentage per radio channel CBR_a to the facilities services (e.g. CA basic service, DEN basic service, etc.) based on the internal DCC parameters.

Parameters

- External interface to DCC_FAC (FM_SAP): available CBR percentage per radio channel CBR_a (Message Generation parameters shown in figure 6).

NOTE: This limit is provided per channel to enable multi-channel operation, having in mind that the DCC_FAC has to map it to a limit per traffic class.

- Internal usage from DCC parameter evaluation: available CBR percentage per radio channel CBR_a for one station (internal DCC parameters shown in figure 6), as defined in clause 6.2.

7 DCC limits specification

7.1 Overview

The objective of the DCC algorithms is to efficiently schedule traffic of the same class among ITS-S, as well as of multiple traffic classes per ITS-S. The ITS applications are differentiated into several traffic classes according to their required share of the channel resources. Among all ITS applications potentially requiring the transmission of different messages at various modulation and priority levels, the common instrument to measure, adapt and test the sharing of channel resources between ITS-S is the time during which each ITS-S is granted access to the medium to transmit its data in the ITS ad hoc network.

In the present document, the CBR is the metric used to measure the used channel resources. It represents the fraction of time that an individual radio channel is sensed busy. A testable limit for the transmit ratio per single ITS-S is defined as a function of the CBR. The DCC algorithm within the DCC parameter evaluation function provides an individual transmit ratio per radio channel used. With this, a channel overload by the aggregated transmissions of all ITS-S contributing to the channel load will always be avoided. Clause 7.2 describes the upper limit of the transmit ratio per radio channel and per ITS-S.

The local CBR value can be derived from the CL measurement per radio channel as described in ETSI TS 102 687 [2].

The concept of using testable limits rather than specific DCC algorithms is detailed in ETSI TR 101 612 [i.1].

7.2 Requirements

REQ021: An individual ITS-S shall be able to limit its individual transmission in order not to exceed its transmit ratio.

In addition, the transmit power level may optionally be used to control its own contribution to the aggregate channel utilization.

REQ022: The idle time shall be equal to or greater than the minimum of (1 000 ms - T_{on}) and $T_{off\ Limit}$, as calculated according to Equation 1, where T_{on} is the message duration. All timing values are related to transmission time on the air.

$$T_{offLimit} = \frac{1}{C_W} \times T_{on} \times \left(4\,000 \times \frac{CBR - C_{TH}}{CBR} - 1\right) \qquad (1)$$

Equation 1 corresponds to Equation 7 in ETSI TR 101 612 [i.1]. T_{on} and $T_{off\ Limit}$ are time parameters, CBR is a ratio. The coefficient values (4 000 and C_{TH}) are chosen to avoid radio channel overload based on the traffic scenarios described in ETSI TR 101 612 [i.1].

A negative value of $T_{off\ Limit}$ indicates that no DCC limitation needs to be applied, which is the case when the CBR value is less than or equal to the congestion threshold C_{TH}. $T_{off\ Limit}$ is multiplied with a weight factor C_w.

REQ023: C_w is a configuration parameter of the ITS-S. It is in the range from 0 to 1 (0 being excluded). The default value for C_w shall be $C_w = 1$.

REQ024: The CBR value related to a given radio channel used in Equation 1 shall be either:

- the locally evaluated CBR; or
- when the global CBR is available, the global CBR provided by DCC_NET.

The $T_{off\ Limit}$ defined in this clause is calculated under the assumption that there is a fixed sensitivity threshold for the CL measurement for all stations in the system (see ETSI TS 102 687 [2] for more details).

Figure 7 shows the $T_{off\ Limit}$ for typical message durations T_{on} with a DCC weight factor of $C_w = 1$.

