ETSI TR 103 667 V1.1.1 (2021-09)

Intelligent Transport Systems (ITS);
Study on Spectrum Sharing between ITS-G5 and LTE-V2X technologies in the 5 855 MHz - 5 925 MHz band

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Reference

DTR/ERM-TG37-274

Keywords

ITS, radio, spectrum

ETSI

650 Route des Lucioles
F-06921 Sophia Antipolis Cedex - FRANCE

Tel.: +33 4 92 94 42 00 Fax: +33 4 93 65 47 16

Siret N° 348 623 562 00017 - APE 7112B
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Foreword

This Technical Report (TR) has been produced by ETSI Technical Committee Electromagnetic compatibility and Radio spectrum Matters (ERM).

Modal verbs terminology

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1 Scope

The present document proposes an overall framework based on combinations of co-channel and/or non-co-channel operation, as presented to CEPT, to address spectrum sharing between ITS-G5 and LTE-V2X ITS technologies enabling both technologies to use the same spectrum in the same geographical area. The overall framework may consist of several options for such combined operation.

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.

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[i.1] ETSI TR 103 766: "Intelligent Transport Systems (ITS); Pre-standardization study on co-channel co-existence between IEEE- and 3GPP-based ITS technologies in the 5 855 MHz-5 925 MHz frequency band".

[i.2] ECC Decision (08)01: "The harmonised use of Safety-Related Intelligent Transport Systems (ITS) in the 5875-5935 MHz frequency band", latest amendment on 06 March 2020.

[i.3] Commission Implementing Decision (EU) 2020/1426 of 7 October 2020 on the harmonised use of radio spectrum in the 5 875-5 935 MHz frequency band for safety-related applications of intelligent transport systems (ITS) and repealing Decision 2008/671/EC.

[i.4] ETSI EN 302 665 (V1.1.1) (09-2010): "Intelligent Transport Systems (ITS); Communications Architecture".

[i.5] ETSI EN 302 663 (V1.3.1) (01-2020): "Intelligent Transport Systems (ITS); ITS-G5 Access layer specification for Intelligent Transport Systems operating in the 5 GHz frequency band".

[i.6] IEEE Std 802.11™-2020: "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.7] IEEE/ISO/IEC 8802-2™ -1998: "Information technology -- Telecommunications and information exchange between systems -- Local and metropolitan area networks -- Specific requirements -- Part 2: Logical Link Control".

[i.8] IEEE 802.11e™ -2005: "IEEE Standard for Information technology - Local and metropolitan area networks - Specific requirements - Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications - Amendment: Medium Access Method (MAC) Quality of Service Enhancements".

[i.9] ANSI/IEEE Std 802.1D™ 1998: "IEEE Standard for Information technology - Telecommunications and information exchange between systems - Local and metropolitan area networks - Common specifications - Part 3: Media Access Control (MAC) Bridges".

[i.10] ETSI EN 303 613 (V1.1.1) (01-2020): "Intelligent Transport Systems (ITS); LTE-V2X Access layer specification for Intelligent Transport Systems operating in the 5 GHz frequency band".

[i.11] ETSI TS 136 213: "LTE; Evolved Universal Terrestrial Radio Access (E-UTRA); Physical layer procedures (3GPP TS 36.213 version 15.9.0 Release 15)".

[i.12] ETSI TS 136 211: "LTE; Evolved Universal Terrestrial Radio Access (E-UTRA); Physical channels and modulation (3GPP TS 36.211 version 14.3.0 Release 14)".

[i.13] ETSI TS 136 300: "LTE; Evolved Universal Terrestrial Radio Access (E-UTRA) and Evolved Universal Terrestrial Radio Access Network (E-UTRAN); Overall description; Stage 2 (3GPP TS 36.300 version 14.3.0 Release 14)".

[i.14] ETSI TS 136 321: "LTE; Evolved Universal Terrestrial Radio Access (E-UTRA); Medium Access Control (MAC) protocol specification (3GPP TS 36.321 version 14.2.1 Release 14)".

[i.15] ETSI TS 136 101: "LTE; Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) radio transmission and reception (3GPP TS 36.101 version 14.4.0 Release 14)".

[i.16] ETSI TS 103 723 (V1.2.1) (2020-11): "Intelligent Transport Systems (ITS); Profile for LTE-V2X Direct Communication".

