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Technical Specification

Intelligent Transport Systems (ITS); Harmonized Channel Specifications for Intelligent Transport Systems operating in the 5 GHz frequency band

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Foreword

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

Introduction

The present document describes the access layer configuration and derives requirements of the higher-layer use of the ITS-G5 channels allocated for road safety and efficiency in Europe. The specification is the bases for the detailed definition of the cross layer Decentralized Congestion Control (DCC).

The present document is centred on the notion of routing different communication traffic streams to different channels, depending on the current congestion state of the respective channels, and assigning channel-access priorities. Furthermore, it introduces *rate control* in order to keep traffic offered on the channels below reasonable bounds. The configuration settings of channel routing and rate control are under full control of the Management Layer.

1 Scope

The present document specifies details of the channel usage in the ITS G5A and ITS G5B bands including multi-channel operation support which includes

- Control and service channels operation for ITS G5;
- Usage of ITS G5 channels for road safety and traffic efficiency ITS applications;
- ITS G5 transmit and receive policies, channel selection and configuration;
- Per-traffic-stream and per-channel rate control;
- Reference usage scenarios and parameters;
- ITS G5 adjacent channel interference considerations.

The specified parameters and procedures will be used in the definition of the cross layer DCC algorithms and management entities.

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.

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

[2] ISO/IEC 7498-1: "Information technology - Open Systems Interconnection - Basic Reference Model: The Basic Model".

[3] ETSI ES 202 663: "Intelligent Transport Systems (ITS); European profile standard for the physical and medium access control layer of Intelligent Transport Systems operating in the 5 GHz frequency band".

[4] 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".

[5] IEEE Std. 802: "IEEE Standard for Local and Metropolitan Area Networks: Overview and Architecture".

[6] ETSI EN 302 571 (V1.1.1): "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".

[7] Commission Decision 2008/671/EC of 5 August 2008 on the harmonised use of radio spectrum in the 5 875-5 905 MHz frequency band for safety-related applications of Intelligent Transport Systems (ITS).

[8] 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

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 TS 102 636-4-1: "Intelligent Transport System (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".

3 Definitions and abbreviations

3.1 Definitions

For the purposes of the present document, the terms and definitions given in [1] to [5] and the following apply:

channel configuration: act of assigning traffic offered to the Access Layer to one of a discrete, fixed set of available channels

DCC profile: set of transmission parameters for the identification and control of a traffic stream (like CAM, DENM, SPAT, etc.) and the basis for traffic discrimination in the Access and Network and Transport Layers

NOTE: The DCC profiles are managed in the DCC management entity.

rate control: act of controlling the rate of traffic offered to the Access Layer by delaying the transmission of frames or dropping them

safety related applications and services: applications and services whose aim is to reduce the number of traffic fatalities or accidents using vehicle-to-vehicle or roadside-to-vehicle communications

safety critical context: context in which a vehicle is operating safety related services and the vehicle is detecting a potentially dangerous situation

3.2 Abbreviations

For the purposes of the present document, the abbreviations given in [1] to [5] and the following apply:

CAM	Cooperative Awareness Message
CCH	Control Channel
CP	Communication Profile
DCC	Decentralized Congestion Control
DENM	Decentralized Environmental Notification Message
DP-ID	DCC Profile Identifier
DSRC	Dedicated Short-Range Communications
ITS	Intelligent Transportation System
P_{CCH_rel}	Maximum allowed TX power on the CCH channel in DCC state Relaxed
P_{CCH_act}	Maximum allowed TX power on the CCH channel in DCC state Active
P_{CCH_res}	Maximum allowed TX power on the CCH channel in DCC state Restricted
$P_{SCH\#\_rel}$	Maximum allowed TX power on the SCH# (# = 1 …4) channel in DCC state Relaxed
$P_{SCH\#\_act}$	Maximum allowed TX power on the SCH# (# = 1 …4) channel in DCC state Relaxed
$P_{SCH\#\_res}$	Maximum allowed TX power on the SCH# (# = 1 …4) channel in DCC state Relaxed
SAP	Service Access Point
SCH	Service Channel
SPAT	Signal Phase And Time

TC Technical Committee

4 General Overview

In addition to the functional entities already included in the ETSI profile standard [3] covering the Access Layer of the ITS G5A and ITS G5B systems the present document will define the channel mapping under the control of the decentralized congestion control (DCC) algorithm. The needed functional blocks and the requirements will be specified. The overall architecture of an ITS G5 station is depicted in Figure 1 including the distributed DCC functional blocks in the different layers.

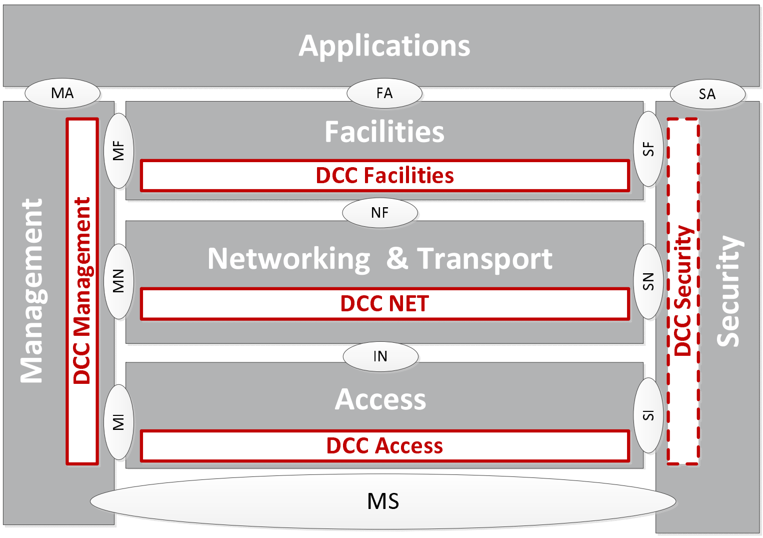

Figure 1: The ITS Communication Architecture including DCC functionality

In the present document, the *Channel Configuration entity* distributes traffic offered to the Access Layer via the IN-SAP over a fixed set of channels available, according to certain requirements under control of the Management Layer and the corresponding DCC Management entity. The Channel-Configuration is part the Access Layer of the ETSI TC ITS Protocol Stack, which is shown in Figure 1, adapted from [1].

The Channel-Configuration entity manages the transmission to and reception from multiple channels. For the three-channel ITS-G5A and the two-channel ITS-G5B, this is shown schematically Figure 2. In Figure 2, we have omitted some of the internal interfaces for readability. Also, except for the IN-SAP and the interfaces to the IT G5 channels, the internal structure shown may not be adhered to in actual implementation. It is chosen in order to explain the overall over all functionality of the Access Layer. The Decentralized Congestion Control functionality is an inherent part of the overall Access Layer operation. The Access Layer DCC is not a separate entity but a distributed functionality provided by the Access layer.

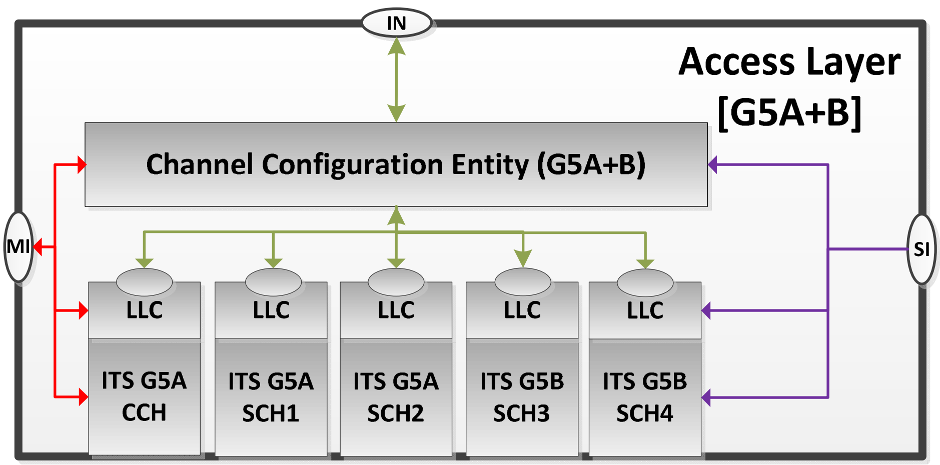

Figure 2: Functional Structure of the Access Layer

The ETSI TC ITS Access Layer is responsible for the Physical and Data Link Layers of the ISO/OSI RM [2] of each physical interface, through a single, unified SAP, viz., the IN-SAP. The Channel Configuration Entity represents a new sub-layer in the Access Layer. Its purpose it to distribute traffic offered through the Access Layer IN-SAP interface over multiple bands and within each band, across multiple channels. More details are given in the informative Annex E.