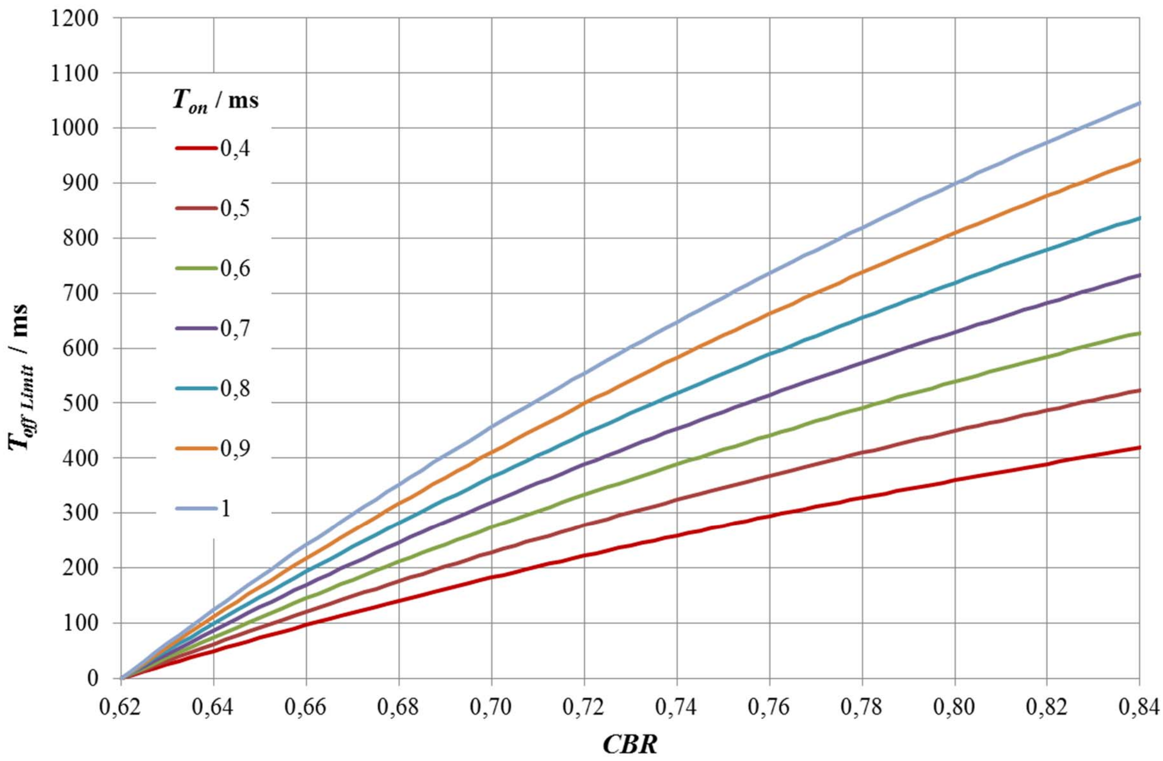

Figure 7: $T_{off\ Limit}$ representation

Although the present document does not specify a specific DCC algorithm, Annex C describes two algorithms that are capable of satisfying testable T_{off} limits using a specific set of parameters. These algorithms are capable of coexisting with each other (see [i.3]).

REQ025: Other algorithms fulfilling the limits specification shall be capable of mutually coexisting with each other.

8 Interfaces

8.1 Overview

The DCC_CROSS entities offer the interfaces illustrated in Figure 1. The primitives transferred over these interfaces are compliant with ETSI TS 102 723-1 [5].

8.2 Interface (1) with DCC_ACC (MI SAP)

8.2.1 MI-GET.request

8.2.1.1 Function

This primitive allows retrieving parameters from the access layer, as described in clauses 6.2 and 6.3.

8.2.1.2 Semantics

The parameters of the primitive MI-GET.request shall be as follows:

MI-GET.request (
MAC-ID,
CommandRef,
Sequence of I-Param.No
)

Table 1: Parameters of the MI-GET.request for DCC

Name	ASN.1 type	Valid range	Description
MAC-ID	Structure as specified in ETSI TS 102 723-1 [5]	Specified in ETSI TS 102 723-1 [5]	Unique identifier of the Communication Interface
CommandRef	INTEGER	Integer number	Unique cyclic reference number of request
	INTEGER	0 to 255	Number of subsequent I-Param.No elements
I-Param.No	INTEGER	0 to 255	See Table 5

8.2.2 MI-GET.confirm

8.2.2.1 Function

This primitive reports the result of a previous MI-GET.request.

8.2.2.2 Semantics

The parameters of the primitive MI-GET.confirm shall be as follows:

MI-GET.confirm (
MAC-ID,
CommandRef,
Sequence of I-Param
)

Table 2: Parameters of the MI-GET.confirm for DCC

Name	ASN.1 type	Valid range	Description
MAC-ID	Structure as specified in ETSI TS 102 723-1 [5]	Specified in ETSI TS 102 723-1 [5]	Unique identifier of the Communication Interface
CommandRef	INTEGER	0 to 255	Unique cyclic reference number of request
	INTEGER	0 to 255	Number of subsequent I-Param elements
I-Param.No I-Param.Value	CHOICE	See Table 5	Sequence of parameters

8.2.3 MI-SET.request

8.2.3.1 Function

This primitive allows setting of a parameter in the access layer, as described in clauses 6.2 and 6.3.

8.2.3.2 Semantics

The parameters of the management service primitive MI-SET.request shall be as follows:

MI-SET.request (
MAC-ID,
CommandRef,
Sequence of I-Param
)

Table 3: Parameters of the service primitive MI-SET.request

Name	ASN.1 type	Valid range	Description
MAC-ID	Structure as specified in ETSI TS 102 723-1 [5]	Specified in ETSI TS 102 723-1 [5]	Unique identifier of the Communication Interface
CommandRef	INTEGER	Integer number	Unique cyclic reference number of request
	INTEGER	0 to 255	Number of subsequent I-Param elements
I-Param.No	CHOICE	0 to 255	See Table 5
I-Param.Value		Depends on I-Param.No	

8.2.4 MI-SET.confirm

8.2.4.1 Function

This primitive reports the result of a previous MI-SET.request.

8.2.4.2 Semantics

The parameters of the management service primitive MI-SET.confirm shall be as follows:

MI-SET.confirm (
MAC-ID,
CommandRef,
Sequence of Errors OPTIONAL
)

Table 4: Parameters of the service primitive MI-SET.confirm

Name	ASN.1 type	Valid range	Description
MAC-ID	Structure as specified in ETSI TS 102 723-1 [5]	Specified in ETSI TS 102 723-1 [5]	Unique identifier of the Communication Interface
CommandRef	INTEGER	0 to 255	Unique cyclic reference number of request
	INTEGER	0 to 255	Number of subsequent Errors elements
Errors.I-paramNo	INTEGER	See Table 5	See Table 5
Errors.ErrStatus	ENUMERATED	Specified in ETSI TS 102 723-1 [5]	Indicates error status of request

