ETSI TR 103 442 V1.2.1 (2016-09)

TECHNICAL REPORT

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**Railways Telecommunications (RT);
Shared use of spectrum between
Communication Based Train Control (CBTC)
and ITS applications**

Reference
RTR/RT-JTFIR-45

Keywords
ITS, railways

ETSI

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Foreword

This Technical Report (TR) has been produced by ETSI Technical Committee Railway Telecommunications (RT).

Modal verbs terminology

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Executive Summary

The present document summarizes the possible solution for a shared deployment of the CBTC systems for urban rail systems and cooperative ITS systems based on ETSI ITS-G5 in the band 5 855 MHz to 5 925 MHz.

In the band 5 905 MHz to 5 925 MHz all sharing proposals assume that CBTC urban rail safety related applications will have a prioritization over the C-ITS applications. In the band 5 875 MHz to 5 905 MHz C-ITS will have the priority. In the band 5 855 MHz to 5 875 MHz both systems are treated equally.

Different sharing mechanisms are proposed in the present document:

- Implementation of mitigation techniques on the ITS side like detect and avoid or geolocation based solution using 5 MHz CBTC systems.
- Deployment of the ETSI ITS access mechanisms in the CBTC system with 10 MHz channelization.
- Fully integration of CBTC as part of the 10 MHz based ETSI ITS systems with prioritization mechanisms in all protocol layers based on the existing Decentralized Congestion Control mechanism of the ETSI ITS system.

Introduction

The present document has been developed in cooperation with TC ITS in order to present to the Electronic Communications Committee (ECC) of the European Conference of Post and Telecommunications Administrations (CEPT) a common point of view regarding sharing possibilities between CBTC and ITS applications in the 5 875 MHz to 5 925 MHz frequency band.

After having clearly defined CBTC applications, the present document defines first the functional needs of CBTC regarding its communication. From that, technical needs for the communication system are derived, and the scenarios where sharing the spectrum between CBTC application and ITS road applications could be an issue are described. Finally the different technical means of sharing bandwidth are introduced and the next steps including a proposal for short term regulation are defined.

1 Scope

The present document investigates the possibility of shared use of spectrum between CBTC and ITS applications in the 5 875 MHz to 5 925 MHz under the assumption that CBTC applications have priority over ITS-G5 applications.

2 References

2.1 Normative references

Normative references are not applicable in the present document.

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 referenced 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] ECC/DEC/(08)01: "ECC Decision (08)01 of 14 March 2008 on the harmonised use of the 5875-5925 MHz frequency band for ITS, and subsequent amendments".

[i.2] ETSI TR 103 111 (V1.1.1): "Electromagnetic compatibility and Radio spectrum Matters (ERM); System Reference document (SRdoc); Spectrum requirements for Urban Rail Systems in the 5,9 GHz range".

[i.3] CENELEC EN 50159: "Railway applications - Communication, signalling and processing systems - Safety-related communication in transmission systems".

[i.4] ETSI EN 302 665 (V1.1.1): "Intelligent Transport Systems (ITS); Communications Architecture".

[i.5] ETSI TR 101 607 (V1.1.1): "Intelligent Transport Systems (ITS); Cooperative ITS (C-ITS); Release 1".

[i.6] ETSI TR 102 638: "Intelligent Transport Systems (ITS); Vehicular Communications; Basic Set of Applications; Definitions".

[i.7] ETSI TS 101 556-1 (V1.1.1): "Intelligent Transport Systems (ITS); Infrastructure to Vehicle Communication; Electric Vehicle Charging Spot Notification Specification".

[i.8] ETSI EN 302 637-2 (V1.3.2): "Intelligent Transport Systems (ITS); Vehicular Communications; Basic Set of Applications; Part 2: Specification of Cooperative Awareness Basic Service".

[i.9] ETSI EN 302 637-3 (V1.2.2): "Intelligent Transport Systems (ITS); Vehicular Communications; Basic Set of Applications; Part 3: Specifications of Decentralized Environmental Notification Basic Service".

[i.10] ETSI TS 103 301 (V1.1.1): "Intelligent Transport Systems (ITS); Vehicular Communications; Basic Set of Applications; Facilities layer protocols and communication requirements for infrastructure services".

[i.11] ETSI TS 102 687 (V1.1.1): "Intelligent Transport Systems (ITS); Decentralized Congestion Control Mechanisms for Intelligent Transport Systems operating in the 5 GHz range; Access layer part".

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[i.12] ETSI TR 101 612 (V1.1.1): "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.13] ETSI TS 103 175 (V1.1.1): "Intelligent Transport Systems (ITS); Cross Layer DCC Management Entity for operation in the ITS G5A and ITS G5B medium".

[i.14] ETSI TS 102 792 (V1.2.1): "Intelligent Transport Systems (ITS); Mitigation techniques to avoid interference between European CEN Dedicated Short Range Communication (CEN DSRC) equipment and Intelligent Transport Systems (ITS) operating in the 5 GHz frequency range".