5 Channel Operation

5.1 General Considerations

ITS stations equipped with ITS G5A and G5B transceiver shall adopt channel access requirements for all transmitted messages based on cross layer DCC as defined in the following clauses.

5.2 Access layer Channel monitoring

The Access Layer shall monitor the following status indicators of the ITS G5A and G5B channels as defined in clauses A.1 and A.2 in [3]:

- Channel Busy Ratio: Relative time in % the channel is busy based on the Channel Busy time definition in the relevant specification [3], where the NDL_defDCCSensitivity is assumed as default for the CCA Threshold.
- Receiver Signal Strength Indicator statistics (RSSI statistic).
- Frames transmission indication (if a message has been successfully transmitted or dropped).

In addition the access layer shall:

- Notification of Tx power reduction on a per message base in case the message could not be transmitted using the asked TX power level.

The Access Layer shall provide this information to the DCC_Management Entity via the MI-SAP.

5.3 Void

5.4 ITS G5A

5.4.1 Channel allocation

The ITS G5A band (5,875 GHz to 5,905 GHz) contains the channels CCH, SCH1 and SCH2 [6]. They are dedicated to road safety related service [7].

5.4.2 Channel Usage CCH / SCH1 / SCH2

The usage of the CCH, SCH1 and SCH2 channels shall be under control of the decentralized congestion control (DCC).

CCH:

The Control Channel (CCH) is basically dedicated to cooperative road safety. It is the default channel for the transmission of DP1 and DP2 messages. The transmissions of messages using different DCC profiles (DP3 to DP8) on the CCH are allowed in the DCC state "RELAXED". In this DCC state the channel is not crowded and therefore no restrictions occur.

SCH1:

The Service Channel 1 (SCH1) is the default channel for announcing and offering ITS services for safety & road efficiency under the DCC state ACTIVE and RESTRITIVE of the CCH. The transmissions of other message-types on the SCH1 are allowed if channel conditions according to the restrictions in the present document permit.

SCH2:

The Service Channel 2 (SCH2) is the second service channel on ITS G5A and is used as an alternate channel for traffic safety-related services. Due to its frequency band allocation between the CCH and the SCH1 and the resulting potential adjacent channel interference issues, the flexibility of the deployment of the SCH2 is limited. The limitations are taken into account in the requirement descriptions for the SCH2.

5.4.3 Channel Access Requirements / Operations

5.4.3.1 Introduction

The present document relies on the DCC definition as described in the DCC document [4]. Additionally, extended specifications for access restrictions are considered based on the DCC states (RELAXED, ACTIVE, RESTRICTIVE) for each channel. The basic interactions between the layers are given in annex B.

5.4.3.2 Access layer requirements based on DCC Profiles

In the following tables the access layer requirements for the different DCC profiles (DP0 to DP32) are given for each channel (CCH, SCH1, SCH2, …). An ITS station operating on an ITS G5A channel shall comply with the parameters given for the different channels and DCC states in Table 1 to Table 3. For a single transceiver ITS station only one of the following tables is relevant at a given time. For a multichannel operation with a multi transceiver stations a set of tables covering the active channels shall to be taken into account for the multichannel DCC operation.

For DCC profiles related to more than a single channel the following usage order shall be deployed by the ITS station:

1) Control Channel, CCH

2) Service Channel 1, SCH1

3) Service Channel 2, SCH2

The message received by the access layer will be transmitted using the first possible channel in the usage order depending on the congestion status and the DCC profile of the message. Examples for the usage are given in the informative annex C.

In Table 1 to Table 5 the following definitions are used:

- DP-ID: DCC profile identifier of a message (DP0 to DP32)
- Q#: Physical Queue of the ITS G5 transmitter
- T_{off}: Time between two messages (packet interval) sent on the same physical ITS-G5 channel for a DCC profile per ITS station
- T_{off_min}: Absolute minimum time between two messages sent on all physical ITS-G5 channels across all active transmitter queues and DCC profiles except the messages with DP0. This parameter can be raised by the Coexistence Management entity
- $P_{\mathbf{TX}}$: TX power recommended for a messages and passed as part of the message via the IN-SAP
- $P_{\#}$: Maximum TX power set by the DCC Management entity including the coexistence management. The actual TX power used shall be equal or smaller than $P_{\#}$

Table 1: CCH: Access layer requirement table based on DCC profiles and congestion state

DCC_Profile DP	**CCH Relaxed** $P_{TX} < P_{CCH\_rel}$ $T_{off\_min} = T_{CHH\_min}$	**CCH Active** $P_{TX} < P_{CCH\_act}$ $T_{off\_min} = T_{CHH\_min}$	**CCH Restrictive** $P_{TX} < P_{CCH\_res}$ $T_{off\_min} = T_{CHH\_min}$	**Note** **Additional parameter to be controlled in future releases:** ***D_{TX}: Data rate (fixed in CCH)*** ***R_{CCA}: Variable CCA threshold***
DP0	Q1 $T_{off} \geq 50$ ms $P_{TX} < P_{CCH\_rel}$	Q1 $T_{off} \geq 50$ ms $P_{TX} < P_{CCH\_rel}$	Q1 $T_{off} \geq 50$ ms $P_{TX} < P_{CCH\_rel}$	For emergency messages only, values overwrite the general default values given in the heading, this DP is only for restricted use in emergency cases.
DP1	Q1 $T_{off} \geq 95$ ms	Q1 $T_{off} \geq 190$ ms	Q1 $T_{off} \geq 250$ ms	
DP2	Q2 $T_{off} \geq 95$ ms	Q2 $T_{off} \geq 190$ ms	Q2 $T_{off} \geq 250$ ms	
DP3	*Q3* $T_{off} \geq 250$ ms	*Q3* $T_{off} \geq 500$ ms	*Q3* $T_{off} \geq 1\,000$ ms	
DP4	Q4 $T_{off} \geq 500$ ms	see note	see note	
DP5	Q4 $T_{off} \geq 1$ s	see note	see note	
DP6	Q4 $T_{off} \geq 5$ s	see note	see note	
DP7	Q4 $T_{off} \geq 10$ s	see note	see note	
DP8	Q4 $T_{off} \geq 10$ s	see note	see note	
DP9 to 32	Not Used	Not used	Not used	
NOTE: Switch to next available channel or drop message.				

Table 2: SCH1: Access layer requirement table based on DCC profiles and congestion status

DCC_Profile DP	SCH1 Relaxed $P_{TX} < P_{SCH1\_rel}$ $T_{off\_min} = T_{SCH1\_min}$	SCH1 Active $P_{TX} < P_{SCH1\_act}$ $T_{off\_min} = T_{SCH1\_min}$	SCH1 Restrictive $P_{TX} < P_{SCH1\_res}$ $T_{off\_min} = T_{SCH1\_min}$	Note Additional parameter to be control in future releases: *D_{TX}: Data rate (fixed in CCH)* *R_{CCA}: Variable CCA threshold*
DP1	Not available	Not available	Not Available	
DP2	Q2 $T_{off} \geq 95$ ms	see note	see note	
DP3	*Q3* $T_{off} \geq 95$ ms	*Q3* $T_{off} \geq 500$ ms	see note	
DP4	Q3 $T_{off} \geq 500$ ms	Q4 $T_{off} \geq 500$ ms	see note	
DP5	*Q4* $T_{off} \geq 500$ ms	see note	see note	
DP6	*Q4* $T_{off} \geq 500$ ms	see note	see note	
DP7	*Q4* $T_{off} > 1$ s	see note	see note	
DP8	*Q4* $T_{off} > 1$ s	see note	see note	
DP9	Q1 $T_{off} \geq 100$ ms	Q1 $T_{off} \geq 200$ ms	Q1 $T_{off} \geq 250$ ms	
DP10	Q2 $T_{off} \geq 100$ ms	Q2 $T_{off} \geq 200$ ms	Q2 $T_{off} \geq 250$ ms	
DP11	*Q3* $T_{off} \geq 100$ ms	*Q3* $T_{off} \geq 500$ ms	see note	
DP12	Q4 $\mathrm{T}_{off} \geq 500$ ms	see note	see note	
DP13	Q4 $\mathrm{T}_{off} \geq 1$ s	see note	see note	
DP14	Q4 $\mathrm{T}_{off} \geq 5$ s	see note	see note	
DP15	Q4 $\mathrm{T}_{off} \geq 10$ s	see note	see note	
DP16	Q4 $\mathrm{T}_{off} \geq 10$ s	see note	see note	
DP17 to 32	Not Used	Not used	Not used	
NOTE: Switch to next available channel or drop message.				