8.2.5 DCC Parameters at the MI-SAP

Table 5: List of I-Param for DCC interface at MI SAP

I-Param.No	Name of I-Param	Access	Format	Description
52	Channel Number	R/W	1 octet, Range from 1 to 7	Identifies the radio channel number in the ITS-G5A, G5B or G5D bands. A write to this parameter selects the channel number for consecutive reads or writes. A read from this parameter reports the currently selected channel number.
53	Local CBR	R	1 octet, range from 0 to 100	CBR of the selected channel number. Derived from CL measurement as specified in ETSI TS 102 687 [2]
54	Message length	R	1 octet, granularity is 1 OFDM symbol length = 8 µs	Length of the recently transmitted message (air time) T_{on} on the selected radio channel.
55	Last transmit time	R	4 octets, granularity is 1 OFDM symbol length = 8 µs	Time when the last message was forwarded to the ITS-G5 radio.
56	Idle time	R/W	2 octets, in ms	Idle time T_{off} for the selected radio channel.
57	TX power level limit	R/W	1 octet, Bit 0 to Bit 4: Current output power level limit, E.I.R.P [0 dBm to 31 dBm, unit 1 dBm; values greater than 31 dBm shall be set to 31 dBm]; Bit 5 to Bit 7: Reserved for future use.	Upper TX power level limit for the selected radio channel.

8.3 Interface (2) with DCC_NET (MN SAP)

8.3.1 MN-GET.request

8.3.1.1 Function

This primitive allows retrieving parameters from the network layer, as described in clause 6.2.

8.3.1.2 Semantics

The parameters of the primitive MN-GET.request shall be as follows:

```
MN-GET.request    (
                  NT-ID,
                  CommandRef,
                  Sequence of N-Param.No
                  )
```

Table 6: Parameters of the MN-GET.request for DCC

Name	ASN.1 type	Valid range	Description
NT-ID	INTEGER	Integer number	Unique identifier of the Network Interface (e.g. GN, IP, etc.)
CommandRef	INTEGER	Integer number	Unique cyclic reference number of request
	INTEGER	0 to 255	Number of subsequent I-Param.No elements
I-Param.No	INTEGER	0 to 255	See Table 10

8.3.2 MN-GET.confirm

8.3.2.1 Function

This primitive reports the result of a previous MN-GET.request.

8.3.2.2 Semantics

The parameters of the primitive MN-GET.confirm shall be as follows:

```
MN-GET.confirm   (
                 NT-ID,
                 CommandRef,
                 Sequence of N-Param
                 )
```

Table 7: Parameters of the MN-GET.confirm for DCC

Name	ASN.1 type	Valid range	Description
NT-ID	INTEGER	Integer number	Unique identifier of the Network Interface (e.g. GN, IP, etc.)
CommandRef	INTEGER	0 to 255	Unique cyclic reference number of request
	INTEGER	0 to 255	Number of subsequent N-Param elements
N-Param.No	CHOICE	See Table 10	Sequence of parameters
N-Param.Value			

8.3.3 MN-SET.request

8.3.3.1 Function

This primitive allows setting of a parameter in the network layer, as described in clauses 6.2 and 6.4.

8.3.3.2 Semantics

The parameters of the management service primitive MN-SET.request shall be as follows:

```
MN-SET.request   (
                 NT-ID,
                 CommandRef,
                 Sequence of N-Param
                 )
```

Table 8: Parameters of the service primitive MN-SET.request

Name	ASN.1 type	Valid range	Description
NT-ID	INTEGER	Integer number	Unique identifier of the Network Interface (e.g. GN, IP, etc.)
CommandRef	INTEGER	Integer number	Unique cyclic reference number of request
	INTEGER	0 to 255	Number of subsequent N-Param elements
N-Param.No	CHOICE	0 to 255	See Table 10
N-Param.Value		Depends on N-Param.No	

8.3.4 MN-SET.confirm

8.3.4.1 Function

This primitive reports the result of a previous MN-SET.request.

8.3.4.2 Semantics

The parameters of the management service primitive MN-SET.confirm shall be as follows:

MN-SET.confirm (
NT-ID,
CommandRef,
Sequence of Errors OPTIONAL
)

Table 9: Parameters of the service primitive MN-SET.confirm

Name	ASN.1 type	Valid range	Description
NT-ID	INTEGER	Integer number	Unique identifier of the Network Interface (e.g. GN, IP, etc.)
CommandRef	INTEGER	0 to 255	Unique cyclic reference number of request
	INTEGER	0 to 255	Number of subsequent Errors elements
Errors.N-paramNo	INTEGER	See Table 10	See Table 10
Errors.ErrStatus	ENUMERATED	Specified in ETSI TS 102 723-1 [5]	Indicates error status of request

8.3.5 DCC Parameters at the MN-SAP

Table 10: List of N-Param for DCC interface at MN SAP

N-Param.No	Name of N-Param	Access	Format	Description
0	Global CBR	R	1 octet, range from 0 to 100	Global CBR of the selected channel number (as specified in ETSI TS 102 636-4-2 [4]).
1	Channel Number	R/W	1 octet, Range from 1 to 7	Identifies the radio channel number in the ITS-G5A, G5B or G5D bands. A write to this parameter selects the channel number for consecutive reads or writes. A read from this parameter reports the currently selected channel number.
2	Local CBR	R/W	1 octet, range from 0 to 100	Local CBR value obtained at the MI-SAP for the currently selected channel number.
3	Available resource	R/W	2 octets, mapped to reciprocal value of CBR_a	Available CBR percentage CBR_a on the selected channel
4	Last transmit time	R/W	4 octets, granularity is 1 OFDM symbol length = 8 µs	Time when the last message was forwarded to the ITS-G5 radio
5	Idle time	R/W	2 octets, in ms	Idle time T_{off} per radio channel.
6	TX power level limit	R/W	1 octet, Bit 0 to Bit 4: Current output power level limit, E.I.R.P [0 dBm to 31 dBm, unit 1 dBm; values greater than 31 dBm shall be set to 31 dBm]; Bit 5 to Bit 7: Reserved for future use.	Upper TX power level limit for the selected radio channel.

