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IEEE 802 Report of DSRC Coexistence Tiger Team

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Abstract

With the release of FCC NPRM 13-22 (Docket 13-49), the United States Federal Communications Commission has requested comments regarding allowing unlicensed devices such as those using 802.11-based standards to share the 5.9 GHz band, which is currently allocated for DSRC and other services. If sharing is allowed, the FCC would create a new set of rules for the band that would become U-NII-4. This report is a summary of activities in the IEEE 802.11 Regulatory Standing Committee regarding the issues surrounding U-NII-4 band sharing between WLAN and DSRC; this DSRC Coexistence "Tiger Team" has examined some initial ideas for how band sharing could work. This report describes the work of the Tiger Team since its inception in August 2013, summarizes the issues surrounding the proposed band sharing ideas discussed in the group, and recommends next steps for validating the sharing methods. The goal of this document is to inform regulators about initial discussions regarding the feasibility and practicality of sharing the 5.9 GHz band and outlining future analysis and field/lab testing that needs to take place to assure that these techniques will protect DSRC transmissions from harmful interference when deployed in the mass market.

There was no consensus among the participants.

1. Background

The FCC allocated 75MHz of spectrum in the 5.9GHz band (5850-5925MHz) for Dedicated Short Range Communications (DSRC) in October 1999. In the FCC NPRM 13-22 (Docket 13-49), the United States Federal Communications Commission has requested comments regarding allowing unlicensed devices such as those using 802.11-based standards to share the 5.9 GHz band, which is currently allocated for DSRC, government radiolocation, and non-government fixed satellite service (FSS) operations, to understand if a feasible sharing solution that protects DSRC users could be developed. DSRC would remain as one of the primary users of the band, but if sharing is allowed, the FCC would create a new set of rules for the band that would be designated as U-NII-4. Existing IEEE standards for Wireless Local Area Networks (WLANs) such as 802.11n and 802.11ac could be modified to operate in this new UNII-4 band if such band sharing rules are approved by the FCC. The FCC did not specify the framework or etiquette by which band sharing would occur; the NPRM requested comments from relevant stakeholders. In August 2013, the IEEE 802.11 Regulatory Standing Committee created a subcommittee called the DSRC Coexistence Tiger Team to convene meetings of stakeholders from WLAN, Intelligent Transportation Systems (ITS), regulatory and other communities to explore possible band sharing techniques that could help inform the regulatory process.

2. Regulatory issues in the 5 GHz bands

As the 2.4 GHz Industrial, Scientific and Medical (ISM) band has become increasingly congested, there has been a great deal of interest in the 802.11/Wi-Fi[1] industry to use the 5 GHz bands, which generally fall under the Unlicensed National Information Infrastructure (UNII) rules of the US Federal Communications Commission (FCC). As originally defined[2], the UNII bands were designated as shown in 0:

Band name	Frequency Range (GHz)	Power Level (mW)
U-NII-1	5.15-5.25	250
U-NII-2	5.25-5.35	250 (DFS required)[3]
U-NII-2e	5.47-5.725	250 (DFS required)
U-NII-3	5.725-5.825	1000

TABLE I: 5 GHZ U-NII BAND ALLOCATIONS IN THE US PRIOR TO 2013 NPRM

While the 5 GHz bands offer significantly more spectral capacity than the 83.5MHz available in the 2.4 GHz ISM band in the US, there is concern that the rapidly accelerating popularity of the new generations of 802.11 WLAN will lead to massive congestion in these bands as well. These issues will be addressed in subsequent sections.

The US Congress established the Intelligent Transportation System (ITS) program in 1991 [3]. In 1999 the FCC, in response to a petition from ITS stakeholders, "allocated the 5.9 GHz band [5.850-5.925 GHz] for DSRC-based ITS applications and adopted technical rules for DSRC operations" [4].

[1] The term "Wi-Fi" refers to "Wi-Fi Certified" products. "Wi-Fi Certified" is a trademark of the Wi-Fi Alliance, an industry group that performs certification testing of WLAN devices which are based on IEEE 802.11 specifications. The terms 802.11, Wi-Fi, and WLAN are often used interchangeably.

