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Contents

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Foreword

This Technical Report (TR) has been produced by ETSI Technical Committee Intelligent Transport Systems (ITS).

Modal verbs terminology

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1 Scope

The present document provides a preliminary technical overview of the cross-layer decentralized congestion control (DCC) architecture to be implemented in the ITS-S. It describes DCC functions and testable DCC limits and includes initial performance evaluation results based on simulations. In addition, reference scenarios and parameters used for performance evaluation purposes and the corresponding evaluation metrics are summarized. It will be completed by a Technical Report with validation set-up and results. Both will serve as a basis for the Technical Specification of the Cross Layer DCC control entity in the ITS G5A and ITS G5B media.

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 reference document (including any amendments) applies.

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

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2.1 Normative references

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

Not applicable.

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] IEEE 802.11-2012: "IEEE Wireless Local Access Network - Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications".

[i.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".

[i.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".

[i.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".

[i.5] ETSI TS 102 723-3: "Intelligent Transport Systems (ITS); OSI cross-layer topics; Part 3: Interface between management entity and access layer".

[i.6] ETSI TS 102 723-4: "Intelligent Transport Systems (ITS); OSI cross-layer topics; Part 4: Interface between management entity and networking & transport layer".

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

[i.8] ETSI TS 102 723-10: "Intelligent Transport Systems (ITS); OSI cross-layer topics; Part 10: Interface between access layer and networking & transport layer".

[i.9] ETSI TS 102 723-11: "Intelligent Transport Systems (ITS); OSI cross-layer topics; Part 11: Interface between networking and transport layer and facilities layer".

[i.10] ETSI EN 302 665: "Intelligent Transport Systems (ITS); Communications Architecture".

[i.11] ETSI EN 302 663: "Intelligent Transport Systems (ITS); Access layer specification for Intelligent Transport Systems operating in the 5 GHz frequency band".

[i.12] 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".

[i.13] ECC/DEC/(08)01 ECC Decision on the harmonised use of the 5875-5925 MHz frequency band for Intelligent Transport Systems (ITS).

[i.14] 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".

[i.15] ETSI TS 103 257: "Intelligent Transport Systems (ITS); Access Layer; ITS-G5 Channel Models and Performance Analysis Framework".

[i.16] M. Rondinone et al.: "iTETRIS: A Modular Simulation Platform for the Large Scale Evaluation of Cooperative ITS Applications", Simulation Modelling Practice and Theory, Volume 34, May 2013.

[i.17] M. Boban: "GEMV2: Geometry-based Efficient Propagation Model for V2V Communication", available at http://vehicle2x.net.

[i.18] G. Bansal and J.B. Kenney: "Controlling Congestion in Safety-Message Transmissions: A Philosophy for Vehicular DSRC Systems," Vehicular Technology Magazine, IEEE, vol.8, no.4, pp. 20 - 26, December 2013.

[i.19] B. Kloiber, J. Härri, T. Strang.: "Dice the TX power - Improving Awareness Quality in VANETs by Random Transmit Power Selection", IEEE Vehicular Networking Conference (VNC'12), Seoul, Republic of Korea, November 2012.

[i.20] T.Tielert, D.Jiang, L. Delgrossi, H. Hartenstein, "Design methodology and evaluation of rate adaptation based congestion control for vehicle safety communications," IEEE Vehicular Networking Conference (VNC '11), Amsterdam, Netherlands, Nov. 2011.

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 [i.1], ETSI EN 302 665 [i.10], ETSI EN 302 663 [i.11], ETSI EN 302 571 [i.12] and the following apply:

adaptability: performance characteristic, which indicates that a system is capable of adjusting its parameters to maintain the same level of performance when the input conditions are changing

CBR evaluation: function that transforms the hardware specific CL value into a hardware independent local CBR value

channel access time: variable representing the time for an ITS-S to access the channel and send a packet.

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

NOTE: this is one implementation of the channel load metric.

channel load: reference metrics, ranging between 0 and 1, which represents the relative quality of the channel. The higher the load on the channel, the less reliable the reception of the transmitted message is

NOTE: This value is an indication for the channel usage, provided by the radio hardware.

channel resource limit: maximum amount of usable resources of a channel. 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

communication range: maximum Euclidian distance from the sender where a communication can take place with a message reception rate of more than 95 %

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

DCC_ACC: DCC gatekeeper component located at the Access Layer

DCC channel switching indication: indication sent to the DCC functions at upper layers in the case where a message has been switched to a channel different from the one initially requested

DCC channel switching parameter: parameter indicating to which other channels a message may be rerouted in case the channel initially planned is congested **DCC_FAC:** DCC component located at the facilities layer