[i.17] ETSI TR 103 319 (V1.1.1): "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".

3 Definition of terms, symbols and abbreviations

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3.1 Terms

Void.

3.2 Symbols

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3.3 Abbreviations

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

AC	Access Category
AIFS	Arbitration Interframe Space
AIFSN	AIFS number
AP	Access Point
ARQ	Automatic ReQuest
BE	Best Effort
BK	BacKground
BPSK	Binary Phase Shift Keying
BSS	Basic Service Set
BSSID	BSS IDentifier
CW	Contention Window
DCF	Distributed Coordination Function
DFS	Dynamic Frequency Selection
DIFS	Distributed Interframe Space
DL	Data Link layer
EDCA	Enhanced Distributed Coordination Access
EE	Excellent Effort
HARQ	Hybrid ARQ
IBSS	Independent BSS

ITS	Intelligent Transport Systems
LLC	Logical Link Control
MAC	Medium Access Control
MCS	Modulation and Coding Scheme
MIB	Management Information Base
MPDU	MAC Protocol Data Unit
NC	Network Control
OFDM	Orthogonal Frequency Division Multiplexing
OSI	Open System Interconnect
PHY	Physical Layer
PLCP	Physical Layer Convergence Procedure
PPDU	PLCP Protocol Data Unit
PSCCH	Physical Sidelink Control Channels
PSDU	PLCP Service Data Unit
PSSCH	Physical Sidelink Shared Channels
QAM	Quadrature Amplitude Modulation
QPSK	Quadrature Phase Shift Keying
RB	Resource Block
RLAN	Radio Local Area Network
RSRP	Reference Signal Received Power
RSSI	Received Signal Strength Indicator
SCI	Side Control Information
SPS	Semi-Persistent Scheduling
TTI	Transmission Time Interval
UP	User Priority
VI	VIdeo
VO	VOice

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4 Spectrum Sharing Options for ITS Technologies

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4.1 Introduction

Currently, there are two technologies for short-range wireless communications for cooperative ITS that can be used in the 5,9 GHz band [i.3]: ITS-G5 [i.5] based on IEEE 802.11p [i.6] and LTE-V2X [i.10] developed by 3GPP. Spectrum sharing options are therefore necessary to make sure both technologies can co-exist in a seamless way. The spectrum sharing options need to be defined in the context of the new CEPT band plan for 5,9 GHz, which is depicted in **Figure 1**. It designates a total of 40 MHz in the frequency range 5 875 MHz - 5 915 MHz for safety related ITS prioritized for road ITS. Therefore, the spectrum sharing options which will be proposed are based on the availability of 10 MHz radio channels for road ITS. In addition, the frequency range 5 915 MHz - 5 925 MHz, which is prioritized for urban rail ITS, could be used by road ITS after ETSI has developed polite protocols and/or proper co-channel sharing mechanisms between road ITS and urban rail ITS. According to the ECC decision (08)01 [i.2], the frequency range 5 915 MHz - 5 925 MHz could be used for road ITS I2V applications on a national basis before the development of the above mentioned polite protocols and/or proper co-channel sharing mechanisms, which is out of the scope of the present document. Therefore, the sharing of the frequency range 5 915 - 5 925 MHz between road ITS technologies discussed in clause 4.3.4 assumes that road ITS technologies could access this frequency range by applying the polite protocols and/or proper co-channel sharing mechanisms between road ITS and urban rail ITS specified by ETSI.