[2] The rules for U-NII-1 and U-NII-3 were modified in March of 2014 [2]. There were numerous changes to the U-NII band rules, and the names of some of the bands were changed as shown in Table II. The allowed transmit power was increased in U-NII-1 and its use is now permitted outdoors; the U-NII-3 band was extended to 5.850GHz.

[3] Dynamic Frequency Selection

DSRC services are co-primary in the 5.9 GHz band with the government radiolocation service and with non-government fixed satellite service uplink operations. In 2003 the FCC adopted licensing and service rules for DSRC [4], including modifications to Parts 90 (for Roadside Units, RSUs) and 95 (for On-Board Units, OBUs) of the Commission's rules. As shown in 0, these rules defined a band plan that reserved 5 MHz at the low end of the band (5.850-5.855 GHz) for future developments and specified seven 10 MHz channels, i.e. Ch. 172 (5.855-5.865 GHz) through 184 (5.915-5.925 GHz). Channel 178 is designated as the Control Channel, while the remaining six channels are designated as Service Channels. The rules also permit two 20 MHz service channels, overlapping respectively with channels 174-176 and 180-182. In 2006 the Commission further refined the DSRC rules by designating Channel 172 "exclusively for vehicle-to-vehicle safety communications for accident avoidance and mitigation, and safety of life and property applications." In addition, it designated Channel 184 "exclusively for high-power, longer-distance communications to be used for public safety applications involving safety of life and property, including road intersection collision mitigation" [5].

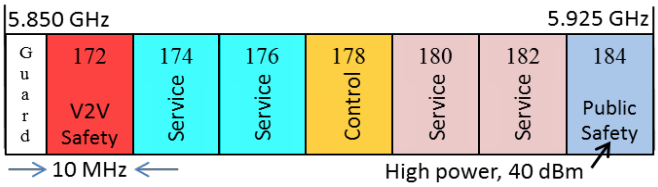

Figure 1: FCC DSRC Band Plan

3. Dedicated Short Range Communications

DSRC is an ITS technology that enables direct vehicle-to-vehicle (V2V) and vehicle-to/from-infrastructure (V2I) communication [6]. In recent years a consortium of automakers, in cooperation with the US Department of Transportation (DOT), has engaged in research directed at deployment of DSRC systems [7, 8]. The focus of the research is V2V communication of vehicle state information (location, speed, acceleration, heading, etc.) through so-called Basic Safety Messages (BSMs) [9], and the development of collision-avoidance applications that use the BSM data to identify potential collision threats and take appropriate action, e.g. warn the driver or other actions. These applications place robustness and latency requirements on the underlying wireless communication system. While the focus in discussions of DSRC is often on V2V safety communication, the system is capable of supporting a wide variety of other ITS applications, including V2I-based safety, automated driving, efficient mobility, reduced environmental impact, and electronic commerce (e.g. tolling). Some of these services also impose robustness and latency requirements on the wireless communication system.

DSRC systems communicate using a variation on the common IEEE 802.11 Physical (PHY) and Medium Access Control (MAC) protocols. This variation, referred to as Wireless Access in Vehicular Environments (WAVE) is specified in the IEEE 802.11p amendment [10]. The WAVE capability enables ad hoc communication with low latency, as required for scenarios in which high speed vehicles are only in range of one another for a few seconds before a potential collision. The relationship between WAVE DSRC and more conventional uses of the IEEE 802.11 protocols is discussed below. The higher layers of the DSRC protocol stack are based on standards defined by the IEEE 1609 Working Group and by SAE International [11].

4. The FCC 13-22 NPRM

In response to the rapidly accelerating adoption of 802.11, particularly the emerging 802.11ac standard, the FCC issued a Notice of Proposed Rulemaking (NPRM) in early 2013 that proposed

adding 195MHz of additional 5GHz spectrum for use by unlicensed devices such as 802.11.[4] In addition, the NPRM proposed changes in the existing U-NII-1, U-NII-2, and U-NII-2e bands to make them more useful for unlicensed devices, including making U-NII-1 available outdoors and streamlining the DFS process for U-NII-2 and U-NII-2e (a portion of these new rules have been approved; see [2]). A mapping between the recently approved or proposed new unlicensed spectrum and 802.11 channels is shown in red in Fig. 2. As a reminder, the band from 5.850-5.925 GHz is allocated to ITS, radiolocation, and FSS, and the inclusion of this band in the NPRM would permit one additional 80 MHz and one additional 160 MHz contiguous channel, as well as several additional non-contiguous 80+80MHz channel combinations for 802.11 operation. Unlicensed devices following standards other than 802.11 would also be permitted to operate anywhere in the bands labelled "New" in the figure.