[i.15] ETSI EN 302 571: "Intelligent Transport Systems (ITS); Radiocommunications equipment operating in the 5 855 MHz to 5 925 MHz frequency band; Harmonised Standard covering the essential requirements of article 3.2 of Directive 2014/53/EU".

[i.16] ETSI EN 302 663: "Intelligent Transport Systems (ITS); Access layer specification for Intelligent Transport Systems operating in the 5 GHz frequency band".

[i.17] IEEE 802.11™: "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".

[i.18] Standardisation mandate addressed to cen, cenelec and etsi in the field of information and communication technologies to support the interoperability of co-operative systems for intelligent transport in the european community (M/453 EN).

NOTE: Available at http://www.etsi.org/about/our-role-in-europe/public-policy/ec-mandates.

[i.19] ETSI TS 103 097: "Intelligent Transport Systems (ITS); Security; Security header and certificate formats".

[i.20] CEPT/ERC Recommendation 70-03: "Relating to the Use of Short Range Devices (SRD)", Tromso 1997, Subsequent amendments 07 February 2014".

[i.21] Commission Decision 2008/671/EC of 5 August 2008 on the harmonised use of radio spectrum in the 5875-5905 MHz frequency band for safety-related applications of Intelligent Transport Systems (ITS).

[i.22] ECC/REC/(08)01: "Use of the band 5855-5875 MHz for Intelligent Transport Systems (ITS)".

[i.23] Commission Implementing Decision 2013/752/EU of 11 December 2013 amending Decision 2006/771 on harmonisation of the radio spectrum for use by short-range devices and repealing Decision 2005/928/EC.

[i.24] IEEE 1474.1™-2004: "IEEE Standard for Communications-Based Train Control (CBTC) Performance and Functional Requirements".

[i.25] Brussels Regional Authority - Institut Bruxellois de Statistique et d'Analyse (IBSA).

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3 Definitions and abbreviations

3.1 Definitions

For the purposes of the present document, the following terms and definitions apply:

data communication system: global communication architecture into which radio communication links are integrated

ITS station: communication equipment implementing an ITS protocol stack according to the ETSI ITS communication architecture

NOTE: Within the present document, this term is more specifically used for on-board units and roadside units transmitting in the ITS-G5 frequency band.

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

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

safety: freedom from unacceptable levels of risks resulting from unintentional acts or circumstances

security: freedom from unacceptable levels of risks resulting from intentional acts or circumstances

3.2 Abbreviations

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

AP	Access Point
ASIL	Automotive Safety Integrity Level
ASIL-A	Automotive Safety Integrity Level
ATC	Automatic Train Control
ATO	Automatic Train Operation
ATP	Automatic Train Protection
ATS	Automatic Train Supervision
C2C-CC	Car to Car Communication Consortium
CAM	Cooperative Aware Message
CBTC	Communication Based Train Control
CEPT	European Conference of Postal and Telecommunications Administrations
C-ITS	Cooperative Intelligent Transportation System
DCC	Decentralised Congestion Control
DCS	Data Communication System
DEC	DECision
DENM	DEN Message
DSRC	Dedicated Short Range Communication
EC	European Community
ECC	Electronic Communications Committee
EDCA	Enhanced Distributed Channel Access
EIRP	Equivalent Isotropically Radiated Power
EM	Electro Magnetic
GN	GeoNetworking
HW	HardWare
IEEE	Institution of Electrical and Electronic Engineers
IP	Internet Protocol
ITS	Intelligent Transportation System
ITS-G	5,9 GHz Cooperative ITS system
ITS-S	Intelligent Transportation System Station
LOS	Line Of Sight
MAC	Medium ACcess
MIMO	Multiple Input Multiple Output
NLOS	Non Line Of Sight
OEM	Original Equipment Manufacturer

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OFDM	Orthogonal Frequency Division Multiplexing
OSI	Open Systems Interconnection
QPSK	Quadrature Phase Shift Keying
REC	RECommendation
SIL	Safety Integrity Level
SNR	Signal to Noise Ratio
SW	SoftWare
TAC	Transmit Access Control
TTT	Transport and Traffic Telematics
V2I	Vehicle to Infrastructure
V2V	Vehicle to Vehicle
VRU	Vulnerable Road User

4 CBTC description

The primary public objective of this system is to provide urban rail and regional railway operators with a means to control and manage the train traffic on their own networks. Metro lines which are operated at a high level of performance and short intervals between successive trains are now installing Communications-Based Train Control (CBTC) systems.

CBTC is a wireless Automatic Train Control (ATC) system, more flexible and cost efficient than traditional ATC.

CBTC systems are deployed on urban and suburban train on dedicated tracks. Tramways, tram trains and buses are not covered by this system.