Table 3: SCH2: Access layer requirement table based on DCC profiles and congestion status

DCC_Profile DP	SCH2 Relaxed $P_{TX} < P_{SCH2\_rel}$ $T_{off\_min} = T_{SCH2\_min}$	SCH2 Active $P_{TX} < P_{SCH2\_act}$ $T_{off\_min} = T_{SCH2\_min}$	SCH2 Restrictive $P_{TX} < P_{SCH2\_res}$ $T_{off\_min} = T_{SCH2\_min}$	Note Additional parameter to be control in future releases: D_{TX}: *Data rate (fixed in CCH)* R_{CCA}: *Variable CCA threshold*
DP1	Not available	Not available	Not available	
DP2	Not available	Not available	Not available	
DP3	Not available	Not available	Not available	
DP4	Q1 $T_{off} \geq 500$ ms	Q2 $T_{off} \geq 500$ ms	Q2 $T_{off} \geq 500$ ms	
DP5	*Q3* $T_{off} \geq 500$ ms	see note	see note	
DP6	*Q3* $T_{off} \geq 500$ ms	see note	see note	
DP7	*Q3* $T_{off} \geq 1$ s	see note	see note	
DP8	*Q3* $T_{off} > 2$ s	see note	see note	
DP9	Q4 $T_{off} \geq 2$ s	Q4 $T_{off} \geq 5$ s	Q4 $T_{off} \geq 10$ s	
DP10	Q4 $T_{off} \geq 5$ s	Q4 $T_{off} \geq 10$ s	Q4 $T_{off} \geq 10$ s	
DP11	*Q4* $T_{off} \geq 5$ s	*Q4* $T_{off} \geq 10$ s	see note	
DP12	Q4 $T_{off} \geq 5$ s	see note	see note	
DP13	Q4 $T_{off} \geq 5$ s	see note	see note	
DP14	Q4 $T_{off} \geq 10$ s	see note	see note	
DP15	Q4 $T_{off} \geq 20$ s	see note	see note	
DP16	Q4 $T_{off} \geq 20$ s	see note	see note	
DP17 to 32	Not Used	Not used	Not used	
NOTE: Switch to next available channel or drop message.				

5.5 ITS G5B

5.5.1 Channel allocation

The ITS G5B band (5,855 GHz to 5,9875 GHz) contains the channels SCH3 and SCH4. It is considered for general purpose ITS services (e.g. road efficiency, service announcements, multi-hopping, etc.). The ITS G5B band is not allocated European wide. Thus local usage restrictions might apply.

5.5.2 Channel Usage and Operations SCH3 / SCH4

All traffic shall be compliant with DCC. An ITS station operating on the ITS G5B channel shall comply with the requirements given in Table 4 and Table 5.

5.5.3 Channel Access Requirements

For DCC profiles related to more than a single channel the following usage order shall be deployed by the ITS station:

1) Service Channel 3, SCH3
2) Service Channel 4, SCH4

The message received by the access layer will be transmitted using the first possible channel in the usage order depending on the congestion status and the DCC profile of the message. Examples for the usage are given in the informative annex C.

In Table 4 and Table 5 the access layer requirements are depicted for the two service channels in the ITSG5B band. The abbreviations are explained in clause 5.3.2.1.

Table 4: SCH3: Access layer requirement table based on DCC profiles and congestion status

DCC_Profile DP	SCH3 Relaxed (see note 2) $P_{TX} < P_{SCH3\_act} \leq$ 23 dBm T_{off_min}= 0 ms	SCH3 Active $P_{TX} < P_{SCH3\_act} \leq$ 23 dBm $T_{off\_min} = T_{SCH3\_min}$	SCH3 Restrictive $P_{TX} < P_{SCH3\_res} \leq$ 23 dBm $T_{off\_min} = T_{SCH3\_min}$	Note Additional parameter to be control in future releases: *D_{TX}: Data rate (fixed in CCH)* *R_{CCA}: Variable CCA threshold*
DP1 - 4	Not available	Not available	Not available	
DP5	Q1 $T_{off} \geq$ 100 ms	Q1 $T_{off} \geq$ 200 ms	Q1 $T_{off} \geq$ 250 ms	
DP6	Q2 $T_{off} \geq$ 100 ms	Q2 $T_{off} \geq$ 200 ms	Q2 $T_{off} \geq$ 250 ms	
DP7	*Q3* $T_{off} \geq$ 250 ms	*Q3* $T_{off} \geq$ 500 ms	see note 1	
DP8	Q4 $T_{off} \geq$ 500 ms	see note 1	see note 1	
DP9	Q4 $T_{off} \geq$ 1 000 ms	see note 1	see note 1	
DP10	Q4 $T_{off} \geq$ 1 000 ms	see note 1	see note 1	
DP11	Q4 $T_{off} \geq$ 1 000 ms	see note 1	see note 1	
DP12	Q4 $T_{off} \geq$ 1 000 ms	see note 1	see note 1	
DP13	Q4 $T_{off} \geq$ 1 000 ms	see note 1	see note 1	
DP14	Q4 $T_{off} \geq$ 1 000 ms	see note 1	see note 1	
DP15	Q4 $T_{off} \geq$ 1 000 ms	see note 1	see note 1	
DP16	Q4 $T_{off} \geq$ 1 000 ms	see note 1	see note 1	
DP17	Q1 $T_{off} \geq$ 100 ms	Q1 $T_{off} \geq$ 200 ms	Q1 $T_{off} \geq$ 250 ms	
DP18	Q2 $T_{off} \geq$ 100 ms	Q2 $T_{off} \geq$ 200 ms	Q2 $T_{off} \geq$ 250 ms	
DP19	*Q3* $T_{off} \geq$ 250 ms	*Q3* $T_{off} \geq$ 500 ms	*Q3* $T_{off} \geq$ 1 000 ms	
DP20	Q4 $T_{off} \geq$ 500 ms	see note 1	see note 1	

DCC_Profile DP	SCH3 Relaxed (see note 2) $P_{TX} < P_{SCH3\_act} \leq$ 23 dBm T_{off_min}= 0 ms	SCH3 Active $P_{TX} < P_{SCH3\_act} \leq$ 23 dBm $T_{off\_min} = T_{SCH3\_min}$	SCH3 Restrictive $P_{TX} < P_{SCH3\_res} \leq$ 23 dBm $T_{off\_min} = T_{SCH3\_min}$	Note Additional parameter to be control in future releases: *D_{TX}: Data rate (fixed in CCH)* *R_{CCA}: Variable CCA threshold*
DP21	Q4 $T_{off} \geq$ 1 000 ms	see note 1	see note 1	
DP22	Q4 $T_{off} \geq$ 1 000 ms	see note 1	see note 1	
DP23	Q4 $T_{off} \geq$ 1 000 ms	see note 1	see note 1	
DP24	Q4 $T_{off} \geq$ 1 000 ms	see note 1	see note 1	
DP25 to 32	Not used	Not used	Not used	
NOTE 1: Switch to next available channel or drop message. NOTE 2: In the case of $P_{SCH3\_rel} \leq$ 10 dBm the T_{off} values in the relaxed state have no restrictions. For ITS stations with more than one transceiver the DCC management entity shall take care of controlling the potential interference from the ITS-G5B channel into the ITS-G5A channels when operating in safety critical contexts.				

Table 5: SCH4: Access layer requirement table based on DCC profiles and congestion status

DCC_Profile DP	SCH4 Relaxed (see note 2) $P_{TX} < P_{SCH4\_rel} \leq$ 0 dBm T_{off_min}= 0 ms	SCH4 Active $P_{TX} < P_{SCH4\_act} \leq$ 0 dBm $T_{off\_min} = T_{SCH4\_min}$	SCH4 Restrictive $P_{TX} < P_{SCH4\_res} \leq$ 0 dBm $T_{off\_min} = T_{SCH4\_min}$	Note Additional parameter to be control in future releases: *D_{TX}: Data rate (fixed in CCH)* *R_{CCA}: Variable CCA threshold*
DP1 - DP8	Not available	Not available	Not available	
DP9	Q1 T_{off} : No restrictions	Q1 $T_{off} \geq$ 200 ms	Q1 $T_{off} \geq$ 250 ms	
DP10	Q2 T_{off} : No restrictions	Q2 $T_{off} \geq$ 200 ms	Q2 $T_{off} \geq$ 250 ms	
DP11	*Q3* T_{off} : No restrictions	*Q3* $T_{off} \geq$ 500 ms	see note 1	
DP12	Q4 T_{off} : No restrictions	see note 1	see note 1	
DP13	Q4 T_{off} : No restrictions	see note 1	see note 1	
DP14	Q4 T_{off} : No restrictions	see note 1	see note 1	
DP15	Q4 T_{off} : No restrictions	see note 1	see note 1	
DP16	Q4 T_{off} : No restrictions	see note 1	see note 1	
DP17	Q1 T_{off} : No restrictions	Q1 $T_{off} \geq$ 200 ms	Q1 $T_{off} \geq$ 250 ms	
DP18	Q2 T_{off} : No restrictions	Q2 $T_{off} \geq$ 200 ms	Q2 $T_{off} \geq$ 250 ms	
DP19	*Q3* T_{off} : No restrictions	*Q3* $T_{off} \geq$ 500 ms	*Q3* $T_{off} \geq$ 1 000 ms	
DP20	Q4 T_{off} : No restrictions	see note 1	see note 1	
DP21	Q4 T_{off} : No restrictions	see note 1	see note 1	