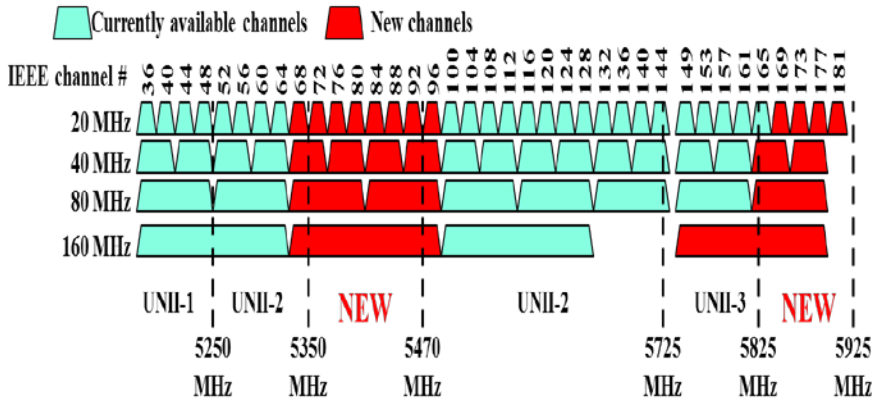

Figure 2: Current and proposed 5 GHz channels for 802.11ac

The previous designations and the new designations for these unlicensed bands are shown in 0

Frequency (GHz)	Old Name	New Name
5.15-5.25	U-NII-1	U-NII-1
5.25-5.35	U-NII-2	U-NII-2A
5.35-5.47		U-NII-2B
5.47-5.725	U-NII-2e	U-NII-2C
5.725-5.850 (Upper band edge extended to 5.850 in 2014)	U-NII-3	U-NII-3
5.85-5.925	ITS	U-NII-4

TABLE II: 5 GHZ U-NII BAND DESIGNATIONS PRIOR TO 2013 AND AS DESCRIBED IN FCC NPRM 13-22

The most significant proposed change is allowing the band allocated to DSRC to be shared with unlicensed devices such as 802.11, which would become the proposed U-NII-4 band. The automotive and WLAN industries have thus engaged in dialog to discuss possible mechanisms that could facilitate DSRC-WLAN sharing in U-NII-4 while not causing harmful interference to DSRC, which is a requirement for Part 15 devices.

[4] In this paper, references to the "NPRM" mean FCC NPRM 13-22, which is Docket 13-49.

5. Mission and Scope of IEEE 802.11 REG SC DSRC Coexistence Tiger Team

The FCC's NPRM asked for comments on the feasibility of band sharing between DSRC and unlicensed devices; the Regulatory Standing Committee of the 802.11 Working Group created this DSRC Coexistence Tiger Team in August 2013 to explore band sharing between DSRC and a possible future 802.11 amendment. [12]. The mission of this Tiger Team was to "work toward a document that would describe and quantify possible coexistence mechanisms between DSRC and extensions of the 802.11 base standard into the proposed UNII-4 band, if the FCC allows such band sharing in a future R&O."[13] Because this is a group within the Regulatory Standing committee, it can take into account the regulatory issues described previously. Only IEEE 802.11 Working Group participants may vote on certain matters before the Regulatory Standing Committee, but anyone has been able to participate in this Tiger Team activity. To date the group has attracted a global spectrum of participants from the automotive industry, 802.11 WLAN chip and system vendors, and other stakeholders from government and industry.

6. Goals

The goals of the DSRC Coexistence Tiger Team have been [13]:

- Review of ITS/DSRC field trials
- Review of work to date on coexistence
- Modelling/simulation of possible coexistence approaches
- Testing and presentation of results from proposed prototype approaches

7. Timeline

The DSRC Coexistence Tiger Team established several milestones [12]:

- Completion of review of field trials and coexistence work
- Call for proposals for coexistence mechanisms [November 2013]
- Snapshot of progress to date [February 2014]
- Complete modelling/simulation of possible coexistence approaches
- Testing and presentation of results from prototype testing
- Final report with evaluation of results and recommendations

There have not been any presentations on modelling, simulation, or testing during the duration of this Tiger Team, so those items are not within the scope of this Report.