8.4 Interface (3) with DCC_FAC (MF SAP)

8.4.1 MF-SET.request

8.4.1.1 Function

This primitive allows setting of a parameter in the facilities layer, as described in clause 6.5.

8.4.1.2 Semantics

The parameters of the management service primitive MF-SET.request shall be as follows:

MF-SET.request (
FAC-ID,
CommandRef,
Sequence of F-Param
)

Table 11: Parameters of the service primitive MF-SET.request

Name	ASN.1 type	Valid range	Description
FAC-ID	INTEGER	Integer number	Unique identifier of the Facilities Interface
CommandRef	INTEGER	Integer number	Unique cyclic reference number of request
	INTEGER	0 to 255	Number of subsequent F-Param elements
F-Param.No	CHOICE	0 to 255	See Table 13
F-Param.Value		Depends on F-Param.No	

8.4.2 MF-SET.confirm

8.4.2.1 Function

This primitive reports the result of a previous MF-SET.request.

8.4.2.2 Semantics

The parameters of the management service primitive MF-SET.confirm shall be as follows:

MF-SET.confirm (
FAC-ID,
CommandRef,
Sequence of Errors OPTIONAL
)

Table 12: Parameters of the service primitive MF-SET.confirm

Name	ASN.1 type	Valid range	Description
FAC-ID	INTEGER	Integer number	Unique identifier of the Facilities Interface
CommandRef	INTEGER	0 to 255	Unique cyclic reference number of request
	INTEGER	0 to 255	Number of subsequent Errors elements
Errors. F-paramNo	INTEGER	See Table 13	See Table 13
Errors.ErrStatus	ENUMERATED	Specified in ETSI TS 102 723-1 [5]	Indicates error status of request

8.4.3 DCC Parameters at the MF-SAP

Table 13: List of F-Param for DCC interface at MF SAP

F-Param.No	Name of F-Param	Access	Format	Description
0	Channel Number	R/W	1 octet, Range from 1 to 7	Identifies the radio channel number in the ITS-G5A, G5B or G5D bands. A write to this parameter selects the channel number for consecutive reads or writes A read from this parameter reports the currently selected channel number.
1	Available resource	R/W	2 octets, mapped to reciprocal value of CBR_a	Available CBR percentage CBR_a on the selected channel.

9 Test procedures

9.1 Introduction

The objective is to define some test cases where the device under test (DUT) receives different signals emulating a certain amount of channel load and to verify the corresponding reaction of the transceiver to the radio channel status. This verification can be performed by monitoring the transmit ratio of the DUT. The injected signal may vary the following parameters:

- channel load (messages per time unit);
- message length;
- RX power distribution (homogeneous, heterogeneous, time varying, etc.);
- packet message format (hidden nodes);
- channel model between RX device and TX device (Additive White Gaussian Noise, AWGN).

The radio environment given by a road traffic scenario is an external constraint that cannot be controlled in a test environment. Since the radio environment determines the number of ITS-S N_{Sta} contributing to the CBR, N_{Sta} sufficiently describes the relevant network properties from a DCC system point of view. This number of contributing stations N_{Sta} can be controlled in a test environment.

The local CBR value is evaluated from the actual local CL measurement for a given radio channel to estimate the system wide channel usage. This estimation can be enhanced by dissemination of this local CBR value between the ITS-S in radio range (global CBR for the given radio channel).

For an individual ITS-S the following parameters influence the local CL measurement result:

- Number of ITS-S (N_{Sta}) in reception and in carrier sense range.
- Radio environment (defines the coverage).
- Road traffic scenario (vehicle densities in reception and in carrier sense range).
- Message duration (T_{on}).
- Message rate (R_M) or idle time (T_{off}).
- Transmit power level (P_{TX}) (target transmission range).

Figure 8 depicts the basic test setup for the evaluation of the DCC function of the DUT for a local only CBR operation. The signal generator depicted in figure 8 has to generate ITS packets with different power levels in order to be able to emulate a set of ITS-S in the surrounding of the DUT. In this test the reaction of the DUT to a given channel load setting is evaluated based on the DUT TX signal duty cycle and T_{off} timing.