DCC_Profile DP	SCH4 Relaxed (see note 2) $P_{TX} < P_{SCH4\_rel} \leq$ 0 dBm T_{off_min}= 0 ms	SCH4 Active $P_{TX} < P_{SCH4\_act} \leq$ 0 dBm $T_{off\_min} = T_{SCH4\_min}$	SCH4 Restrictive $P_{TX} < P_{SCH4\_res} \leq$ 0 dBm $T_{off\_min} = T_{SCH4\_min}$	Note Additional parameter to be control in future releases: *D_{TX}: Data rate (fixed in CCH)* *R_{CCA}: Variable CCA threshold*
DP22	Q4 T_{off} : No restrictions	see note 1	see note 1	
DP23	Q4 T_{off} : No restrictions	see note 1	see note 1	
DP24	Q4 T_{off} : No restrictions	see note 1	see note 1	
DP25 to 32	Not used	Not used	Not used	

NOTE 1: Switch to next available channel or drop message.
NOTE 2: For ITS stations with more than one transceiver the DCC management entity shall take care of controlling the potential interference from the ITS-G5B channel into the ITS-G5A when operating in safety critical contexts.

5.6 Multi-hop Channel Operations

5.6.1 ITS G5A

Multi-hoping of ANY type of message using the CCH shall only be allowed in DCC state "Relaxed" of the CCH.

This implies that single transceiver ITS station in safety critical context cannot participate in the multi-hop operation in the case the CCH is in DCC state ACTIVE or RESTRITIVE.

Multi-hoping of ANY type of message using the SCH1 shall only be allowed in DCC state "Relaxed" of the SCH1. Any message requiring to be forwarded shall be relayed on **SCH2** in the congestion states **ACTIVE** and **RESTRICTIVE** of the SCH1 and CCH. This is meant to avoid increasing channel congestion on SCH1.

If all ITSG5A channel are in the congestion states ACTIVE or RESTRICTIVE no multi-hop operation shall be allowed.

5.6.2 ITS G5B

In general the ITS G5B channels are available for non-safety related ITS related services. Non-safety related applications requiring multi-hop capabilities should be allowed to use the ITS-G5B channel for multi-hopping operations. In order to avoid congestion situations on the ITS-G5B channels the facility layer and the application registration process shall restrict access to the multi-hop capabilities.

Multi-hop operations on the ITSG5B channels shall only be allowed in DCC state RELAXED.

Annex A (informative): Adjacent Channel Interference

A.1 Introduction

Adjacent-channel interference has the following causes:

1) When transmitting on a particular channel, an ITS Station emits spurious emissions in adjacent channels (above and below), or even in channels beyond. This is due to a transmit spectrum mask that is not ideal.

2) When receiving on a particular channel, an ITS Station picks up interference from adjacent channels (above and below), or even beyond, negatively affecting the SINR. This is due to a receive spectrum mask that is not ideal.

Actually, a third effect occurs due to Doppler shifts of the signal into adjacent channels. However, it is assumed that the effects of Doppler shifts are negligible compared to the two effects described above. Moreover, typical mitigation strategies against Doppler effects are present at the physical (OFDM) layer. Therefore, these are not considered here.

In order to assess the impact of adjacent-channel interference, the following assumptions are made:

- Adjacent channel interference is primarily caused by effect 1, due to non-linear behaviour of the transmit stages, causing intermodulation products in nearby channels. Effect 2 arises in the receiver stages, but these are generally far more linear than transmitter stages (due to small-signal design). Furthermore, IF filtering removes most of the nearby-channel energy.

- With both effects, it is highly unlikely that a transmission on a particular channel is correctly decoded on a nearby/adjacent channel. For instance, the spacing of the sub-carriers on the adjacent channel will be different from that originally sent.

The result is that the interference level at an ITS Station is negatively affected by transmissions on adjacent/nearby channel. This may:

- increase the bit/frame error rate;

- decrease transmit opportunities (as the interference may result in a channel-busy assessment);

- increase channel-load samples in DCC, since DCC cannot in general distinguish between signal and interference on the channel.

From the preceding arguments, it is clear that the dominant parameters affecting adjacent-channel interference are:

- Transmitter spectral mask;

- Transmit power;

- Receive Filter (channel selectivity).

A.2 Mitigation Strategies

The following strategies can help mitigate the effects of adjacent-channel interference:

- Reduce power (or some other DCC measure) on the adjacent channel if adjacent channel interference is detected. The problem here is that it cannot generally be detected if interference is caused by nearby channels.

- Reduce power (or some other DCC measure) on the adjacent channel if the channel becomes 'congested' in terms of the measured channel load being above threshold.

- Increase power on a channel if adjacent channel interference is detected. However, this is very problematic. Adjacent-channel interference cannot be measured directly, and one of the few indications is a high measured channel load. However, in such a case, increasing the transmit power contradicts the DCC strategies.
- Do not use adjacent channels (guard bands). This fails at the boundaries of the bands, of which there are many. However, in ITS G5A, this is an option worth considering.
- Severely limit the max transmit power on channels adjacent to the CCH.
- Synchronize transmissions on a pack of channels. This required further investigation, but seems to hold a promise.
- Some form of 'TDMA': For instance, certain intervals on the CCH should be protected from transmissions on nearby channels. The disadvantage of this general class of approaches is the need for time synchronization. However, most ITS Stations are necessarily equipped with GPS already. Also, this typically leads to lower utilization of the channels.
- Improve the spectral masks. This leads to higher expenses in the RF components. It also reduces the number of players on the market capable of delivering RF products with stringent spectral masks.
- An interesting thought is to redistribute the channels in the available 30 MHz ITS G5A band as follows: 5 MHz guard + single 20 MHz channel + 5 MHz guard.
- Transmitter-blocking due to significant ACI can be tackled by increasing the CCA threshold. A typical approach can be to use the local waiting time of the message in the queue.

Annex B (normative): Cross-layer DCC operation

B.1 Channel Configuration Entity processing of messages

Each message passed to the access layer via the IN-SAP to be transmitted using ITS G5A and ITS G5B shall have a DCC profile identifier (DP-ID). The DCC profile identifier defines a set of transmission parameters of the messages arriving at the access layer (IN-SAP). The DCC profile identifiers are part of the communication profile (CP). The application/facility layer shall use these DCC profile identifier to define the behaviour of the message on the access layer. Up to 32 different basic DCC profiles DP1 to DP32 are assumed. The parameters of the DCC profile tables shall be controlled by the DCC_Management entity in the Management Layer. Upon request from the Access Layer the Management Layer shall provide the DCC profile parameters via the MI-SAP interface corresponding to the DCC profile identifier provided by the Access Layer. This operation is depicted in Figure B.1.

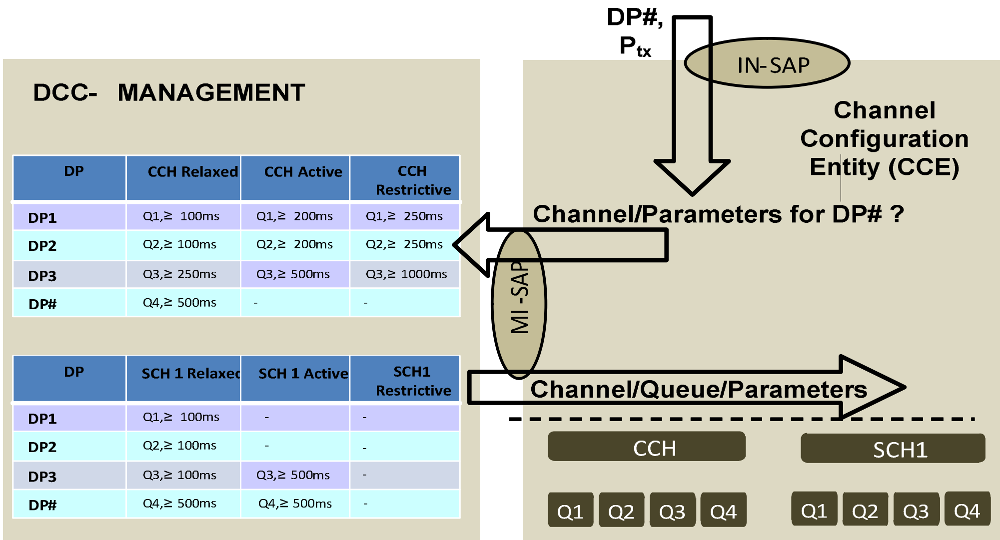

Figure B.1: General control flow operation of the Access Layer DCC

The DCC profile parameters are depicted in Figure B.1 (Queue, minimum Interpacked spacing T_{off}, maximum TX power $P_{\#}$). The maximum TX $P_{\#}$ power shall be valid for all queues related to a specific channel (e.g. CCH, SCH1, etc.).