8. Overview of DSRC Coexistence Activities since its inception

As noted previously, the Tiger Team was created in August of 2013. Between the group's creation and the end of 2014, the group held 25 conference calls, reviewed 12 presentations, and had extended discussions about the issues surrounding band sharing. The following are the types of presentations that the group reviewed:

- Presentations on use cases
- Presentations on interference
- Presentations on CCA
- Presentations on European activities
- Presentations on USDoT activities
- Presentations on proposed coexistence techniques
- Presentations on DSRC response to proposals

An exact list of presentations with a link to each on the IEEE 802.11 document server called Mentor is listed in Appendix B.

While the presentations on use cases, CCA, and regulatory activities were useful to help frame the discussion, there were presentations on two specific proposals for band sharing which directly addressed the group's charter:

1) "Proposal for U-NII-4 Devices," Peter Ecclesine, [15] and
2) "Proposal for DSRC band Coexistence," Tevfik Yucek [18]

The remainder of this report will summarize these two proposals and the group's support for carrying this work forward.

9. Proposal 1: Sharing using existing DSRC channelization and CCA in 10MHz channels

Prior to the formation of the DSRC Coexistence TT, there was a presentation in the 802.11 Wireless Next Generation Standing Committee (WNG SC) that outlined some initial ideas for band sharing [14] and addressed the issue of CCA in 10 MHz channels. After the initial DSRC Coexistence TT meeting, a preliminary proposal was brought to the Tiger Team in September of 2013. In particular, a document entitled "Proposal for U-NII-4 Devices" [15], also known as the 13/0994 proposal, has been reviewed by the group. Highlights of the proposal are:

- Detection of DSRC by WLAN in 5850-5925 MHz
- -85dBm detection of 802.11p preambles in 10MHz bandwidth
- Must detect on any of the seven 10MHz channels in the U-NII-4 band – if any channel is busy, then unlicensed devices should defer so they don't impart co-channel or out-of-channel interference
- >90% detection probability within 8μsec
- Once a 10 MHz preamble (802.11p) has been detected, the frequency band from 5825-5925MHz will be declared busy for at least 10 seconds. During a busy period, the DSRC channels will continue to be monitored, and any new DSRC packet detection will extend the CCA busy state for ten seconds from the time of detection.
- The maximum time of transmission for any U-NII-4 packet will be 3 msec

Note that several of the numeric values listed above are intended to be subject to further discussion. There are also some differences between the timing parameters between 802.11p and 802.11ac; these would need to be resolved as noted in [14] and [16].

Note that this proposal is a hybrid of traditional CCA and DFS. It uses standard 802.11 CCA (in a 10 MHz bandwidth) for detection of the DSRC user, taking advantage of very specific knowledge of the primary signal characteristics. It also employs CCA not only on the channel of intended operation, but also on other DSRC channels. Most importantly, once detection has occurred, the CCA function will define the channel state as busy, i.e. unavailable for unlicensed transmissions, for a relatively long period compared to normal CCA deference. In this way, CCA-based detection resembles DFS in structure. On the other hand, the non-occupancy is likely to be significantly shorter than the 30 minute silence period requirement for DFS. There is also no separate channel availability check as in DFS; this is combined with the 10 second busy holdover time after the most recent detection. Another difference from DFS is that under the 13/0994 proposal, every STA that wants to use the U-NII-4 band performs DSRC detection; there is no master or client role as there is in DFS. Finally, there is no distinct channel move time; once a DSRC transmission is detected, unlicensed use of the band ceases immediately.

While this approach specifically leverages commonality between unlicensed 802.11 and licensed DSRC signals, it could in theory also be employed by non-802.11 devices wishing to share the band on an unlicensed basis. From a technical perspective, any device can implement this detection function. From a practical perspective, non-802.11 devices may not find adding this CCA mechanism cost effective.

