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Broadband Radio Access Networks (BRAN);
5 GHz high performance RLAN;
Mitigation techniques to enable sharing between RLANs and Road Tolling and Intelligent Transport Systems in the 5 725 MHz to 5 925 MHz band

Reference

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Foreword

This Technical Report (TR) has been produced by ETSI Technical Committee Broadband Radio Access Networks (BRAN).

Modal verbs terminology

In the present document "**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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Executive Summary

The present document contains mitigation technique studies related to RLANs in the 5 795 MHz to 5 815 MHz and 5 855 MHz to 5 925 MHz frequency ranges. These have been triggered by the EC Mandate on 5 GHz [i.1] and by the activities on WRC-15 Agenda Item 1.1 [i.49] and subsequent work at CEPT. In particular CEPT have requested clarification on what mitigation techniques RLAN systems intend to employ to protect other systems that presently operate in the 5 725 MHz to 5 925 MHz band and in adjacent bands.

Some of the parameters within the present document are included in square brackets based upon proposals and discussions within TC BRAN, these are intended as starting points upon which to continue future work and develop technical requirements.

At the time of drafting the present document the status of the various sharing and compatibility studies related to Road Tolling and ITS is as detailed in ECC Report 244 [i.15] and is summarized below:

Compatibility between RLAN and road tolling in the band 5 795 MHz to 5 815 MHz

MCL calculations for both directions of interference have been performed and showed the need for significant separation distances if compatibility is dependent upon protection to an I/N level of -6 dB. No studies have been conducted to analyse the actual effects of this I/N level being reached due to intermittent interference.

As a result, work on mitigation techniques was initiated at ETSI BRAN which focused on the following approaches, previously suggested in ECC Report 244 [i.15], to enable the coexistence between RLAN and road-tolling:

- Implementation in RLAN of a detection mechanism to detect road tolling applications based on energy detection. Under the assumptions considered preliminary analysis indicated that for an RLAN system operating with 23 dBm/20 MHz a detection threshold of the order of -100 dBm/500 kHz and for a RLAN system with 23 dBm/160 MHz a detection threshold of the order of -90 dBm/500 kHz would be required for a reliable detection of road tolling. Further consideration is required, including on the feasibility of such a detection threshold and its impact on the RLAN operation.

- Transmission from the road tolling applications of predefined signals (beacons) which indicate that the used channels are busy, similar to one of the mitigation techniques used to facilitate ITS and Road Tolling adjacent channel coexistence.

- Ensure coexistence with the road tolling systems through the detection of ITS. This is based on the assumption that there will always be ITS systems in the close vicinity of road-tolling road-side units. Under this approach, once ITS have been detected by RLAN under the conditions described in clause 2 of ECC Report 244 [i.15], the road tolling frequency band 5 795 MHz to 5 815 MHz will also be considered as occupied and thus, not available for RLAN use.

- Use of geo-location database approach. The geo-location database should hold actual information from static and, due to construction sites, temporary tolling installations. The implementation of such a platform, its access and its maintenance should be addressed. In addition, the role and responsibilities of the stakeholders have to be clearly defined.

Compatibility between RLAN and ITS in the bands 5 855 MHz to 5 875 MHz (non-safety ITS), 5 875 MHz to 5 905 MHz (safety-related ITS) and 5 905 MHz to 5 925 MHz (ITS extension band)

Compatibility considered in the present document includes Wi-Fi and ITS technology as defined in ETSI EN 302 663 [i.3]. LTE-V2X and LAA technologies as defined in ETSI TS 136 211 [i.10], ETSI TS 136 101 [i.11] and ETSI TS 136 104 [i.12] are not part of the present document.

MCL calculations for both directions of interference have been performed and showed the need for significant separation distances if compatibility is dependent upon protection to an I/N level of -6 dB. No studies have been conducted to analyse the actual effects of this I/N level being reached due to intermittent interference.

As a result, work on mitigation techniques was initiated at ETSI BRAN to help improve the compatibility between individual RLAN devices and ITS. These studies have focussed on "listen-before-talk" processes, where the potential interferer tries to detect whether a channel is busy before transmitting a data packet.

Two possible approaches that have been suggested in ECC Report 244 [i.15] are:

- Generic Energy Detection without any consideration of the interferer and victim signal frames: Under the assumptions considered, preliminary studies show that in the case of an energy detection threshold of -90 dBm/10 MHz for an RLAN system operating with 23 dBm/20 MHz, an ITS device with 23 dBm/20 MHz is not reliably detected. Further consideration is required, including on the feasibility of such a detection threshold and its impact on the RLAN operation.

