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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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Foreword

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

Modal verbs terminology

In the present document "**shall**", "**shall not**", "**should**", "**should not**", "**may**", "**need not**", "**will**", "**will not**", "**can**" and "**cannot**" are to be interpreted as described in clause 3.2 of the ETSI Drafting Rules (Verbal forms for the expression of provisions).

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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].

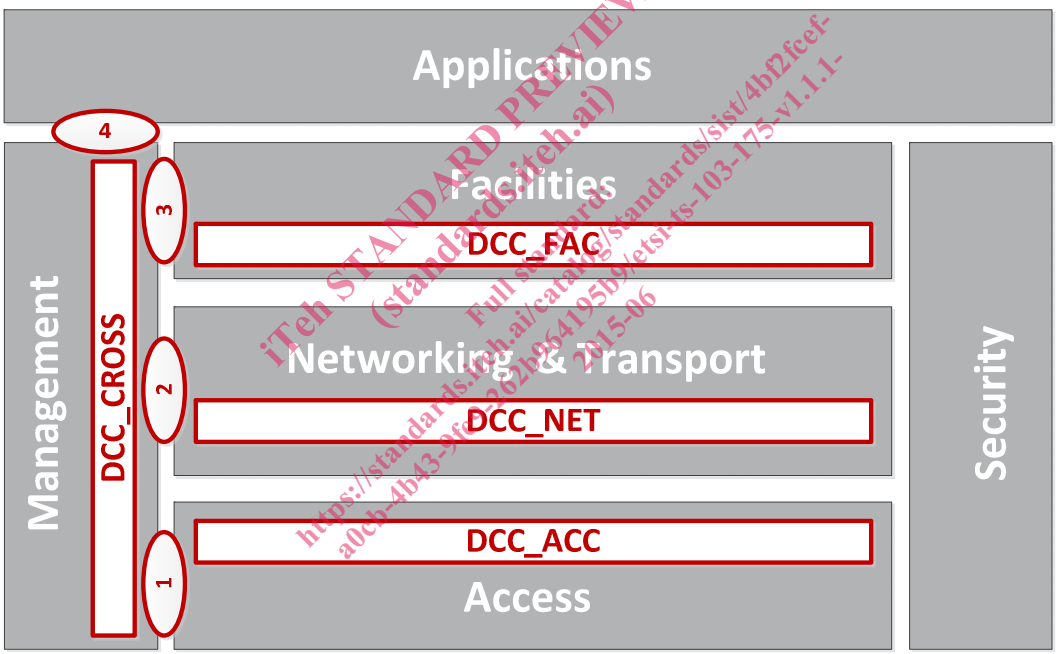

Figure 1: DCC Architecture

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.