While no definitive action has been taken on this proposal during the duration of the Tiger Team, the concepts outlined should be carried forward into analysis and simulation studies to determine their merit. Note that the proposed CCA threshold (-85 dBm) is well above the sensitivity level of typical 802.11p/DSRC implementations, so this level may have to be revised downward Some implementations of DSRC have a sensitivity level approaching -95dBm, so the CCA threshold of a U-NII-4 device would need to be comparable to this level.

Some Tiger Team members suggested there are two issues with this approach:

- Changes will be required to modify the behavior of existing 802.11ac systems. The current CCA mechanism is not defined for 10MHz channels (although it is for other parts of the 802.11 family such as 802.11a) and, more importantly, the secondary CCA mechanisms defined in 802.11ac do not comprehend secondary devices using Carrier Sense in multiple channels, certainly not the seven channels in DSRC; in the case of DSRC coexistence, secondary CCA at Carrier Sense levels (<-85dBm) would have to be performed in multiple channels simultaneously [17]. This would require changes in the base 802.11 specification and would add complexity to existing 802.11ac chipsets.
- Even if Carrier Sense could be demonstrated to operate at levels below -90dBm in 10MHz channels, there is no guarantee that modified 802.11ac systems would not impact DSRC operation. Adequate testing would be required to make sure that deployment of these 802.11 systems would not impact the critical functions of DSRC systems, particularly collision avoidance.

10. Proposal 2: Sharing using modified DSRC channelization and CCA in 20MHz channels

Another submission that has been made in the group proposes changes to DSRC [18,19,20]; also known as document 13/1449r2, it would revamp the existing band plan as defined in the FCC Report and Order 03-324 and allow unlicensed devices such as 802.11 to share only the lower 45MHz portion of the band, while reserving several channels at the top of the band exclusively for the use of DSRC systems. It also proposes that non-safety-of-life DSRC applications use only 20MHz channels in the lower 40MHz of the band (5855-5895MHz), not the existing 10MHz channels. Figure 3 shows how the proposed new band plan would look.

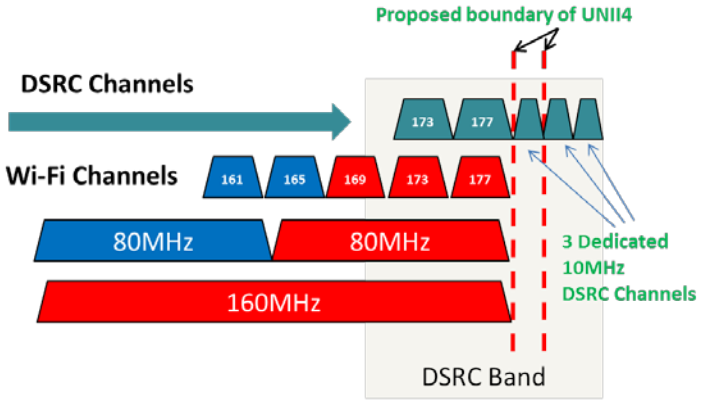

Figure 3: Proposed rebanding of DSRC channels in 13/1449r2

Like Proposal 1 (13/0994), Proposal 2 would require further study and testing to verify that it would adequately protect DSRC applications from harmful interference. This proposal would possibly require a new FCC rulemaking to change the FCC 03-324 band plan, as well as some new testing of DSRC systems to verify that these changes would have little or no impact. Certainly some aspects of the existing tests, such as upper layer messaging (parts of P1609 and J2735), would still be relevant, but the potential for new forms of co-channel interference, adjacent channel interference, and congestion would mean that at least some portions of the testing would have to be re-done. In addition, changing the lower 40MHz portion of the DSRC band to two 20MHz channels instead of four 10MHz channels is not comprehended in the P1609 specification, so that would need to be re-written and tested[5].

[5] The existing spectrum allocation allows two 20MHz channels spanning channels 174-176 and 180-182.

On the other hand, the objectives of this proposal were to provide protection for BSM traffic because they would not have to share with unlicensed devices at all, and to allow modified 802.11ac chipsets to be used with 160MHz bandwidth channels to span from U-NII-3 into the new (shared) U-NII-4 band. While the secondary CCA mechanism in 802.11ac currently uses Energy Detect, which is 20dB higher than the threshold defined for Carrier Sense, modification of the existing 802.11ac standard to incorporate 20MHz Carrier Sense secondary CCA in the U-NII-4 band would likely not result in a major change (if any) to existing standards or chipsets, since 20MHz CCA is already defined and in use.