- Combination of energy detection and carrier sensing, such as one of the Clear Channel Assessment (CCA) modes defined in the IEEE Std. 802.11™-2016 [i.2]. Further study is required to assess the applicability to ITS of the interference avoidance techniques currently employed in 5 GHz RLAN systems.

Introduction

The present document studies the feasibility and impact on RLAN operation with regards to proposed mitigation techniques to enable sharing with Road Tolling and Transport equipment within the 5 795 MHz to 5 815 MHz and 5 855 MHz to 5 925 MHz frequency ranges. The report proposes and evaluates mitigation techniques based upon simulation and analytical investigation. Some of the parameters within the present document are included in square brackets based upon proposals and discussions within TC BRAN, these are intended as starting points upon which to continue future work and develop technical requirements. Recommendations for future work are included in clause 7.7.

1 Scope

The present document contains mitigation technique studies related to RLAN operation in the 5 795 MHz to 5 815 MHz and 5 855 MHz to 5 925 MHz frequency ranges. These have been triggered by the EC Mandate on 5 GHz [i.1] and by the activities on WRC-15 Agenda Item 1.1 [i.49] and subsequent work at CEPT.

Mitigation techniques between RLAN and the following equipment are considered in the present document:

- Road tolling in the bands 5 795 MHz to 5 805 MHz and 5 805 MHz to 5 815 MHz.
- Traffic safety-related applications in the band 5 875 MHz to 5 905 MHz.
- Possible Future extension of ITS spectrum in the band 5 905 MHz to 5 925 MHz. This band is proposed to be considered for safety-related ITS applications.
- Recommended for ITS non-safety applications in the band 5 855 MHz to 5 875 MHz.

The only RLAN technology considered in the present document is Wi-Fi as defined under IEEE Std. 802.11™-2016 [i.2]. The only ITS technology considered in the present document is as defined in ETSI EN 302 663 [i.3].

The present document is intended to guide further work on coexistence studies in CEPT in order to enable sharing between RLANs and other equipment using these frequency bands.

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] EC Mandate to CEPT on 5 GHz: "Mandate to CEPT to study and identify harmonised compatibility and sharing conditions for Wireless Access Systems including Radio Local Area Networks in the bands 5350-5470 MHz and 5725-5925 MHz ('WAS/RLAN extension bands') for the provision of wireless broadband services".

[i.2] IEEE Std. 802.11™-2016: "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.3] ETSI EN 302 663 (V1.2.1) (07-2013): "Intelligent Transport Systems (ITS); Access layer specification for Intelligent Transport Systems operating in the 5 GHz frequency band".

[i.4] Commission Decision 2005/513/EC of 11 July 2005 on the harmonised use of radio spectrum in the 5 GHz frequency band for the implementation of wireless access systems including radio local area networks (WAS/RLANs). .

[i.5] Commission Decision 2007/90/EC of 12 February 2007 amending Decision 2005/513/EC on the harmonised use of radio spectrum in the 5 GHz frequency band for the implementation of Wireless Access Systems including Radio Local Area Networks (WAS/RLANs).

[i.6] ECC/DEC/(04)08: "ECC Decision of 9 July 2004 on the harmonised use of the 5 GHz frequency bands for the implementation of Wireless Access Systems including Radio Local Area Networks (WAS/RLANs) (30/10/2009)".

[i.7] Resolution 229: "(WRC-03, Rev. WRC-12) on the use of the bands 5150-5250 MHz, 5250-5350 MHz and 5470-5725 MHz by the mobile service for the implementation of wireless access systems including radio local area networks".

[i.8] Recommendation ITU-R M.1652: "Dynamic frequency selection in wireless access systems including radio local area networks for the purpose of protecting the radio-determination service in the 5 GHz band".

[i.9] ETSI EN 301 893 (V2.1.1) (05-2017): "5 GHz RLAN; Harmonised Standard covering the essential requirements of article 3.2 of Directive 2014/53/EU".

[i.10] ETSI TS 136 211 (V13.3.0) (11-2016): "LTE; Evolved Universal Terrestrial Radio Access (E-UTRA); Physical channels and modulation (3GPP TS 36.211 version 13.3.0 Release 13)".

[i.11] ETSI TS 136 101 (V11.17.0) (09-2016): "LTE; Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) radio transmission and reception (3GPP TS 36.101 version 11.17.0 Release 11)".