Each message shall have a TX power P_{TX} bound to the message passed by the Network Layer to the Access layer via the IN-SAP. As long as this TX power P_{TX} is smaller than the maximum allowed TX power in a given DCC state of the chosen channel the message shall be transmitted using its recommended TX power P_{TX}. If the power P_{TX} is higher than the allowed maximum TX power $P_{\#}$, the message shall use the maximum power $P_{\#}$ evaluated by the DCC management entity via the DCC profile.

B.2 Access layer DCC entity control

The DCC state shall be evaluated by a centralized DCC entity in the management layer. This DCC_Management entity shall take into account the DCC information from the other layer like Access layer or Network layer.

Annex C (informative): Deployment examples

C.1 Introduction

In this informative annex some used cases will be presented in order to better understand the deployment of the proposed multi-channel usage concept. The main assumption is that the DCC control unit will be a centralized unit using all available information for the evaluation of the actual DCC state and the corresponding DCC control parameter for the different layer. The DCC profiles are part of the Communication Profiles and are communicated between the different layers from the facility layer down to the Access layer. The application itself or the facility layer has to chose the DP as part of the CP in order to define the treatment of the message at the different layers. The DP need to be chosen according to the specific requirements of the message including the latency, the data rate, packet size and the priority.

Here only the operation in the Access layer will be presented.

C.2 CAM

C.2.1 Scenario

The CAM (Cooperative Awareness Message) is sent periodically in the ITS G5A CCH (Control Channel) at a defined repetition rate of up to 10 Hz. Depending on the decentralized congestion state (DCC state) of the CCH the repetition rate and the TX power of the CAM transmission will be adjusted for minimizing the potential congestion of the channel. If the channel is in a highly congested situation it may occur that older CAMs will be discarded from the transmission queues of the ITS-Stations. The CAM message is generated in the facility layer based on the available information and actual needs. In this case the facility layer will chose the required DP as part of the communication profile. A typical maximum rate of CAM transmission will be 10 Hz. The chosen CAM rate at the facility layer will depend on the speed of the vehicle and the congestion state of the CCH and the SCH1. The required information will be delivered by the DCC_Management entity.

The proposed DP for the CAM is a DP2.

C.2.2 Access layer operation

The CAM will be delivered by the Network layer to the Access layer via the IN-SAP including the DP identifier. In this example the DP# of the CAM is DP2. In Figure C.1 the situation is depicted for the CCH and SCH1 DCC status relaxed. In this case the Access layer will get the information from the Management layer using the MN-SAP that the message can be transmitted using the CCH channel. No additional restriction will apply in this case. The CCH can support a message rate up to 10 Hz. If the CCH now is in the active DCC state the supported rate would only be 5 Hz. For a message with higher transmission rates the additional messages need to be transferred using the SCH1. This situation is depicted in Figure C.2 for the CCH state of ACTIVE and the SCH1 state RELAXED. Here the Access layer will transfer the message first using the CCH and then the SCH1.

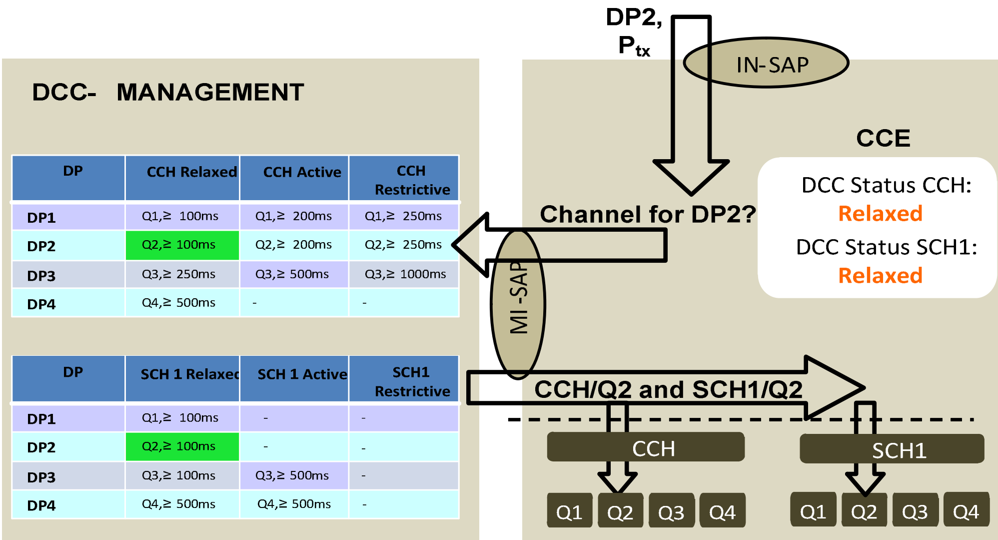

Figure C.1: Example: CAM with DP2 in CCH status relaxed

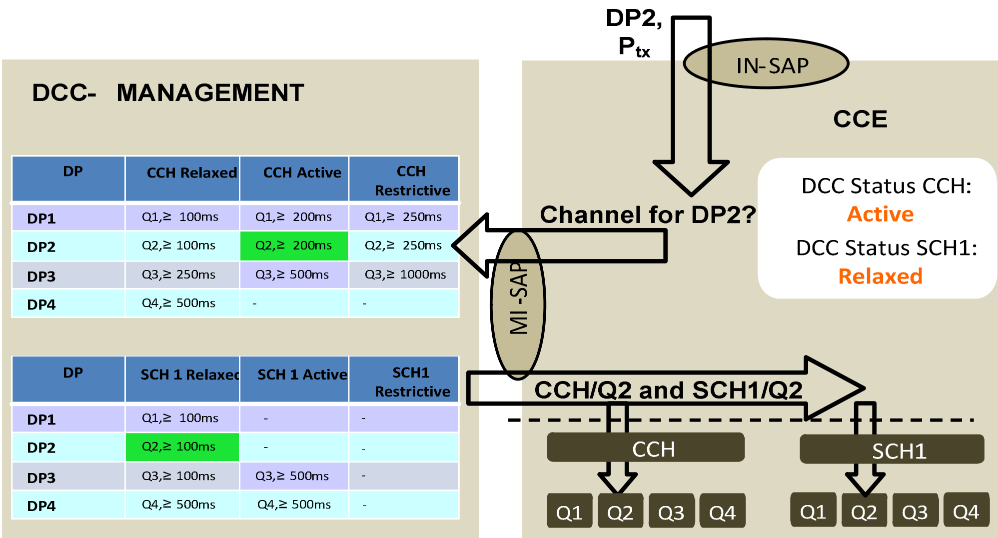

Figure C.2: Example: CAM with DP2 in CCH status active

In the DC state active the facility layer limits the rate of the application packet in order to reduce the need in the Access Layer to move traffic to other channels than the CCH. For the single transceiver ITS station messages might need to be dropped in case the CAM rate is higher than the maximum allowed packet rate.

C.2.3 Conclusion

The proposed operation and mapping of the CAM message using the DP2 will allow for a proper operation over a large range of DCC situations.

C.4 SPAT

C.4.1 Scenario

The SPAT (Signal Phase and Timing) message is sent periodically by the ITS roadside unit (RSU) from the traffic light controller in the ITS G5A CCH (Control Channel) using single hop broadcast (SHB, see [i.1]) and the DCC profile DP3 (see Table 1). The repetition rate based on this profile is limited to a maximum of 4 Hz in a non congested CCH channel situation (DCC state relaxed). The transmit power is not changed as the SPAT message has to cover the area of all approaching lanes in an intersection and has to inform public transportation about the SPAT status. If the traffic on an approaching lane nearby an intersection increases and the cooperative decentralized congestion state on a lane changes from relaxed to active the repetition rate of the SPAT message will be changed to 2 Hz. Thus the over non congested lanes will still receive enough SPAT messages for determination of traffic light changes in advance. In DCC restrictive the SPAT message will be sent out on a rate of 1 Hz. In a typical installation the RSU will be mounted in the intersection with one omni-directional antenna in the middle of the intersection. The antenna has to cover all the approaching lanes. Different congestion situation may occur on different lanes. Therefore if the CCH channel traffic becomes "ACTIVE" on one lane, it may be in "RELAXED" state on the other lanes. Therefore the reduction of SPAT repetition is almost a trade of minimizing congestion on a lane and keeping informed the "RELAXED" traffic on the other lanes in a sufficient way. Therefore the power should not be reduced, thus the SPAT message will be received by the vehicles in all lanes within a radio coverage of approximately 400 m.