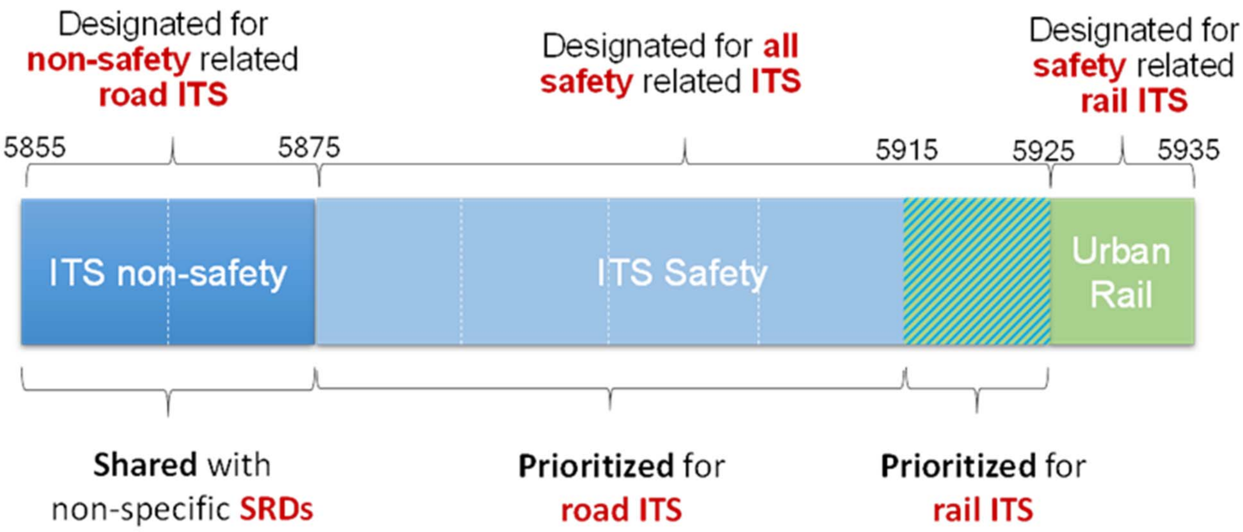

Figure 1: New CEPT band plan for ITS technologies

Table 1 shows the frequency range for each of the four radio channels in 5 875 MHz - 5 915 MHz prioritized for road ITS and a proposed mapping of these radio channels to the channel numbers used in the present document. In addition, the same nomenclature is used in the present document for the frequency range 5 915 MHz - 5 925 MHz prioritized for urban rail ITS under the assumption that road ITS technologies can access this frequency range by applying the polite protocols and/or proper co-channel sharing mechanisms between road ITS and urban rail ITS specified by ETSI (not covered by the present document, as above clarified).

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Table 1: The frequency range of road ITS radio channels and the numbers assigned to them

Channel 1	Channel 2	Channel 3	Channel 4	Channel 5
5 875 MHz - 5 885 MHz	5 885 MHz - 5 895 MHz	5 895 MHz - 5 905 MHz	5 905 MHz - 5 915 MHz	5 915 MHz - 5 925 MHz

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4.2 Framework for non-prioritized use of road ITS channels

This framework means that all road ITS radio channels can be accessed on equal footing by all road ITS technologies through a co-channel co-existence method. The decision to use a specific channel is not based on technology but rather on other criteria, which could for example be based on use cases, where different channels would be used for different clusters of use cases, such as basic CAM/DENM safety messages, platooning messages, collective perception messages, etc. Addressing the requirements for such scenarios is out of the scope of the present document.

This framework means that all road ITS radio channels can be accessed on equal footing by all ITS technologies, and the decision to use a specific channel is not based on technology but on other criteria. One example scenario is "use case" as a criterion, where different channels would be used for different clusters of use cases, such as basic CAM/DENM safety messages, Platooning messages, cooperative perception messages, etc. Addressing the requirements for such scenarios is out of the scope of the present document.

There are several proposed methods for co-channel coexistence between the road ITS technologies ITS-G5 and LTE-V2X in ETSI TR 103 766 [i.1].

4.3 Priority-based framework for using road ITS channels

4.3.1 Overview

Unlike the non-prioritized framework of the previous clause 4.2, the priority-based framework assigns technology-dependent priorities to individual road ITS channels. The goal is to develop a framework for spectrum sharing because co-channel sharing is not yet defined, and it is not still assessed if such sharing would be feasible with acceptable performance degradation. The purpose is the assignment of priorities to different ITS technologies in the different ITS radio channels shown in Table 1. For this purpose, the following driving criteria are considered:

1) The basic essential safety messages need to be delivered with the reliability and latency requirements defined for such messages.

2) Other safety and non-safety messages can be delivered with a different level of reliability and latency.