[i.12] ETSI TS 136 104 (V13.5.0) (10-2016): "LTE; Evolved Universal Terrestrial Radio Access (E-UTRA); Base Station (BS) radio transmission and reception (3GPP TS 36.104 version 13.5.0 Release 13)".

[i.13] CEPT Report 57: "Compatibility and sharing conditions for WAS/RLAN in the bands 5350-5470 MHz and 5725-5925 MHz".

[i.14] CEPT Report 64: "To study and identify harmonised compatibility and sharing conditions for Wireless Access Systems including Radio Local Area Networks in the bands 5350-5470 MHz and 5725-5925 MHz ('WAS/RLAN extension bands') for the provision of wireless broadband services".

[i.15] ECC Report 244: "Compatibility studies related to RLANs in 5725-5925 MHz".

[i.16] ECC/DEC/(02)01: "ECC Decision of 15 March 2002 on the frequency bands to be designated for the co-ordinated introduction of Road Transport and Traffic Telematic Systems".

[i.17] ECC/DEC(12)04: "ECC Decision on 02 November 2012 on the withdrawal of ECC Decision (02)01".

[i.18] Directive 2004/52/EC of the European Parliament and of the Council of 29 April 2004 on the interoperability of electronic road toll systems in the Community.

[i.19] ERC Recommendation 70-03: "Relating to the use of Short Range Devices (SRD)".

[i.20] ETSI EN 300 674-2-1 (V2.1.1) (09-2016): "Transport and Traffic Telematics (TTT); Dedicated Short Range Communication (DSRC) transmission equipment (500 kbit/s / 250 kbit/s) operating in the 5 795 MHz to 5 815 MHz frequency band; Part 2: Harmonised Standard covering the essential requirements of article 3.2 of the Directive 2014/53/EU; Sub-part 1: Road Side Units (RSU)".

[i.21] ETSI EN 300 674-2-2 (V2.1.1) (11-12016): "Transport and Traffic Telematics (TTT); Dedicated Short Range Communication (DSRC) transmission equipment (500 kbit/s / 250 kbit/s) operating in the 5 795 MHz to 5 815 MHz frequency band; Part 2: Harmonised Standard covering the essential requirements of article 3.2 of Directive 2014/53/EU; Sub-part 2: On-Board Units (OBU)".

[i.22] Commission Implementing Regulation (EU) 2016/799 of 18 March 2016 implementing Regulation (EU) No 165/2014 of the European Parliament and of the Council laying down the requirements for the construction, testing, installation, operation and repair of tachographs and their components.

[i.23] Directive (EU) 2015/719 of the European Parliament and of the Council of 29 April 2015 amending Council Directive 96/53/EC laying down for certain road vehicles circulating within the Community the maximum authorised dimensions in national and international traffic and the maximum authorised weights in international traffic.

[i.24] ETSI ES 200 674-1 (V2.4.1) (05-2013): "Intelligent Transport Systems (ITS); Road Transport and Traffic Telematics (RTTT); Dedicated Short Range Communications (DSRC); Part 1: Technical characteristics and test methods for High Data Rate (HDR) data transmission equipment operating in the 5,8 GHz Industrial, Scientific and Medical (ISM) band".

[i.25] Commission Decision 2008/671/EC of 5 August on the harmonised use of radio spectrum in the 5875-5905 MHz frequency band for safety-related application of Intelligent Transport Systems (ITS).

[i.26] ECC/REC/(08)01: "Use of the band 5855-5875 MHz for Intelligent Transport Systems (ITS)".

[i.27] Directive 2010/40/EU on the framework for the deployment of Intelligent Transport Systems in the field of road transport and for interfaces with other modes of transport.

[i.28] M/453 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.

[i.29] ETSI TR 103 083 (V1.1.1) (03-2014): "Electromagnetic compatibility and Radio spectrum Matters (ERM); System Reference document (SRdoc); Technical characteristics for pan European harmonized communications equipment operating in the 5,855 GHz to 5,925 GHz range intended for road safety and traffic management, and for non-safety related ITS applications".

[i.30] ECC/DEC/(08)01: "ECC Decision of 14 March 2008 on the harmonised use of the 5875-5925 frequency band for Intelligent Transport Systems (ITS)", approved 14 March 2008 and amended 3 July 2015.

[i.31] 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.32] ECC Report 228: "Compatibility Studies between the Intelligent Transport Systems (ITS) in the Band 5 855 MHz to 5 925 MHz and other systems in adjacent bands".

[i.33] 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.34] Austrian HGV Tolling System: "EETS OBE Requirements Specification", V1.13, 2015.