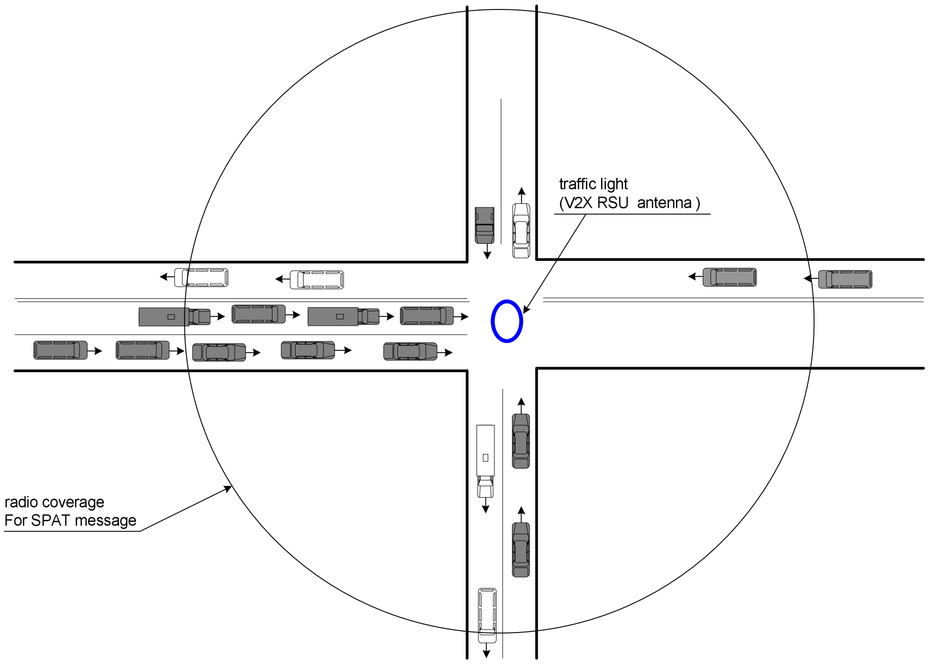

Figure C.3: Traffic scenario in an intersection area, SPAT coverage.

C.4.2 Access layer operation

The SPAT message will be delivered by the Network layer to the Access layer via the IN-SAP including the DCC profile (DP) information field. In this example the DP of the SPAT message is DP3 (see Table 1). In Figure C.6 the situation is depicted for the CCH status "Relaxed". In this case the Access layer will get the information from the Management layer using the MN-SAP that the message can be transmitted using the CCH channel with a repetition rate of 10 Hz and a transmission coverage of 400 m. No additional restriction will apply in this case. If the CCH changes to the congestion state "Active" the repletion rate will be decreased to 2 Hz, no changes in the TX power (see Figure C.5). In a more congested situation the CCH channel becomes "restrictive" and the SPAT repetition rate will be decreased to 1 Hz with no changes in the transmit power (see Figure C.6).

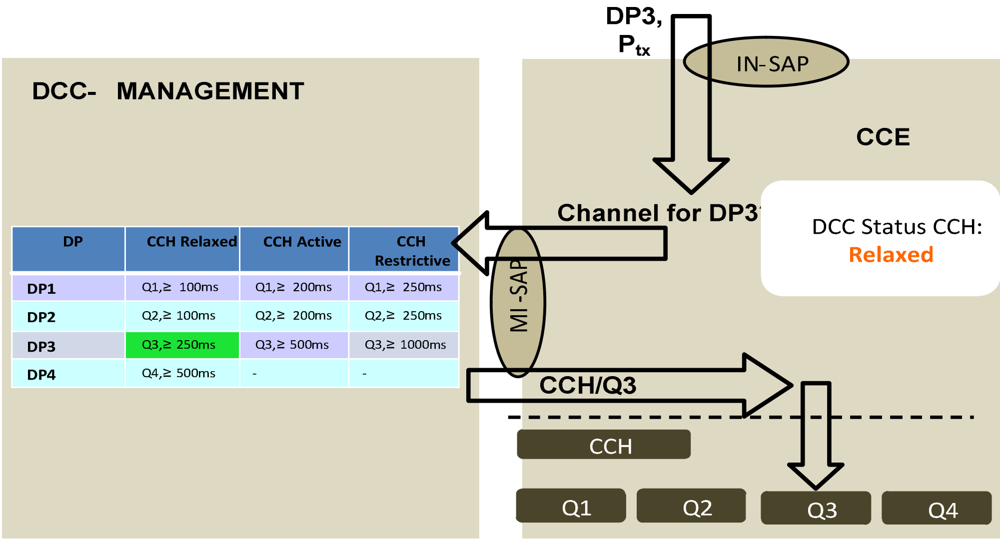

Figure C.4: SPAT using DP3 in CCH status "Relaxed"

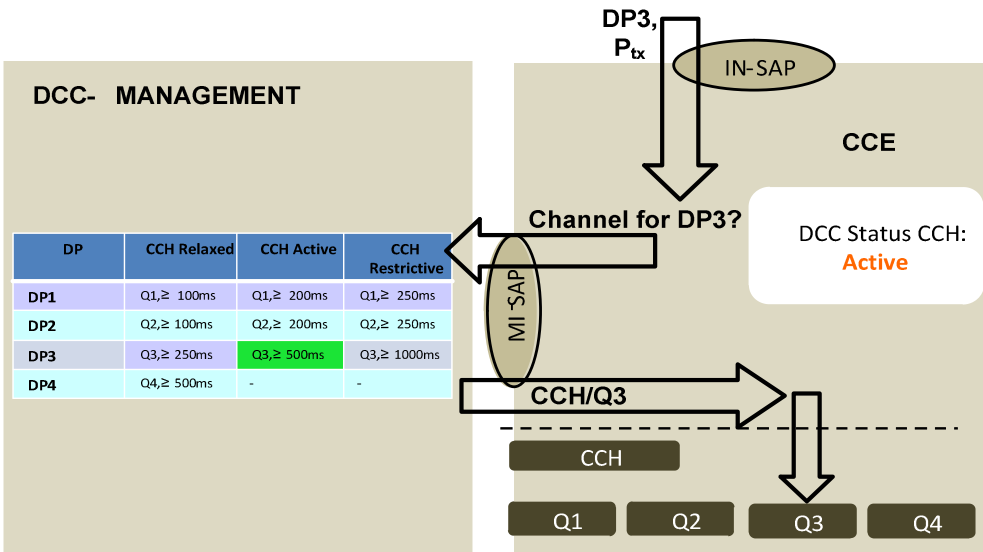

Figure C.5: SPAT using DP3 in CCH status "Active"

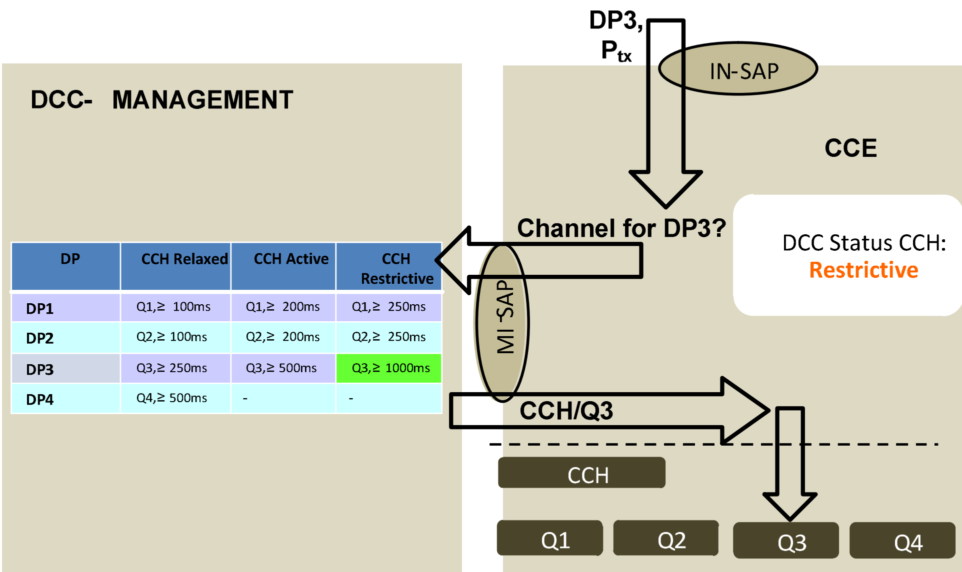

Figure C.6: SPAT using DP3 in CCH status "Restrictive"

C.5 MAP

C.5.1 Scenario

The MAP message contains the topology of a traffic infrastructure (e.g. traffic deviation, intersection, etc.). In an intersection scenario the MAP is also sent in combination of a SPAT message (see clause C.4). The MAP contains additional information and is essential for a vehicle to relate the signal phase and timing information of the traffic light to the lane topology. The MAP information is rather static and may change not so often (e.g. lane direction change from morning to evening traffic, or one of the lanes reserved for public transport in rush hour, etc.). Nevertheless the MAP information is an essential part of information, which comes together with the SPAT information. The MAP message is sent periodically by the ITS roadside unit (RSU) from the traffic light controller in the ITS G5A CCH (Control Channel) using the geonetwork single hop broadcast protocol (SHB, see [i.1]) and the DCC profile DP5 (see Table 1). The repetition rate based on this profile is limited to a maximum of 1 Hz in a non congested CCH channel situation (DCC state relaxed). The transmit power may be regulated based on DCC algorithm defined within the DCC-Management plane. With increased traffic, in DCC congestion state "Active" the repetition rate should be limited to 0,5 Hz with the same power regulation as in the "Relaxed" DCC state. In heavy traffic situations with high V2X communication (DCC state = "Restrictive") the repetition rate is still 0,5 Hz but the Quality of service changes to Q4.