The ultimate objective of criterion 1 is to make sure that essential safety messages will be reliably transmitted over a 10 MHz radio channel. In this context, the reliability of the safety messages is a key factor for the selection of a proposed spectrum sharing option. Because such option aims at coexistence between the two road ITS technologies with different radio air interfaces, its selection in a manner to avoid impacts on the structure of the radio air interface of the involved technologies might be challenging, especially for the latency requirement in the case of short timescale interaction (in the order of µs) with high reliability. Also, the impact on existing specifications depends on the detection capability and the envisaged target reliability. A high-level pictorial representation of different trade-offs involved in developing a coexistence solution is shown in the example of Figure 2.

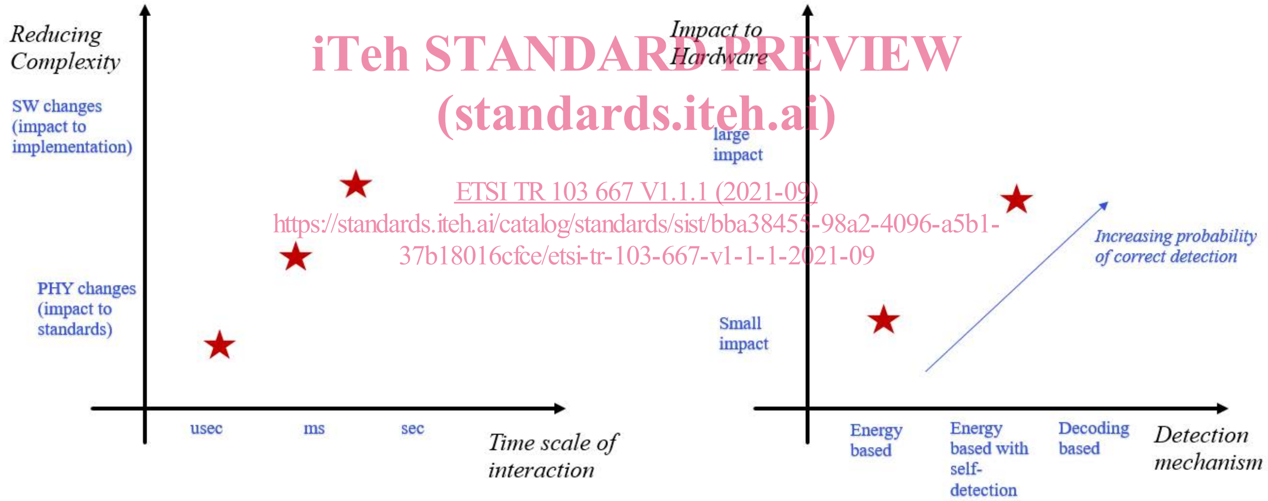

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Figure 2: An example of trade-offs in designing/developing a coexistence solution

4.3.2 Description of the basic idea of priority-based framework

Based on the above observations, a hybrid approach is proposed where different technologies need to fulfil different coexistence requirements on different radio channels. The coexistence requirements depend on priorities assigned to specific technologies in specific channels. A set of radio channels is meant to be used for essential safety messages of a certain technology. To guarantee high reliability in such channels, a priority level is assigned to each technology in each of the channels. Depending on way the priority levels are assigned to different technologies, different options will result.

A pictorial presentation of the basic idea is depicted in Figure 3, assuming two different technologies, Tech A and Tech B, operating in the band prioritized for road ITS. The example can be summarized as follows:

- Tech A and Tech B share the available 40 MHz spectrum (4 radio channels each 10 MHz).

- Two 10 MHz radio channels are assigned for essential safety with different priority levels for Tech A and Tech B:
  - In the channel with the highest priority level assigned to Tech A (Tech B), Tech A (Tech B) does not need to perform any detection of the presence of Tech B (Tech A).
- The other two 10 MHz channels are shared in time between the two technologies, for example based on one of the methods described in ETSI TR 103 766 [i.1].