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

DCC_CROSS_Access: function in the DCC_CROSS component that provides DCC control parameters to DCC_ACC

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

DCC_CROSS_Net&Tr: function in the DCC_CROSS component that provides DCC channel switching parameters to the networking and transport layer and a DCC channel switching indication to the DCC_CROSS_Facilities

DCC fairness: a concept where any ITS-S under the same channel conditions have an equal opportunity of accessing the 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 functionalities

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

DCC_NET: DCC component 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

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

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

DCC queues: set of buffer space in the DCC_ACC component in the access layer that stores the transmission requests sorted according to their priority (access class)

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-Ss 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

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 broadcasted to neighbouring ITS-S

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

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

inter-reception rate: receiver-based metric representing the time between the successful reception of two CAM messages

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

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

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

neighbour density: metric illustrating the average number of ITS-S per square meter in the communication range of an ITS-S

resilience: performance characteristic, which indicates that a system is capable of providing a sufficient level of performance under certain conditions

responsiveness: performance characteristic, which indicates that a system is capable of adjusting its parameters fast enough to maintain a certain level of performance to sudden, brief and recurring changes in the input conditions

RSSI/RCPI: indication of the received signal power level at the receiver

NOTE: RSSI/RCPI is a receiver-centric metrics that indicates the distance to the transmitter as well as the potential impact of interfering radio signals.

scalability: performance characteristic, which indicates that a system is capable of keeping the level of performance while increasing the number of participating ITS-S

TTT Road Tolling: radio interface specified at CEN mainly for road tolling applications

NOTE: Formerly referred to as CEN DSRC.

3.2 Symbols

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

CR_{limit}	Channel Resources Limit
CBR_{limit}	Channel Busy Ratio Limit
CBR^{target}	Target Channel Busy Ratio
N_{Sta}	Number of ITS-Ss
P_{TX}	Transmit Power
R_{limit}	Message Rate Limit
R^{tx}	Transmit Rate
R_M	Message Rate

T_{off}	Time during which a DCC queue is closed (OFF), in order to regulate congestion from the DCC queue; also considered to be the idle time for the DCC flow control function
T_{on}	Time during which a DCC queue is open (ON) and messages from the DCC queues are sent to the ITS-G5 radio also considered to be the message transmit duration for the DCC flow control function
$Toff_{limit}$	Idle Time Limit

3.3 Abbreviations

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

ACC-XDCC	DCC_CROSS_Access
AI	Adaptive Increase
AIMD	Additive Increase Multiplicative Decrease
ANPI	Average Noise Power Indicator
C2X	Car-to-X communication system
CAM	Cooperative Awareness Message
CAT	Channel Access Time
CBR	Channel Busy Ratio
CCH	Control Channel
CEN	Commité Européen de Normalisation
CL	Channel Load
CR	Communication Range
CS	Carrier Sensing
CSMA/CA	Carrier Sense Multiple Access with Collision Avoidance
DCC	Decentralized Congestion Control
DENM	Decentralized Environmental Notification Message
DSRC	Dedicated Short Range Communication
DTN	Delay Tolerant Networks
DUT	Device Under Test
DVB-H	Digital Video Broadcast - Handheld
EDCA	Enhanced Distributed Channel Access
FA	Facility Layer-Application Layer
FAC-XDCC	DCC_CROSS_Facilities
GN	GeoNetworking
IDR	Information Dissemination Rate
IRT	Inter-Reception Time
ITS	Intelligent Transportation System
ITS-S	ITS Station
KPI	Key Performance Indicator
LOS	Line-of-Sight
MD	Multiplicative Decrease
NET-XDCC	DCC_CROSS_Net&Tr
NLOS	Non Line-of-Sight
OFDM	Orthogonal Frequency Division Multiplexing
OBU	On-Board Unit
PDA	Personal Digital Assistant, e.g., smartphone
QPSK	Quadrature Phase Shift Keying
RCPI	Received Channel Power Indicator
RF	Radio Frequency
RSNI	Received Signal-to-Noise Indicator
RSSI	Received Signal Strength Indicator
RSU	Road Side Unit
RX	Receiver
SAP	Service Access Point
SHB	Single Hop Broadcast
STA	Stations
TC	Traffic Class
TTT	Transport & Traffic Telematics
TCP	Transmission Control Protocol
TX	Transmitter
UMTS	Universal Mobile Telecommunication Systems

VT	Vehicular Technology
XDCC	DCC_CROSS

4 Introduction

The DCC functionality is part of the ITS station (ITS-S) reference architecture given in ETSI EN 302 665 [i.10]. A schematic description including interfaces is displayed in Figure 1. It consists of the following DCC components:

- DCC_ACC located in the Access as specified in ETSI TS 102 687 [i.2];
- DCC_NET located in the Networking and Transport as specified in ETSI TS 102 636-4-2 [i.4];
- DCC_FAC located in the Facilities;
- DCC_CROSS located in the management plane.