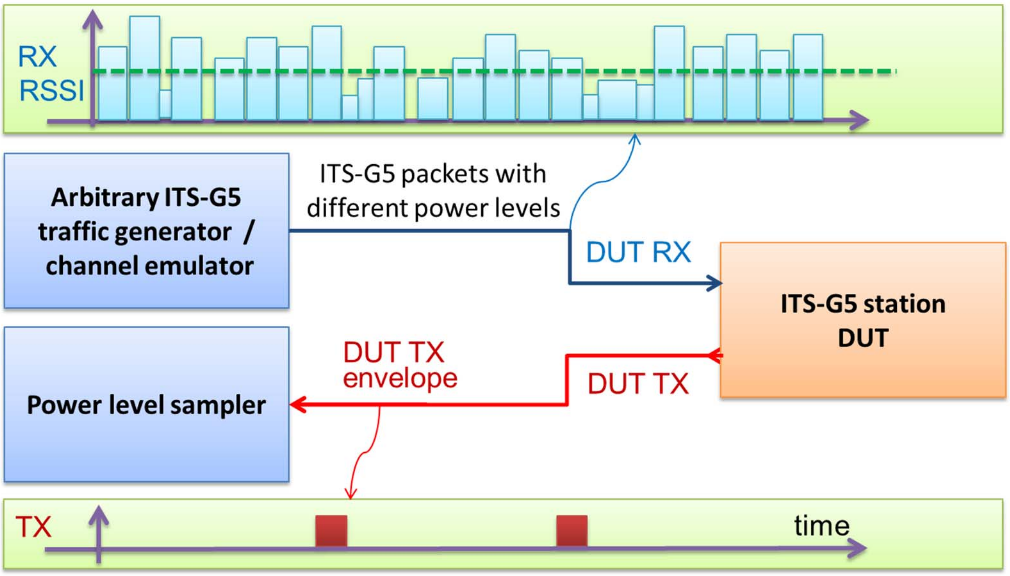

Figure 8: Basic Test principle for the local CBR evaluation

In order to be able to test the deployment of the global CBR and the distribution of the global CBR the test set-up has to be extended by a signal generator with the capability of generating ITS packets with geo-header containing the global CBR value. This is depicted in figure 9.

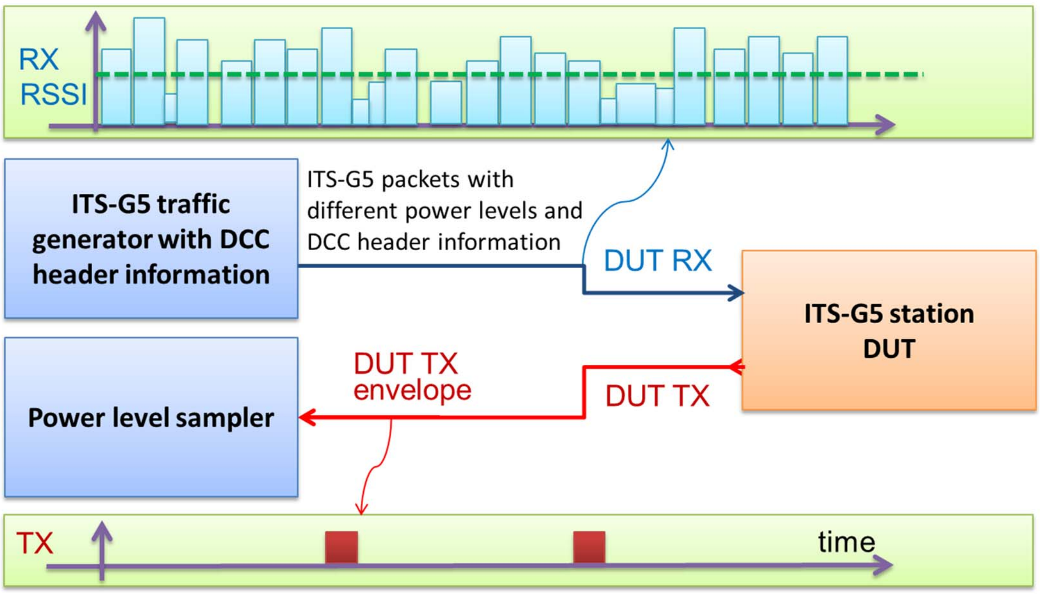

Figure 9: Basic test principle for evaluating the deployment of the global CBR information

In figures 8 and 9 the monitoring of the DUT reaction is performed by a detector and a sampling unit. Other equivalent setups are possible.

9.2 General Test requirements

REQ026: The device manufacturer shall declare which DCC operation the equipment supports:

- Local CBR.
- Global CBR.
- Single Channel.
- Multi-Channel.

Based on the declared DCC operational mode the corresponding test cases and parameter sets are to be chosen.

Table 2 provides a step instantiation of Equation 1 from clause 7.2 to be used when running the test cases outlined in clauses 9.3 to 9.6. For a CBR smaller than 0,64, the message transmission rate can be above 10 Hz and should be limited by other means to the low duty cycle restrictions defined by the frequency regulatory framework. The CBR value of 0,63 is given here as an example to show this fact and should not be used for testing.

Table 2: Idle time test limits

T_{on} / ms	0,4	0,6	0,8	1	1,2	1,4	1,6
CBR	$T_{off\ Limit}$ / ms	$T_{off\ Limit}$ / ms	$T_{off\ Limit}$ / ms	$T_{off\ Limit}$ / ms	$T_{off\ Limit}$ / ms	$T_{off\ Limit}$ / ms	$T_{off\ Limit}$ / ms
0,63	25,0	37,5	50,0	62,5	75,0	87,5	100,0
0,64	49,6	74,4	99,2	124,0	148,8	173,6	198,4
0,65	73,4	110,2	146,9	183,6	220,3	257,1	293,8
0,66	96,6	144,9	193,1	241,4	289,7	338,0	386,3
0,68	140,8	211,2	281,6	351,9	422,3	492,7	563,1
0,70	182,5	273,7	364,9	456,1	547,4	638,6	729,8
0,72	221,8	332,7	443,6	554,6	665,5	776,4	887,3
0,74	259,1	388,6	518,1	647,6	777,2	906,7	1 036,2
0,75	276,9	415,4	553,9	692,3	830,8	969,3	1 107,7
0,76	294,3	441,5	588,7	735,8	883,0	1 030,2	1 177,3
0,78	327,8	491,7	655,6	819,5	983,4	1 147,3	1 311,2
0,80	359,6	539,4	719,2	899,0	1 078,8	1 258,6	1 438,4

9.3 Test case 1: Homogeneous ITS traffic, energy threshold test

The objective of this test is to evaluate the performance of the DCC for the energy measurement option of the CL measurement in contrast to the header decoding option and the evaluation of an efficient limitation of the transmit ratio.