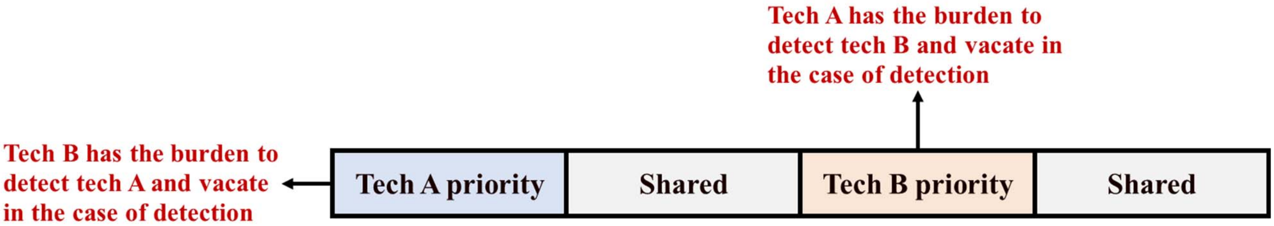

Figure 3: Proposed hybrid approach for road ITS coexistence

On the priority channels the burden of detection will be on the technology which has the least priority. On the other hand, in the shared channels, the burden of detection is shared between the two technologies. Based on this principle, two coexistence mechanisms can be defined:

- A mechanism for the channels assigned with high priority level to a specific technology. In this case, the burden of detection will be on the technology which does not have priority. In particular, the technology that intends to use the channel, that is prioritized for the other technology, would need to meet additional coexistence criteria which requires the detection of the channel use by the other technology. These criteria, e.g. detect and vacate, are not yet defined and are out of the scope of the present document. Existing detect and vacate schemes, e.g. DFS in RLAN to protect radars where an access point monitors the frequency for some time and coordinates channel switching cannot be applied to ITS, since ITS stations are highly mobile and communicate via broadcast without connection establishment. The technology with lower priority cannot assign a service solely to this channel without risking service interruption. Therefore, additional mechanisms for service continuity are required in this case.
- A different mechanism will be used for the channels which are shared. For such channels, both technologies need to detect the presence of each other based on the equal sharing principle. The solution is defined in ETSI TR 103 766 [i.1].

The detect and vacate method is not studied in detail in the present document and needs to be investigated in the future. Similar studies on detection with other technologies have been done in other ETSI deliverables such as ETSI TR 103 319 [i.17]. Detect and vacate needs to be implemented to achieve a good trade-off between protection of prioritized technologies and efficient use of spectrum.

So, in summary for channels which are shared, the coexistence solution will be based on the co-channel coexistence study in ETSI TR 103 766, while requirements associated to the imbalance priority case will be defined in a future ETSI specification.

The priority channels identified for safety are some sort of "anchor" channels: one technology can always use the 10 MHz assigned with high priority for basic safety applications but can only get access to the other channels if the coexistence requirements defined for those channels are met. This approach represents a trade-off between optimizing spectrum utilization and providing reliable access to the "anchor" channels. The benefit of the proposed approach is that from day 1 both technologies can operate on such "anchor" channels, where they have the highest priority, without requiring any change to their radio air interface specifications. The potential disadvantage is that initially deployed technologies without sharing capability may stay on their priority channels for the future and could impact other technologies using those channels for safety applications in the case that priorities for using those channels are changed. At the same time, the shared channels could be used by all technologies provided additional requirements for the co-channel coexistence are met.

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4.3.3 Formalization and extension of the priority-based framework

The proposed approach can be formalized as follows:

- For each radio channel a priority level is assigned to each technology, called mapping between a radio channel and the priority level assigned to a specific technology in that channel.
- Based on the assigned priority level in a specific channel, a decision is made by a technology in that channel in case of detection of the other technology (if detection required).

Depending on the number of priority levels used and the mapping between the radio channels and the priority levels assigned to different technologies, several options are possible as presented below. For this purpose, the following priority levels are defined:

- "0": the radio channel cannot be used, since it is either reserved for future services or no sharing between technologies with different access schemes is allowed, unless the technology with a lower priority applies a channel access scheme compatible with that of the technology with the higher priority.
- "1": the radio channel could be accessed by Tech A (Tech B), which has lower priority, provided it is not occupied by Tech B (Tech A), which has higher priority.
- "2": the radio channel is shared in time between Tech A and Tech B on a non-prioritized basis.
- "3": the radio channel is prioritized for Tech A (Tech B) but could be used by Tech B (Tech A), provided it is not occupied by the technology, which the radio channel is prioritized for.

Depending on the mapping between a radio channel and the assigned priority to a specific technology in that channel, one of the following actions will be taken by this technology if it detects another technology in the considered radio channel.