The components are connected through the DCC interface 1 to interface 4 as shown in Figure 1. These interfaces are mapped to the corresponding cross-layer interfaces as described in ETSI TS 102 723-3 [i.5], ETSI TS 102 723-4 [i.6] and ETSI TS 102 723-5 [i.7].

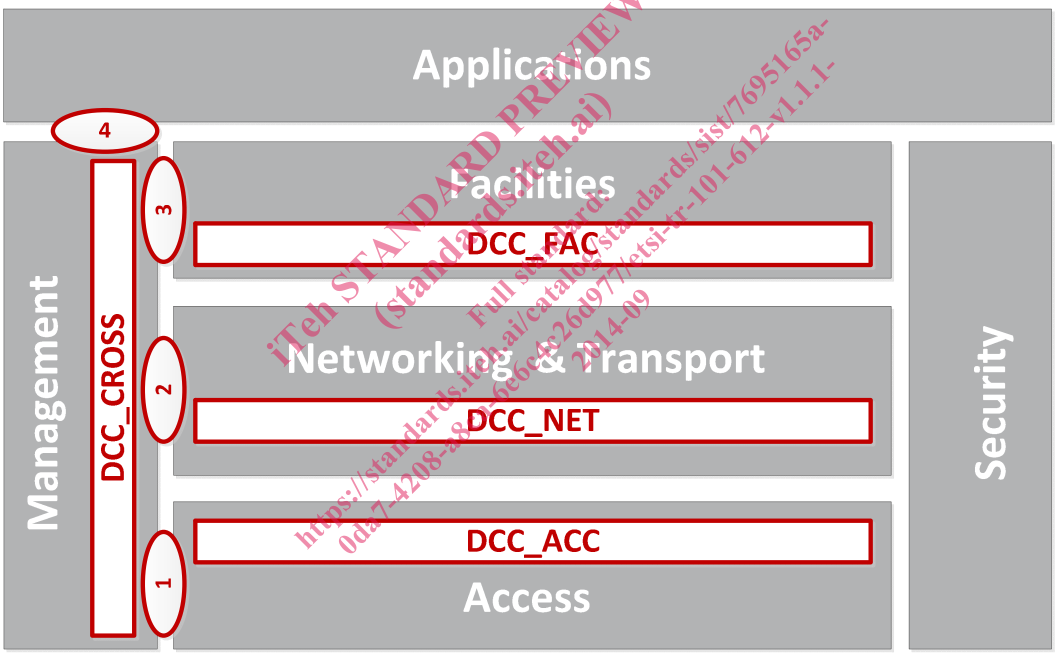

Figure 1: Overview of DCC Architecture

The present document describes the cross-layer architecture of the DCC mechanisms for ITS-G5 and focuses more specifically on the DCC management functions in the DCC_CROSS component and the DCC functions in each layer, as well as their interactions.

The present document does not specify a particular DCC algorithm to control the load on the channel between ITS-Ss; instead channel load limits are provided that all ITS-Ss need to follow regardless of DCC implementation.

Further, the present document proposes a set of scenarios for simulation as well as an evaluation methodology to be able to test and compare different approaches of the DCC algorithms The present document provides initial simulation results for two different DCC algorithms.

5 Architecture

5.1 Introduction

The primary objective for the DCC algorithm in the ITS-S is to calculate based on input parameters the currently allowed channel resource limit.

Four different configurations of the DCC architecture have been identified depending on if the ITS-S is operating on a single channel or multiple channels and if only local or both local and global input parameters to the DCC algorithm are present. In Table 1, the different configuration possibilities are outlined.

Table 1: The different identified DCC configurations

	Supported channels		Input parameters	
	Single	**Multi**	**Local only**	**Local and global**
DCC configuration 1	X		X	
DCC configuration 2	X		X	X
DCC configuration 3	X	X	X	
DCC configuration 4	X	X	X	X

The specification of the cross-layer DCC behaviour (DCC_CROSS) should support interoperability between the different DCC configurations. For all configurations, it is assumed that a measurement of the channel load (CL) is provided by the ITS-G5 radio component. This is the primary input to the DCC algorithm. The DCC entity processes the CL measurement data and feeds the DCC algorithm with a local channel busy ratio (CBR). All DCC configurations listed in Table 1 provide the local CBR value and support single channel operation. In DCC configurations 2 and 4, global parameters are also available through the use of ETSI TS 102 636-4-2 [i.4], which is the media-dependent part of the GeoNetworking (GN) protocol. By using this functionality of the GN protocol, the ITS-S can disseminate information about its local CL, the highest received CL from its neighbour ITS-S, its current message rate, output power etc., in GN single-hop broadcast (SHB) packets. When global input parameters are available those are saved in the GN location table of the GN protocol. The DCC configurations are detailed in clauses 5.2.1-5.2.4.