[i.35] ETSI TS 102 687 (V1.1.1) (07-2011): "Intelligent Transport Systems (ITS); Decentralized Congestion Control Mechanisms for Intelligent Transport Systems operating in the 5 GHz range; Access layer part".

[i.36] ETSI TS 102 637-2: "Intelligent Transport Systems (ITS); Vehicular Communications; Basic Set of Applications; Part 2: Specification of Cooperative Awareness Basic Service".

[i.37] ETSI TS 102 894-2 (V1.2.1): "Intelligent Transport Systems (ITS); Users and applications requirements; Part 2: Applications and facilities layer common data dictionary".

[i.38] IEEE 802.11™-03/940r4: "TGn Channel Models", May 2004.

[i.39] Kenney, Barve, Rai and Kanai: "Comparing Communication Performance of DSRC OBEs from Multiple Suppliers", ITS World Congress 2012.

[i.40] ETSI TC BRAN(16)000078r2 DSRC-RLAN-mitigation-simulations, May 2016.

[i.41] ETSI TC BRAN(16)000081r3 and BRAN(16)000165 Challenges in spectrum sharing between ITS-G5 and RLAN, September 2016.

[i.42] ETSI TC BRAN(16)000138r4 RLAN-ITS-G5 Coexistence Evaluation, May 2017.

[i.43] ETSI TR 102 960 (V1.1.1) (11-2012): "Intelligent Transport Systems (ITS);Mitigation techniques to avoid interference between European CEN Dedicated Short Range Communication (RTTT DSRC) equipment and Intelligent Transport Systems (ITS) operating in the 5 GHz frequency range; Evaluation of mitigation methods and techniques".

[i.44] Mangel, T., Klemp, O. and Hartenstein, H: "5.9 GHz inter-vehicle communication at intersections: a validated non-line-of-sight path-loss and fading model". EURASIP Journal on Wireless Communications and Networking, 2011(1), 1-11.

[i.45] WINNER Channel Models, WINNER II Project, D1.1.2 V1.2, 2007.

[i.46] National Highway Traffic Safety Administration (NHTSA), Department of Transportation (DOT): "Notice of Proposed Rulemaking, Federal Motor Vehicle Safety Standards; V2V Communications, 49 CFR Part 571", Docket No. NHTSA-2016-0126, RIN 2127-AL55, January 2017.

[i.47] Irfan Khan and Jérôme Härri: "Can IEEE 802.11p and Wi-Fi Coexist in the 5.9GHz ITS band?", IEEE 18th International Symposium on A World of Wireless, Mobile and Multimedia Networks (WoWMoM), Macao, 2017.

[i.48] CAR 2 CAR Communication Consortium: "Coexistence investigations between ETSI ITS and RLAN in the band 5.855GHz to 5.925GHz", White Paper, 2017.

[i.49] World Radiocommunication Conference 2015 (WRC-15) Agenda.

NOTE: Available at https://www.itu.int/dms_pub/itu-r/oth/12/01/R12010000014A01PDFE.pdf.

3 Definitions, symbols and abbreviations

3.1 Definitions

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

IEEE 802.11p: amendment to the IEEE 802.11™ standard to add wireless access in vehicular environments, defining enhancements to 802.11™ (the basis of products marketed as Wi-Fi) required to support ITS applications

observation slot: period during which the operating channel is checked for the presence of ITS transmissions

RLAN devices: 5 GHz wireless access systems (WAS) including RLAN equipment

Transport and Traffic Telematic (TTT): systems in which information and communication technologies are applied in the field of transport (depending on technical restrictions for road rail, water and air), traffic management, navigation and mobility management, as well as for interfaces with other modes of transport including communication in vehicles between vehicles (e.g. vehicle-to-vehicle), and between vehicles and fixed locations (e.g. vehicle-to-infrastructure)

NOTE: In the actual regulatory discussion and documents RTTT is being replaced with TTT, see ERC Recommendation 70-03 [i.19].