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- VOID/ COMPATIBLE ACCESS: corresponds to the priority level "0" assigned to a technology in a radio channel and means that a device implementing this technology cannot use the radio channel.
- VACATE: corresponds to the priority level "1" assigned to a technology in a radio channel and means that a device implementing this technology should vacate the radio channel if it detects there a device implementing a technology with a higher assigned priority for that radio channel.
- SHARE: corresponds to the priority level "2" assigned to a technology in a radio channel and means that the radio channel is shared between the technologies operating in this channel by using one of the coexistence methods defined in ETSI TR 103 766 [i.1].
- STAY: corresponds to the priority level "3" assigned to a technology in a radio channel and means that a device implementing this technology may access the channel without any need for modifications in its channel access mechanism. Such device does not need to perform any assessment about the presence of another technology in such radio channel and even if does so and detects in the radio channel a device implementing a technology with a lower assigned priority for that radio channel, it should stay in the radio channel. In other words, the technology with a lower priority, which can use the channel, carries the full burden of assessing whether the technology with a higher priority is operating in the channel and needs to vacate the channel if it detects a device implementing the technology with the higher priority.

Based on the framework above, different priority options can be set in different situations. What matters is that for the supported priority the device fulfils the minimum requirement associated to that priority.

Option 1: Two prioritized channels and 3 priority levels

It is the option in Figure 3 and the mapping between the radio channels and the priority levels assigned to different technologies is shown in Table 2. In this option, the anchor channels will consist of 10 MHz.

Table 2: Example of assigned priorities

	Priorities			
	Channel 1	Channel 2	Channel 3	Channel 4
Tech A	3	2	1	2
Tech B	1	2	3	2

Depending on the mapping between the radio channels and the priority level assigned to a specific technology in Table 2, the actions shown in Table 3 need to be taken in the case that one technology detects another technology.

Table 3: Decisions to be taken by each technology in case of detection

	Decision in case of detection			
	Channel 1	Channel 2	Channel 3	Channel 4
Tech A	STAY	SHARE	VACATE	SHARE
Tech B	VACATE	SHARE	STAY	SHARE

The abovementioned actions put specific requirements on PHY mechanisms which would allow to facilitate channel access depending on the priority level. Depending on the prioritization, each technology will then choose to multiplex its traffic across different channels in the most appropriate way as outlined below.

- Tech A:
    - It can use channel 1 with very relaxed/no PHY additional requirement.
    - It can use channel 2 and channel 4 with a specific PHY additional requirement not covered in the present document. This requirement is one of the possible co-channel coexistence requirements defined in ETSI TR 103 766 [i.1].
    - It can use channel 3 with a specific PHY additional requirement not covered in the present document. This requirement can be defined in an ETSI specification and should be a very stringent requirement since it needs to allow the other technology to use the same channel with a high priority level. The goal is that the channel is not used if the other technology is present.

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- Tech B:
    - It can use channel 3 with very relaxed/no PHY additional requirement.
    - It can use channel 2 and channel 4 with a specific PHY additional requirement not covered in the present document. This requirement is one of the possible co-channel coexistence requirements defined in ETSI TR 103 766 [i.1].
    - It can use channel 1 with a specific PHY additional requirement not covered in the present document. This requirement can be defined in an ETSI specification and should be a very stringent requirement since it needs to allow the other technology to use the same channel with high priority. The goal is that the channel is not used if the other technology is present.

Option 2: Four prioritized channels and 2 priority levels

In the option presented in Figure 4, one of the shared channels in Option 1 is assigned to Tech A with the priority level "3" whereas the other shared channel is assigned to Tech B with the priority level "3". In this option, the anchor channels will consist of 20 MHz (two 10 MHz radio channels). The corresponding priorities and decisions to be taken in case of detecting the other technology are shown in Table 4 and Table 5, respectively.

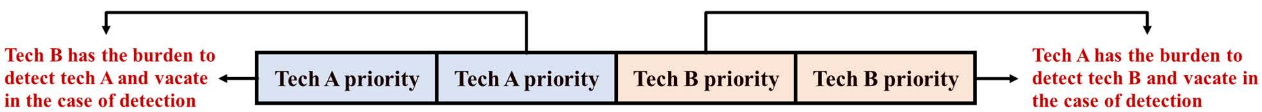

Figure 4: An approach for road ITS coexistence with four prioritized channels