- Set the signal generator to emulate different channel loads ranging from 0 % up to 80 % in 5 % steps.
- AWGN channel only with thermal noise (no multipath propagation, no Doppler effect).
- RX power at the DUT should be greater than -65 dBm.
- Use unmodulated multicarrier burst signals (52 carriers with 10 MHz bandwidth) which all have the same burst power level (equivalent to an unmodulated 6 Mbit/s ITS-G5 signal).
- Set the burst length to 700 µs.
- Vary emulated channel load by controlling the idle time between the bursts.
- Set DUT in a mode with the highest possible duty cycle (e.g. CAM rate 10 Hz).
- Repeat the test for all supported radio channels.

Monitor the duty cycle of the DUT.

The T_{off} time of the DUT shall conform to the limits defined in table 2.

Monitor the disseminated CBR value in the Single Hop Broadcast, Extended Header of GN (specified in ETSI TS 102 636-4-2 [4]) and compare it with the actual channel load; the disseminated CBR value shall conform to the local channel load with an absolute deviation of ±0,01.

9.4 Test case 2: Homogeneous ITS traffic, header decoding test

The objective of this test is to evaluate the performance of the DCC for the header decoding option of the CL measurement in contrast to the energy measurement option and the evaluation of an efficient limitation of the transmit ratio.

- Set the signal generator to emulate different channel loads with real correctly coded ITS-messages, ranging from 0 % up to 80 % in 5 % steps.
- AWGN channel only with thermal noise (no multipath propagation, no Doppler effect).
- The RX power level at the DUT shall be P_{RX} = -75 dBm ± 6 dB (-81 dBm < P_{RX} < -69 dBm).
- All ITS messages shall have the same power level.
- Set the ITS message length to 700 µs.
- Vary the emulated channel load by controlling the idle time between the bursts.
- Set DUT in a mode with the highest possible duty cycle (e.g. CAM rate 10 Hz).
- Repeat the test for all supported radio channels.

Monitor the duty cycle of the DUT. The T_{off} time of the DUT shall conform to the limits defined in table 2.

Monitor the disseminated CBR value in the Single Hop Broadcast, Extended Header of GN (specified in ETSI TS 102 636-4-2 [4]) and compare it with the actual channel load, the disseminated CBR value shall conform to the local channel load with an absolute deviation of ±0,01.

9.5 Test case 3: Sensitivity threshold correction

The objective of this test is to verify the sensitivity and the threshold correction of the CBR value sent in the GN header according to different antenna gains and power levels.

- Set the signal generator to emulate different channel loads ranging from 0 % up to 80 % in 5 % steps.
- AWGN channel only with thermal noise (no multipath propagation, no Doppler effect).
- Use emulated real ITS packets.
- Set the burst length to 700 µs.
- Vary emulated channel load by controlling the idle time between the bursts.
- Set DUT in a mode with the highest possible duty cycle (e.g. CAM rate 10 Hz).
- Decrease the RX power at the DUT from -80 dBm to -100 dBm.
- Repeat the test for all supported radio channels.

Monitor the disseminated CBR value in the Single Hop Broadcast, Extended Header of GN (specified in ETSI TS 102 636-4-2 [4]) and compare it with the actual channel load, the disseminated CBR value shall conform to the local channel load with an absolute deviation of ±0,01.

9.6 Test case 4: DCC stability

The objective of this test case is to verify that the DCC implementation does not introduce instable behaviour into the distributed control loop and the evaluation of an efficient limitation of the transmit ratio.

- Set DUT in a mode with the highest possible duty cycle (e.g. CAM rate 10 Hz) and use a fixed message length T_{on}.
- AWGN channel only with thermal noise (no multipath propagation, no Doppler effect).

- RX power at the DUT should be greater than -65 dBm.
- Use unmodulated multicarrier burst signals (52 carriers with 10 MHz bandwidth) which all have the same burst power level (equivalent to an unmodulated 6 Mbit/s ITS-G5 signal).
- Set the burst length to 700 µs.
- Vary emulated channel load by controlling the idle time between the bursts.
- Set the signal generator to emulate different channel load steps between no load (0 %) and testing load values ranging from 64 % up to 80 % (in 2 % steps):
  1) Set the channel load to 0 % (no burst) .
  2) Wait until the DUT transmits at constant rate (e.g. 10 Hz) .
  3) Set the emulated channel load corresponding to a CBR of 0,64.
  4) Monitor the idle time T_{off} of the DUT for the next transmissions until T_{off} gets stable.
  5) Loop back to 1, testing the next value of the emulated channel load.
- Set the signal generator to emulate different channel load steps between full load (~95 %) and testing load values ranging from 64 % up to 80 % (in 2 % steps):
  1) Set the channel load to 95 % (almost no idle time between the bursts) .
  2) Wait until the DUT transmits at constant rate (e.g. 1 Hz) .
  3) Set the emulated channel load corresponding to a CBR of 0,64.
  4) Monitor the idle time T_{off} of the DUT for the next transmissions until T_{off} gets stable.
  5) Loop back to 1, testing the next value of the emulated channel load.
- Repeat the test for all supported radio channels.

The measured equilibrium of the DUT idle time T_{offm} after the transient process shall conform to the limits defined in table 2.