5.2 Configurations of the DCC architecture

5.2.1 DCC configuration 1

In DCC configuration 1, single channel and local DCC input parameters are present.

The calculation of available resources of the channel is only based on local CL measurements, transformed to internal DCC parameters and distributed to the DCC_CROSS_Facilities and DCC_CROSS_Access functions. The facilities can use the information to restrict the number of generated packets but it also gives the facilities the possibility to prioritize between different types of data traffic. If higher layers perform according to the output from the DCC algorithm, the access layer does not have to for example restrict the number of packets on the channel.

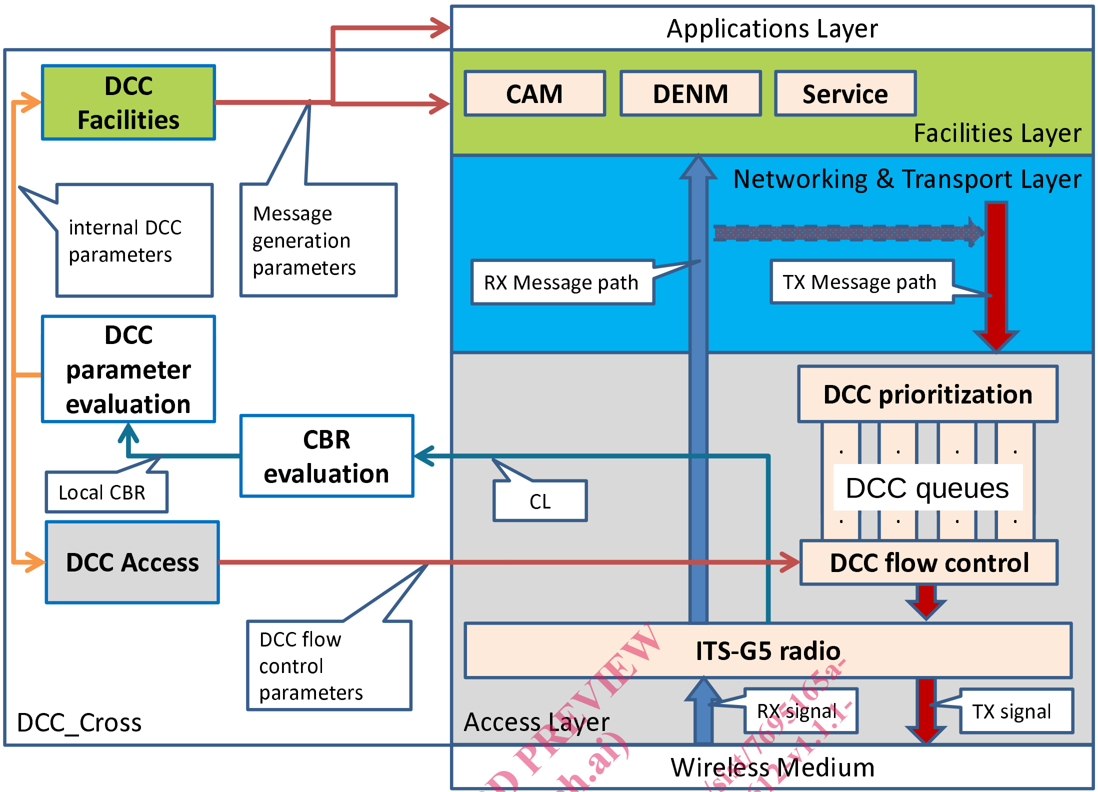

Figure 2: Architecture overview of the DCC configuration 1: Single channel operation with local DCC information

5.2.2 DCC configuration 2

In DCC configuration 2, the ITS-S only operates on a single channel but has access to global input as well as local.

Adding global DCC parameters provides the possibility to align the DCC parameters among all ITS-S in communication range (Figure 3). These parameters are stored in a neighbour table in the networking & transport. For example, ETSI TS 102 636-4-2 [i.4] specifies the dissemination of global DCC parameters and their storage in the GN location table. Together with the local CL measurement the global DCC parameters are taken as input for the evaluation of the internal DCC parameters, which are distributed and used in the same way as in the first configuration (Figure 2). Having a global DCC coordination also enables the control of the transmit power level as part of the DCC mechanism in the future. This will reduce the impact of the hidden node problem that may occur if this control is not provided.