11. Next Steps

As mentioned previously, this report only outlines some proposed band sharing ideas; more detailed analysis, simulation, and – most importantly – field testing will be necessary to adequately verify that unlicensed devices are not causing harmful interference to DSRC systems under a proposed band sharing method[6]. Field trials will be an important part of evaluating DSRC coexistence in the U-NII-4 band; as analysis continues on these proposals beyond the time frame of this Tiger Team, prototype development of sharing technologies can occur in parallel. The materials considered in this Tiger Team, particularly the use cases, should be of significant value in designing these field trials. While it is not known if a test bed, such as the one deployed in Ann Arbor (MI) for the US Department of Transportation's DSRC Model Deployment, will be available for testing of the DSRC coexistence techniques described in this report, it is expected that there will be facilities available to perform "real world" testing to insure that the proposed coexistence approaches achieve satisfactory band sharing performance. It is assumed that stakeholders from the ITS/DSRC and 802.11 communities, as well as potentially from government agencies, will participate in field/lab testing of any of these candidate spectrum sharing technical solutions.

12. Conclusion

The 5 GHz band is of great importance to both the 802.11 WLAN and V2V/V2I industries. With the release of the 13-22 NPRM, the FCC has created the possibility for a substantial increase in available unlicensed spectrum for 802.11 WLAN, particularly the ability to use 160MHz channels as described in 802.11ac. The proposed sharing of the ITS/DSRC band from 5.85-5.925 GHz poses numerous technical challenges that the WLAN and ITS industries must address to make sure that the applications – including crash avoidance - enabled by DSRC are not harmfully interfered with by unlicensed users of this band. With the conclusion of this activity, this 802.11 DSRC Coexistence Tiger Team has brought the various stakeholders together and laid the groundwork for field/lab testing once one or more sharing proposals are fully developed and prototype U-NII-4 devices become available. While the Tiger Team did not agree on a single consensus position for band sharing, information given in this report along with subsequent follow-on testing can form the basis of future regulatory policy, standards efforts, and technology deployments.

13. References

1. Lansford, J.; Kenney, J.B.; Ecclesine, P., "Coexistence of unlicensed devices with DSRC systems in the 5.9 GHz ITS band," IEEE Vehicular Networking Conference (VNC), Boston, 2013, pp.9-16, 16-18 Dec. 2013.
2. "Unlicensed National Information Infrastructure (U-NII) Devices in the 5 GHz Band",https://www.federalregister.gov/articles/2014/05/01/2014-09279/unlicensed-national-information-infrastructure-u-nii-devices-in-the-5-ghz-band
3. Intermodal Surface Transportation Efficiency Act (ISTEA), Public Law 102-240, December 18, 1991.
4. FCC 03-324 Report and Order, Dec. 17, 2003.

[6] In particular, the signal levels for unlicensed devices that establish a threshold for what constitutes "harmful interference" to DSRC is an important criterion to assess.