For all transmissions made by the DUT, the variation of the idle time T_{off} shall meet the condition set out in inequality 2.

$$|T_{off}(t) - T_{off}(t+1)| < 2 \times |T_{offm} - T_{off}(t)| \quad (2)$$

where $T_{off}(t)$ is the idle time after a transmission and $T_{off}(t+1)$ is the idle time after the consecutive transmission.

Annex A (informative): List of requirements

A.1 Introduction

In this annex, all requirements included in the present document are presented in a list format, see table A.1. This allows the simple identification of the testable requirements as input to the corresponding test specifications.

A.2 Requirements

Table A.1: List of requirements

Requirement Number	Clause	Description	Mandatory/ Optional/ Conditional	Condition
REQ001	5.2	DCC_ACC entity in the access layer of an ITS-S	M	
REQ002	5.3	DCC_NET entity in the network and transport layer of an ITS-S	M	
REQ003	5.5	DCC_CROSS entity in the management plane of an ITS-S.	M	
REQ004	6.2	DCC parameter evaluation function: available channel resources calculation	M	
REQ005	6.2	DCC parameter evaluation function: local CBR from the DCC_ACC entity	M/O	
REQ006	6.2	DCC parameter evaluation function: local CBR value	M	
REQ007	6.2	DCC parameter evaluation function: input for the DCC limits evaluation.	M	
REQ008	6.2	DCC parameter evaluation function: output to the DCC_NET entity	M/O	
REQ009	6.2	DCC parameter evaluation function: CBR target value	M	
REQ010	6.2	DCC parameter evaluation function: internal DCC parameters	M	
REQ011	6.3	DCC_CROSS_Access function in the DCC_CROSS entity	M	
REQ012	6.3	DCC_CROSS_Access function: output of idle time T_{off}	M/C	GeoNetworking over ITS-G5 is used
REQ013	6.3	DCC_CROSS_Access function: input from DCC_ACC entity	M	
REQ014	6.3	DCC_CROSS_Access function: input from DCC parameter evaluation function	M	

Requirement Number	Clause	Description	Mandatory/ Optional/ Conditional	Condition
REQ015	6.3	DCC_CROSS_Access function: value of T_{off}	M	
REQ016	6.3	DCC_CROSS_Access function: output of DCC power control parameters	C	DCC power control is implemented
REQ017	6.3	DCC_CROSS_Access function: time when the last message was forwarded to the ITS-G5 radio	C	GeoNetworking over ITS-G5 is used
REQ018	6.4	DCC_CROSS_Net function in the DCC_CROSS entity	M	
REQ019	6.4	DCC_CROSS_Net function: output to the DCC_NET entity	C	DCC_CROSS_Net is implemented
REQ020	6.5	DCC_CROSS_Facilities function: output to the facilities services	C	DCC_CROSS_Facilities is implemented
REQ021	7.2	DCC limits: individual transmission limitation per ITS-S	M	
REQ022	7.2	DCC limits: idle time value	M	
REQ023	7.2	DCC limits: configuration parameter C_w	M	
REQ024	7.2	DCC limits: CBR value in Equation 1	M	
REQ025	7.2	DCC limits: mutual coexistence of algorithms	M	
REQ026	9.2	Test procedures: declaration of DCC operation type	M	

Annex B (informative): Other DCC entities

B.1 Introduction

The DCC entities located in the different layers of the data transfer plane are described in ETSI TR 101 612 [i.1]. Their functionalities are briefly reminded in the present annex.

B.2 DCC_ACC

The DCC_ACC is part of the access layer. It is described in ETSI TS 102 687 [2]. It includes the following functionalities:

- CBR evaluation. It derives the local CBR from the measured channel load (CL), for all radio channels used by the ITS-S.
- DCC prioritization. It selects the DCC queue where to forward the message according to the traffic class (TC) indicated in the message. The TC corresponding to the highest EDCA access class is mapped to the highest priority DCC queue, so that it is dequeued by the DCC flow control first.
- DCC queue. It stores temporarily a TX message if the radio channel is overloaded. It drops the message when the queuing time exceeds the message lifetime. This process is an internal mechanism to the DCC_ACC. It sends an indication of that event to the DCC_CROSS, which is forwarded to the originator of the message if the related DCC interface is implemented.
- DCC power control. When available, it determines the TX power level associated with the message based on information provided by the DCC_CROSS entity.
- DCC flow control. It performs traffic shaping based on parameters provided by DCC_CROSS_Access, as specified in ETSI TS 102 687 [2], ETSI TS 102 792 [9] and clause 7 of the present document. Following these requirements, it dequeues the highest priority message stored in the DCC queue and forwards it to the ITS-G5 radio, for transmission on the wireless medium.

B.3 DCC_NET

The DCC_NET is part of the network and transport layer. It is described ETSI TS 102 636-4-2 [4]. It includes the following functionalities:

- Store global DCC paramet ers received from other ITS-S and evaluate them to forward the global CBR to the DCC_CROSS entity.
- Disseminate local DCC parameters to neighbouring ITS-S by inserting their value in the GN header.
- Indicate the following DCC channel resources parameters to the GN forwarding algorithm:
    - The current idle time T_{off} per radio channel.
    - When available, the time when the last message was forwarded to the ITS-G5 radio, as reported by the DCC_ACC entity.

B.4 DCC_FAC

The DCC_FAC is part of the facilities layer. No messages are dropped by this function. Only rate is reduced as content-based decision at higher layers. The DCC_FAC includes the following functionalities:

- Control of the load generated by the CAM and DENM service messages on the radio channel. The load is controlled by an indication provided to the basic facilities service or the application generating the messages.
- Potential trigger of channel switching in the case the ITS-S has the capability to execute this function.
- Mapping the message priority set by the basic facilities service or the application into the traffic class field of the message.