C.5.2 Access layer operation

The MAP message will be delivered by the Network layer to the Access layer via the IN-SAP including the DCC profile (DP) information field. In this example the DP of the MAP message is DP5 (see Table 1). In Figure C.7 the situation is depicted for the CCH status "Relaxed". In this case the Access layer will get the information from the Management layer using the MN-SAP that the message can be transmitted using the CCH channel with a repetition rate of 1 Hz. The TX power level is controlled by the algorithm of the DCC management entity and requested by the access via the MN-SAP from the DCC management plane. If the CCH changes to the congestion state "Active" the repletion rate will be decreased to 0,5 Hz and the TX power for each message will be requested from the DCC-Management plane via the MN-SAP interface (see Figure C.8). In a more congested situation the CCH channel becomes "restrictive" and the SPAT repetition rate will remain on 0,5 Hz but the quality of service will change to Q4 (see Figure C.9).

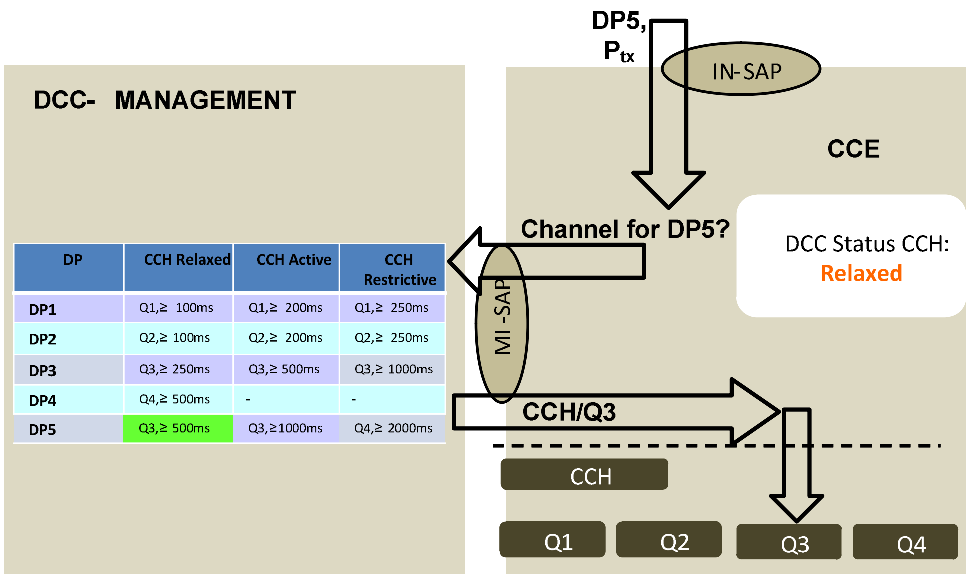

Figure C.7: MAP using DP5 in CCH status "Relaxed"

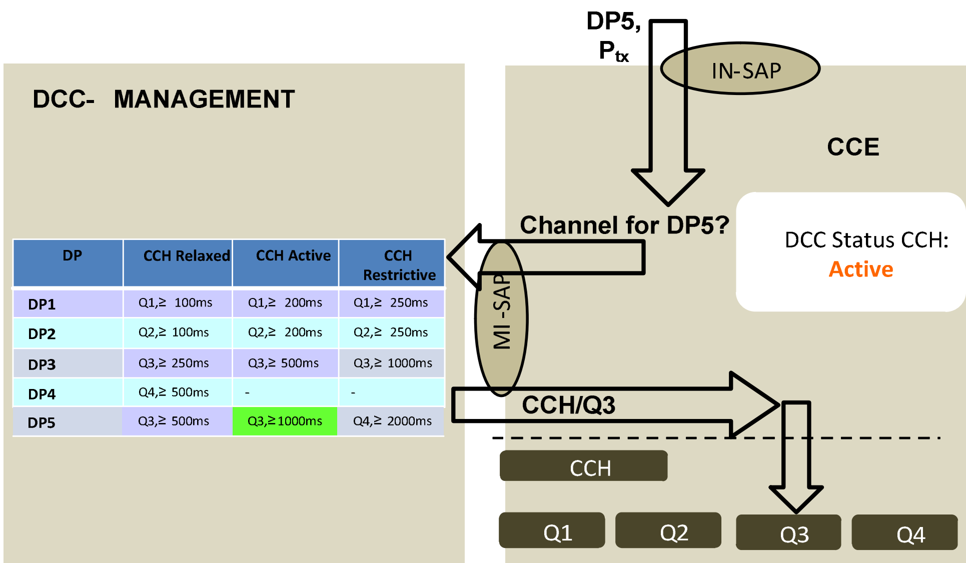

Figure C.8: MAP using DP5 in CCH status "Active"

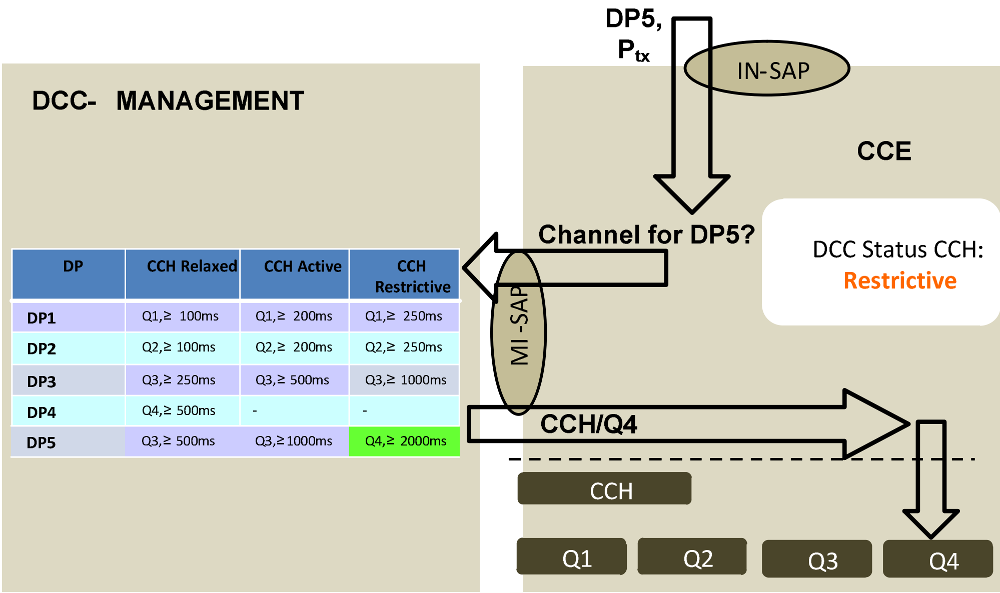

Figure C.9: MAP using DP5 in CCH status "Restrictive"

C.6 Coexistence to CEN DSRC

C.6.1 Example of duty cycle restriction

Coexistence measures are handled by the management plane via the P_{TX} and T_{off_min} parameters independent of the DCC profile. The algorithm specified in TS 102 792 [8] determines an upper limit for P_{TX} and a lower limit for T_{off_min} which is the packet interval for all sent packets over all radio channels. In rare cases these limits are more stringent than the limits defined by the DCC algorithm and they will influence the packet transmission rate on the radio channel. Messages sent with DP0 are excluded from the duty cycle restriction, but they are still counted as transmission, and will therefore block other messages to be sent according to the duty cycle restrictions.

Annex D (informative): Functional transceiver configuration

D.1 Introduction

This annex describes the ITS station architecture for multi-channel and multi-transceiver configuration for operation in ITS G5 band. An ITS station may contain one or more ITS G5 transceivers, each of them being tuned to connected to one or more channels in time, depending on the role of the ITS Station (e.g. safety, traffic efficiency, commercial applications). The possible supported configurations (operating channels and channel switching) for ITS transceivers (number and type of supported ITS G5 transceivers) for ITS Stations are described next.