3.2 Symbols

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

t1 to t10	short training symbols
T1, T2	long training symbols
GI, GI2	Guard intervals

3.3 Abbreviations

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

aCWmax	Contention Window Maximum corresponding to the underlying PHY
aCWmin	Contention Window Minimum corresponding to the underlying PHY
AIFS	Arbitration Inter-Frame Spacing
AIFSN	AIFS Number
ASECAP	Association Européenenne des Concessionnaires d'Autoroutes et d'Ouvrages à Péage European (Association of Operators of Toll Road Infrastructures)
BER	Bit Error Rate
BLL	BandLoadLimit
BSM	Basic Safety Message
BSS	Basic Service Set
CAM	Cooperative Awareness Message
CCA	Clear Channel Assessment
CCSA	Chinese Communications Standards Association
C-ITS	Cooperative ITS
CSMA/CA	Carrier Sense Multiple Access with Collision Avoidance
CWmax	Contention Window maximum
CWmin	Contention Window minimum
D&M	Detect and Mitigate
D&V	Detect and Vacate
DAM	Detect And Mitigate
DAV	Detect And Vacate
DCC	Decentralized Congestion Control
e.i.r.p.	equivalent isotropic radiated power
EDCA	Enhanced Distributed Channel Access
EETS	European Electronic Toll Service
EU	European Union
FCS	Frame Check Sequence
GMES	Global Monitoring for Environment and Security
GNSS	Global Navigation Satellite System
GSM-GPRS	Global System for Mobile telecommunications/General Packet Radio Service
HGV	Heavy Goods Vehicle
I/N	Interference-to-Noise ratio
IEEE	Institute of Electrical and Electronics Engineers
IST	Information Society Technologies
ITS	Intelligent Transport Systems
ITS-G5	Intelligent Transport Systems operating in the 5 GHz band
LAA-LTE	License-Assisted Access of LTE
LBT	Listen Before Talk
LLC	Logical Link Control
LOS	Line Of Sight
LTE	Long Term Evolution
MAC	Medium Access Control
MCL	Minimum Coupling Loss
MCS	Modulation and Coding Scheme
MLFF	Multi-Lane Free Flow
MPDU	MAC Protocol Data Unit
MSDU	Mac Service Data Unit
NLOS	Non-Line Of Sight
NS3	Network Simulator 3
OBE	On-Board Equipment
OBU	On-Board Unit
OFDM	Orthogonal Frequency Division Multiplex
PDR	Packet Detection Rate
PER	Packet Error Rate
PHY	Physical Layer
PLCP	PHY Layer Convergence Procedure
PPDU	PLCP Protocol Data Unit

PRR	Packet Reception Rate
RLAN	Radio Local Area Network
RSPP	Radio Spectrum Policy Programme
RSSI	Received Signal Strength Indicator
RSU	Road Side Unit
SNAP	Subnetwork Access Protocol
TCP	Transmission Control Protocol
TD-LTE	Time Division LTE
TPC	Transmitter Power Control
TTT	Transport and Traffic Telematics
TTT-DSRC	TTT Dedicated Short Range Communications

NOTE: As defined by The European Committee for Standardization.

TXOP	Transmit Opportunity
UDP	User Datagram Protocol
UNI-DSRC	Dedicated Short Range Communications

NOTE: As defined by Ente Nazionale Italiano di Unificazione.

V2V	Vehicle to Vehicle
V2X	Vehicle to everything
WAS	Wireless Access Systems
WINNER	Wireless World Initiative New Radio

4 Overview of services under study

4.1 Existing/Proposed RLAN

4.1.1 Overview

This clause details existing and proposed RLAN regulations and technical characteristics for the 5 GHz bands under study.

4.1.2 Existing regulations in the 5 150 MHz to 5 350 MHz and 5 470 MHz to 5 725 MHz bands

EC Decision 2005/513/EC [i.4] complemented by EC Decision 2007/90/EC [i.5] addresses the designation of the frequency bands 5 150 MHz to 5 350 MHz and 5 470 MHz to 5 725 MHz for the implementation of RLANs in EU members states and ECC/DEC/(04)08 [i.6] addresses their designation within CEPT. At worldwide level these frequency bands have been allocated to the mobile service except aeronautical mobile service on a primary basis in all three regions by World Radiocommunication Conference 2003 (WRC-03). Furthermore Resolution 229 (WRC-03) [i.7] limits the use of this allocation to RLANs. Resolution 229 (WRC-03) [i.7] also requires that RLAN need to protect other specific primary services in these frequency bands.

In the EU/CEPT the following bands were identified for use by RLANs under prescribed conditions in the both the ECC and EC Spectrum Decisions:

- **5 150 MHz to 5 350 MHz:**
  - Only indoor use, mean e.i.r.p. limited to 200 mW, and above 5 250 MHz; the use of mitigation techniques such as dynamic frequency selection (DFS) and transmitter power control (TPC).
- **5 470 MHz to 5 725 MHz:**
  - Indoor as well as outdoor use allowed, mean e.i.r.p. limited to 1 W, and use of mitigation techniques such as dynamic frequency selection (DFS) and transmitter power control (TPC).