5. FCC 06-110 Memorandum Opinion and Order, July 20, 2006.
6. D. Jiang, V. Taliwal, A. Meier, W. Holfelder, and R. Herrtwich ,"Design of 5.9 GHz DSRC-based Vehicular Safety Communication," IEEE Wireless Communications, Vol. 13, No. 5, pp. 36-43, Oct. 2006.
7. *Vehicle Safety Communications – Applications (VSC-A) Final Report*, US Dept. of Transportation, DOT HS 811 492A, September 2011.
8. "Interoperability Issues of Vehicle-to-Vehicle Based Safety Systems Project (V2V-Interoperability)," Project Order 0004, Technical Proposal Statement of Work; US Department of Transportation, National Highway Traffic Safety Administration, Cooperative Agreement DTNH22-05-01277, December 2009.
9. "DSRC Message Set Dictionary," SAE J2735 standard, SAE International, 2009.
10. 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; Amendment 6: Wireless Access in Vehicular Environments, IEEE Std 802.11p™, July 2010.
11. J. Kenney, "DSRC standards in the US," Proceedings of the IEEE, Vol. 99, Issue 7, pp. 1162-1182, July 2011.
12. 802.11 Regulatory Standing Committee Agenda, August 15, 2013, Slide 8. Available at https://mentor.ieee.org/802.11/dcn/13/11-13-0963-00-0reg-august-15th-teleconference-plan-and-agenda.ppt
13. 802.11 DSRC Coexistence Tiger Team Agenda, October 3, 2013. Available at https://mentor.ieee.org/802.11/dcn/13/11-13-1261-00-0reg-agenda-for-dsrc-coexistence-tiger-team-call-04oct2013.ppt
14. "802.11p-DSRC and 802.11ac Coexistence," Jim Lansford and John Kenney, Available at https://mentor.ieee.org/802.11/dcn/13/11-13-0552-00-0wng-802-11p-dsrc-and-802-11ac-coexistence.ppt
15. "Proposal for U-NII-4 Devices," Peter Ecclesine, Available at https://mentor.ieee.org/802.11/dcn/13/11-13-0994-00-0reg-proposal-for-u-nii-4-devices.docx
16. "ITS Politeness Measures," Reza Hedayat and Peter Ecclesine, Available at https://mentor.ieee.org/802.11/dcn/14/11-14-1044-00-0reg-its-politeness-measures.docx
17. "CCA issues for DSRC Coexistence," Jim Lansford, Available at https://mentor.ieee.org/802.11/dcn/14/11-14-0532-00-0reg-cca-issues-for-dsrc-coexistence.ppt
18. "Proposal for DSRC band Coexistence," Tevfik Yucek, Available at https://mentor.ieee.org/802.11/dcn/13/11-13-1449-02-0reg-proposal-for-dsrc-band-coexistence.pptx
19. "Technical discussion on Re-channelization Proposal for DSRC band coexistence," Tevfik Yucek, Available at https://mentor.ieee.org/802.11/dcn/14/11-14-0819-00-0reg-technical-discussion-on-re-channelization-proposal-for-dsrc-band-coexistence.pptx
20. Comments of Qualcomm Incorporated to FCC 14-22, Dean R. Brenner and John W. Kuzin, May 28, 2013
21. "A response to the re-channelization proposal," John Kenney, et al, Available at https://mentor.ieee.org/802.11/dcn/14/11-14-1101-01-0reg-a-response-to-the-re-channelization-proposal.pptx
22. "Technical discussion on Re-channelization Proposal for DSRC band coexistence," Tevfik Yucek and Xinzhou Wu, Available at https://mentor.ieee.org/802.11/dcn/14/11-14-0819-00-0reg-technical-discussion-on-re-channelization-proposal-for-dsrc-band-coexistence.pptx
23. "Communication and Data Movement in Connected Vehicles," Walton Fehr, Available at https://mentor.ieee.org/802.11/dcn/14/11-14-0728-00-0reg-communication-and-data-movement-in-connected-vehicles.ppt

Appendix A: Participants in the DSRC Coexistence Tiger Team

Leadership:
Jim Lansford, Chair, DSRC Coexistence Tiger Team (CSR)
Rich Kennedy, Chair, IEEE 802.11 Regulatory Standing Committee (Mediatek)

Name	Relevant Affiliation
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Dean Brenner	Qualcomm
Mike Brown	SwRI
Bill Carney	Sony
Alan Chachich	USDOT
Bill Check	NCTA
Blake Christie	Nobilis
Patrick Chuang	Booz-Allen-Hamilton
Sean Coffey	Realtek
Jordan Cooper	Industry Canada
Upkar Dhaliwal	Future Wireless Technologies
Ed Drocella	NTIA
Peter Ecclesine	Cisco Systems
Vinko Erceg	Broadcom
Paul Feenstra	ITS Americas
Walton Fehr	USDOT
Volker Fessman	FHWA
Brian Gallagher	DENSO
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Dirk Grunwald	CU Boulder
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Garth Hillman	ETS-Lindgren
Hans Johansson	Kapsche Trafficom
Malik Kahn	Cohda Wireless
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John Kenney	Toyota Info Technology
Aboulmajid Khalilzadeh	Intelsat
Sang Kim	LGE
Marc Klaasen	NXP
Bruce Kraemer	Marvell
Tom Kurihara	TK Standards
John Kuzin	Qualcomm
Jim Lansford	CSR
Joseph Levy	Interdigital
Lan Lin	Hitachi Europe SAS
Dan Lubar	Relay Services
Steve Mace	NCTA
Paul Margie	NCTA
Scott Marin	Nokia Networks
Jim Misener	Qualcomm
John Moring	Kapsche Trafficom
Saishankar Nandagopalan	Adaptence
Paul Nikolich	Chair, IEEE 802
Eric Nordstrom	Ericsson
Alan Norman	Google
John Notor	Notor Research
Ted Osinski	MetLab
Sam Oyama	ARIB
Eldad Perahia	Intel
Danielle Pineres	NCTA
Victoria Poncini	Microsoft
Gary Pruitt	Rockwell Collins
Randy Roebuck	3M/Omniair
John Rosdahl	CSR
Dick Roy	SRA
Tom Schaffnit	A2 Technology Management
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Appendix B: Documents submitted to the DSRC Coexistence Tiger Team (Links on IEEE Mentor server)