Annex C (informative): DCC algorithms capable of satisfying testable limits

C.1 Introduction

Clause 7 of the present document specifies requirements for DCC algorithms in terms of a $T_{off\ Limit}$ function. The present annex describes two algorithms that are capable of satisfying such a limit. ETSI TR 101 612 [i.1] defines two types of DCC algorithm: Reactive and Adaptive. The present annex describes one algorithm of each type. These descriptions are not meant to be a complete specification of either algorithm.

C.2 State-Based Reactive DCC

In ETSI TS 102 687 [2], a framework around a state-based reactive DCC approach has been developed, which supports several different techniques for controlling the network load:

(i) transmit rate control;

(ii) transmit power control;

(iii) transmit datarate control;

(iv) DCC sensitivity control; and

(v) transmit access control.

The general idea behind the state-based approach is that depending on the current state, several techniques for controlling the channel load can be combined. In the simplest case, only one of the proposed techniques is utilized. The two most scrutinized techniques in the literature are transmit rate control and transmit power control. In Figure C.1, a state-based DCC algorithm with five states is depicted.

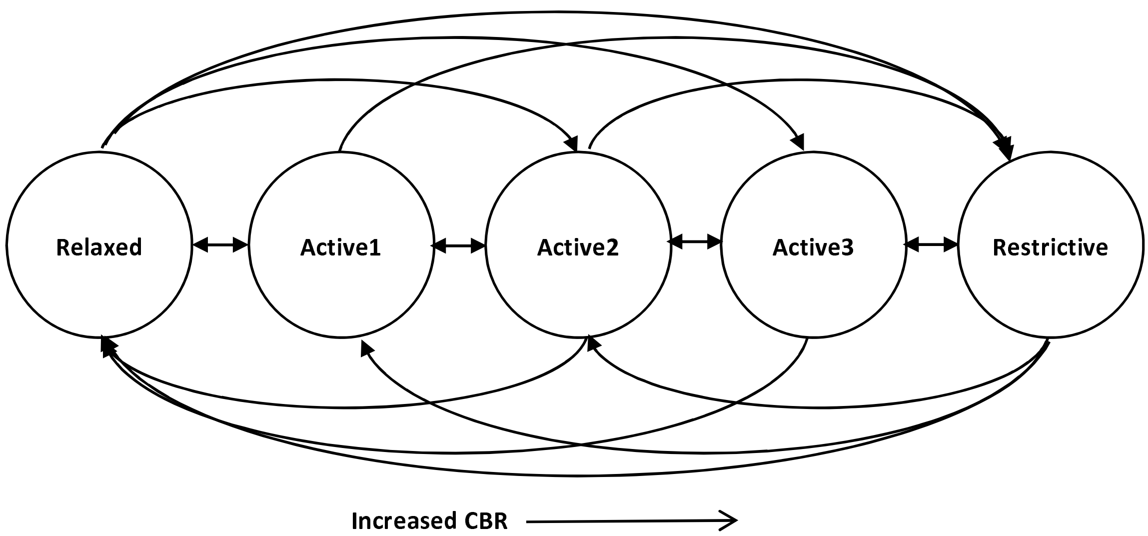

Figure C.1: A possible configuration of the state machine in ETSI TS 102 687 [2]

The current state is depending on the current level of the CBR value. Table C.1 outlines a possible configuration of the state-based DCC using transmit rate control as the only technique for controlling the channel load. This configuration satisfies the limit outlined in clause 7 of the present document.

Table C.1: Mapping of CBR values to state and the currently allowed transmission opportunities per second

State	Channel load	Packet rate	T_{off}
Relaxed	< 30 %	10 Hz	100 ms
Active 1	30 % to 39 %	5 Hz	200 ms
Active 2	40 % to 49 %	2,5 Hz	400 ms
Active 3	50 % to 60 %	2 Hz	500 ms
Restrictive	> 60 %	1 Hz	1 000 ms

There is an inertia built into the state-based algorithm to avoid jumping between states for every update of the CBR value. The inertia is controlled via two parameters called *NDL_timeUp* and *NDL_timeDown*. The default value of *NDL_timeUp* is set to one second and for *NDL_timeDown* this value is set to five seconds. This implies that moving towards a more restrictive state is quicker as a response to an increasing CBR value than moving towards a less restrictive state (which can take up to five seconds if CBR drops rapidly).

C.3 Linear Adaptive DCC

The LIMERIC algorithm is a linear adaptive control algorithm (see [i.2]) that is capable of satisfying the limit function of clause 7. It is sometimes formulated in terms of an allowed message rate (messages per second), but it can be used to adapt a rate in terms of bits per second or in terms of the permitted transmit time T_{on}. The latter formulation is shown here. If $T_{on}(t)$ represents T_{on} for a specific node at time t, then it can be updated from time t to time $t + 1$ according to the linear adaptive update formula:

$$T_{on}\,(t+1) = (1-\alpha) \times T_{on}\,(t) + \beta \times (CBR^{target} - CBR(t)), \qquad \text{(C.1)}$$

where CBR^{target}, α, and β are parameters of the algorithm. A parameterization of the values of α and β is given in ETSI TR 101 612 [i.1]. A published version of the linear adaptive algorithm description (see [i.2]) includes an additional term that limits the magnitude of [$\beta \times (CBR^{target} - CBR(t))$], and thus the change in T_{on} for a single iteration, which ensures algorithm statibility regardless of the number of vehicles contributing to CBR.

History

Document history		
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