The standard IEEE 1474.1™ [i.24] gives the following definition:

A CBTC system is a continuous, automatic train control system utilizing:

- high-resolution train location determination, independent of track circuits;
- continuous, high-capacity, bidirectional train-to-wayside data communications;
- train borne and wayside processors capable of implementing automatic train protection (ATP) functions, as well as optional automatic train operation (ATO) and automatic train supervision (ATS) functions.

CBTC application requirements are defined in the standard IEEE 1474.1™ [i.24].

CBTC systems allow running trains only 90 seconds apart with total safety for the passengers and the staff (or even less, the headway depending upon time spent by the train at every station for passengers to leave and board trains, the distance between stations and profile of the line as well as the possible acceleration, maximum speed and deceleration of the train).

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5 Market information

The automation of existing urban rail lines and the development of fully unattended metro operation (no staff on board) are booming and represent tomorrow's challenges in this sector. Millions of passengers use urban public transport every day (in Europe 31,6 million daily passengers in 48 cities only for metro), and the European Union's modal shift objective means more people using public transport. CBTC markets have been presented in ETSI TR 103 111 [i.2].

6 CBTC Technical information

6.1 CBTC Communication needs

Although IEEE 1474.1™ [i.24] defines the CBTC system and its requirements, the system itself as a whole is not fully standardized which means that some parts, and in particular its communication system, are implementation dependent.

The MODURBAN project issued a functional requirement specification for CBTC systems, and a MODURBAN architecture document (partially public), which allocates functions to a system or subsystem level but leaving some open options and without fully specifying in details the interfaces.

As a consequence, the needs for communication and the definition of messages to be exchanged are not standardized, even if some metro authorities promoted interoperability specifications which enable the construction of a complete CBTC system by assembling subsystems from different manufacturers: one company can provide the wayside ATC subsystem, while another one can provide the on-board ATC subsystem, a third one can provide the data communication system, a fourth one can provide the ATS.

Achieving such compatibility of the subsystems require that an interoperability specification fully defines the interfaces, which include, of course, an extensive definition of all the data exchanges through the radio channel: definition of the protocols, list of the messages, size and detailed consist of each message in terms of functional data, performances including rates of emission and reception for each communicating piece of equipment and each type of message. Nevertheless these interoperability specifications, when they exist, are project dependant.

Finally, the level of performances (for example the headway between trains or the guaranteed reaction time of the system to an unexpected safety hazard) highly influences the requirements allocated to the communication system: it drives the amount of data to be transmitted, the frequency at which they need to be transmitted and the quality of the transmission such as the frame error rate and the latency of the transmission.

Therefore it should be pointed out that all the data given below are based on principles and existing implementations and are used as an example to justify the common needs for communication of CBTC, but cannot be seen as characteristics fulfilled by all CBTC systems on the market.

CBTC communications can be classified in different groups based on their conditions for transmission, and also based on their criticality regarding the system performance.

Some messages need to be transmitted and received regularly in order to ensure that on-board and wayside CBTC subsystems are continuously up-to-date (typically while a train is moving and updating its location) and to ensure they can 'monitor' each other for a safe evaluation of critical functions performed by the other interoperable subsystems. Such messages are typically transmitted periodically and are therefore known as "periodic data". Different periods may coexist at the same time on a same interface.

EXAMPLE: From the above-mentioned interoperable CBTC applications, some messages are transmitted at a period of 200 ms while others are transmitted every 360 ms and some others at a period of a few seconds.

The transmission requirement for periodical data generally gives the base for the calculation of the "mean" required throughput for CBTC. The following periodic CBTC messages are transmitted from train to wayside:

- **A 'Location Report' message** sent by the on-board CBTC of each train to the wayside CBTC ('Zone Controller'). These messages help the Zone Controller to continuously track the trains' position on a portion of the metro line designated as its 'territory'. It should be noted that a train generally communicates with one Zone Controller but it may also have to communicate with two Zones Controllers in order to handle smooth transition from one territory to the next one at their common border. It may even have to anticipate communications with 3 Zone Controllers in some specific configurations (for example when the track is subdivided into two diverging branches).

  The 'Location Report" message includes data such as the location of both ends of the train, its speed, the train consist, etc.

  If that message is received with a delay greater than 100 ms, then it is no longer useful and will be considered as lost by the receiver: only fresh messages can ensure the safety of the application. No messages of that type received during N seconds from a train will stop the transmission of the Movement Authority messages authorizing that train to run (N depends on the specified headway, and can be down to 1 second for highly efficient CBTC).

- A **functional status message** sent by each train to the automatic train supervision system, which is less vital but contains more data: it includes information about the train position but also any modifications of the rolling stock which can influence the operation, and the health status of any on-board redundant equipment, to detect latent failures (hardware failures which have no functional impact but reduce the level of redundancy) and fix it before a second failure occurs and many other items of functional information, and, when there is a driver on a train, some reports on his actions.

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