D.2 ITS G5 transceiver channel configuration

ITS G5 communication should be capable of operating on single channels or on multiple channels according to the requirements of the ITS applications. A base channel is specified for each transceiver configuration, on which the transceiver can receive safety-related messages or service announcements.

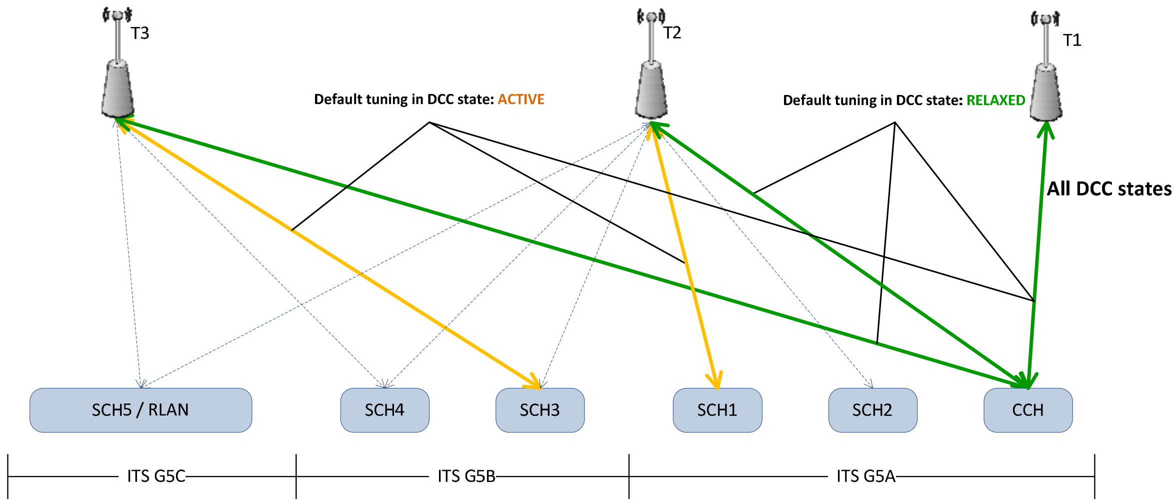

Figure D.1: Multi-Transceiver and Multi-Channel Architecture

An ITS station using one or more ITS G5 transceiver should operate each transceiver in one of the following configurations, as depicted in Figure D.1:

- **Transceiver Configuration 1 (T1):** The transceiver should be tuned exclusively to the CCH channel in the ITS G5A band and should operate based on the DCC requirements.
- **Transceiver Configuration 2 (T2):** The transceiver can be tuned on demand to an arbitrary ITS channel (ITS G5A or G5B) for service operation based on the DCC requirements. Service announcements should take place on SCH1 unless the CCH is in DCC state RELAXED in which case it may be take place on the CCH.
- **Transceiver Configuration 3 (T3):** The transceiver can be tuned on demand to arbitrary ITS channel (ITS G5A, or G5B) for service operation based on the DCC requirements. Service announcements should take place on SCH3 unless the CCH is in DCC state RELAXED in which case it may be take place on the CCH.

In non-safety critical context, e.g. parking situation of a vehicle, the transceiver can be operated in configuration T2 or T3 transceiver configuration. In these transceiver configurations an operation using the G5C channels is permitted. The G5C channels are not under DCC control and thus not in the scope of the present document.

D.3 ITS station channel configuration

D.3.1 Introduction

An ITS station may contain one or multiple ITS G5 transceiver depending on application requirements. An ITS station operating in the ITS G5A or ITS G5B bands should work in compliance with the decentralized congestion control (DCC) mechanisms specified in [4].

D.3.2 Single transceiver ITS station

D.3.2.1 ITS station for safety related ITS services

An ITS station using one ITS G5 transceiver only and only deploying safety related ITS services should operate in configuration T1 (CCH only). This transceiver is permanently tuned to the CCH as long as the transceiver operates in a safety critical context. In a safety critical context a channel switch from CCH to any other channels (e.g. SCH) is not permitted.

D.3.2.2 ITS station for non-safety related services

An ITS station using one ITS G5 transceiver only and deploying non-safety related ITS services (e.g. road efficiency, service announcements, multi-hopping, etc.) should operate in configuration T2 or T3.

D.3.3 Multiple transceiver ITS station

D.3.3.1 ITS station for safety related services

An ITS station using more than one communication transceiver and deploying safety related services should operate one communication transceiver exclusively in configuration T1 (CCH only).

Annex E (normative): Access Layer Requirements summary

ID	Description	Clause	Comments
ACG5AB_R_001	All ITS station operating in the ITS G5A and ITS G5B shall be under DCC control	5.1 5.3.1 5.4.1	
ACG5AB_R_002	An ITS G5 station shall monitor the channel load on all channels participating in the communication under DCC control	5.2	
ACG5AB_R_003	An ITS G5 station shall monitor the RSSI statistic on all channels participating in the communication under DCC control	5.2	
ACG5AB_R_004	An ITS G5 station shall report on request by the management layer all monitored channel parameters to the management layer via the MI-SAP	5.2	
ACCG5AB_R_005	An ITS G5 station shall indicate when the actual transmission of a frame has taken place. Otherwise, if the ITS G5 station dropped the frame, this shall be also indicated. The notified layers shall be Network layer and Management Layer.	5.2	
ACCG5AB_R_006	An ITS G5 station shall notify the Network layer and the Management layer about deployed TX power reduction based on the DCC profile parameters	5.2	
ACG5AB_R_007	The DCC state of each ITS G5A or B channel shall be evaluated by the DCC Management Entity	5.3.2	
ACG5AB_R_008	The DCC Management Entity shall take into account the monitored channel status values provided by the Access Layer	5.3.2	DCC Management Entity
ACG5AB_R_009	An ITS station using ITS G5A channels shall fulfil the usage order CCH, SCH1, SCH2 for all DCC profile identifier valid on more than one channel	5.3.2.1	
ACG5AB_R_010	An ITS station using ITS G5B channels shall fulfil the usage order SCH3, SCH4 for all DCC profile identifier valid on more than one channel	5.4.2	
ACG5AB_R_011	An ITS station using ITS G5A channels shall comply with the parameters given in Table 1 to Table 3	5.3.2.1	
ACG5AB_R_012	An ITS station using ITS G5B channels shall comply with the parameters given in Table 4 and Table 5	5.4.1	
ACG5AB_R_013	An ITS station using ITS G5A: any kind of Multi-hopping shall not be permitted on the CCH in the DCC states ACTIVE or RESTRICTIVE	5.6.1	DCC Network/Transport Entity
ACG5AB_R_014	An ITS station using ITS G5A: any kind of Multi-hopping shall not be permitted on the SCH1 in the DCC states ACTIVE or RESTRICTIVE	5.6.1	DCC Network/Transport Entity
ACG5AB_R_015	An ITS station using ITS G5A: any kind of Multi-hopping shall not be permitted on the SCH2 in the DCC states ACTIVE or RESTRICTIVE	5.6.1	DCC Network/Transport Entity
ACG5AB_R_016	An ITS station using ITS G5B: any kind of Multi-hopping shall not be permitted on the SCH3 and SCH4 in the DCC states ACTIVE or RESTRICTIVE	5.6.2	DCC Network/Transport Entity

Annex F (informative): Bibliography

ETSI TR 102 707: "Intelligent Transport Systems (ITS); ETSI object identifier tree; ITS domain".

ETSI EG 202 798: "ITS testing framework".

IEEE Std. 8802-2: "Information technology -- Telecommunications and information exchange between systems -- Local and metropolitan area networks -- Specific requirements -- Part 2: Logical Link Control".

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

ETSI EN 301 893 V1.5.1: "Broadband Radio Access Networks (BRAN); 5 GHz high performance RLAN; Harmonized EN covering the essential requirements of article 3.2 of the R&TTE Directive".

ETSI TS 102 723-1: "Intelligent Transport Systems; OSI cross-layer topics; Part 11: Interface between network and transport layers and facilities layer".

ETSI TS 102 723-6: "Intelligent Transport Systems; OSI cross-layer topics; Part 6: Interface between management entity and security entity".

ETSI TS 102 723-7: "Intelligent Transport Systems; OSI cross-layer topics; Part 7: Interface between security entity and access layer".

ETSI TS 102 723-11: "Intelligent Transport Systems; OSI cross-layer topics; Part 11: Interface between network and transport layers and facilities layer".

Y. P. Fallah, C. Huang, R. Sengupta and H. Krishnan: "Analysis of Information Dissemination in Vehicular Ad-Hoc Networks With Application to Cooperative Vehicle Safety Systems," IEEE Trans. On Vehicular Technology, vol. 60, no. 1, pp. 233-247, Jan. 2011.

History

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