- https://mentor.ieee.org/802.11/dcn/13/11-13-0552-00-0wng-802-11p-dsrc-and-802-11ac-coexistence.ppt
- https://mentor.ieee.org/802.11/dcn/13/11-13-0541-01-0wng-dsrc-applications-tutorial.pptx
- https://mentor.ieee.org/802.11/dcn/13/11-13-0543-01-0wng-dsrc-support-information.pptx
- https://mentor.ieee.org/802.11/dcn/13/11-13-0994-00-0reg-proposal-for-u-nii-4-devices.docx
- https://mentor.ieee.org/802.11/dcn/13/11-13-1276-00-0reg-proposal-for-sharing-in-unii-4-band.pptx
- https://mentor.ieee.org/802.11/dcn/13/11-13-1309-00-0reg-harmful-interference-to-dsrc-systems.pptx
- https://mentor.ieee.org/802.11/dcn/13/11-13-1360-00-0reg-dsrc-per-versus-rss-profiles.pptx
- https://mentor.ieee.org/802.11/dcn/13/11-13-1449-02-0reg-proposal-for-dsrc-band-coexistence.pptx
- https://mentor.ieee.org/802.11/dcn/14/11-14-0225-00-0reg-use-cases-for-dsrc-coexistence.ppt
- https://mentor.ieee.org/802.11/dcn/14/11-14-0259-00-0reg-v2v-radio-channel-models.ppt
- https://mentor.ieee.org/802.11/dcn/14/11-14-0532-00-0reg-cca-issues-for-dsrc-coexistence.ppt
- https://mentor.ieee.org/802.11/dcn/14/11-14-0550-00-0reg-world-spectrum-sharing.ppt
- https://mentor.ieee.org/802.11/dcn/14/11-14-0728-00-0reg-communication-and-data-movement-in-connected-vehicles.ppt
- https://mentor.ieee.org/802.11/dcn/14/11-14-0819-00-0reg-technical-discussion-on-re-channelization-proposal-for-dsrc-band-coexistence.pptx
- https://mentor.ieee.org/802.11/dcn/14/11-14-1335-01-0reg-dsrc-band-plan-rationale.ppt

Appendix C: Cooperative ITS spectrum regulation in the 5GHz band in Europe

Overview

The European ITS spectrum regulation is based on an decision of the Electronic Communications Committee of the European Conference of Postal and Telecommunications Administrations (CEPT/ECC) (ECC/DEC/(08)01) for the band 5895 MHz to 5905MHz including an extension band from 5905MHz to 5925MHz and a CEPT/ECC recommendation (ECC/REC/(08)01) for the band 5855MHz to 5875MHz. The Recommendations is implemented in a limited number of European countries.
In addition, the European Commission allocates the frequency band 5875 – 5905 MHz in a legally binding way in the European Union for safety-related ITS application (Commission Decision 2008/671/EC), a.k.a. cooperative ITS (C-ITS) and vehicle-to-x communications (V2X).. This band is available for a European wide deployment of cooperative ITS services. The cooperative ITS spectrum allocation in Europe is depicted in Figure C-1. This legal framework is under revision until Q2/2015 with no changes in the spectrum band allocations.

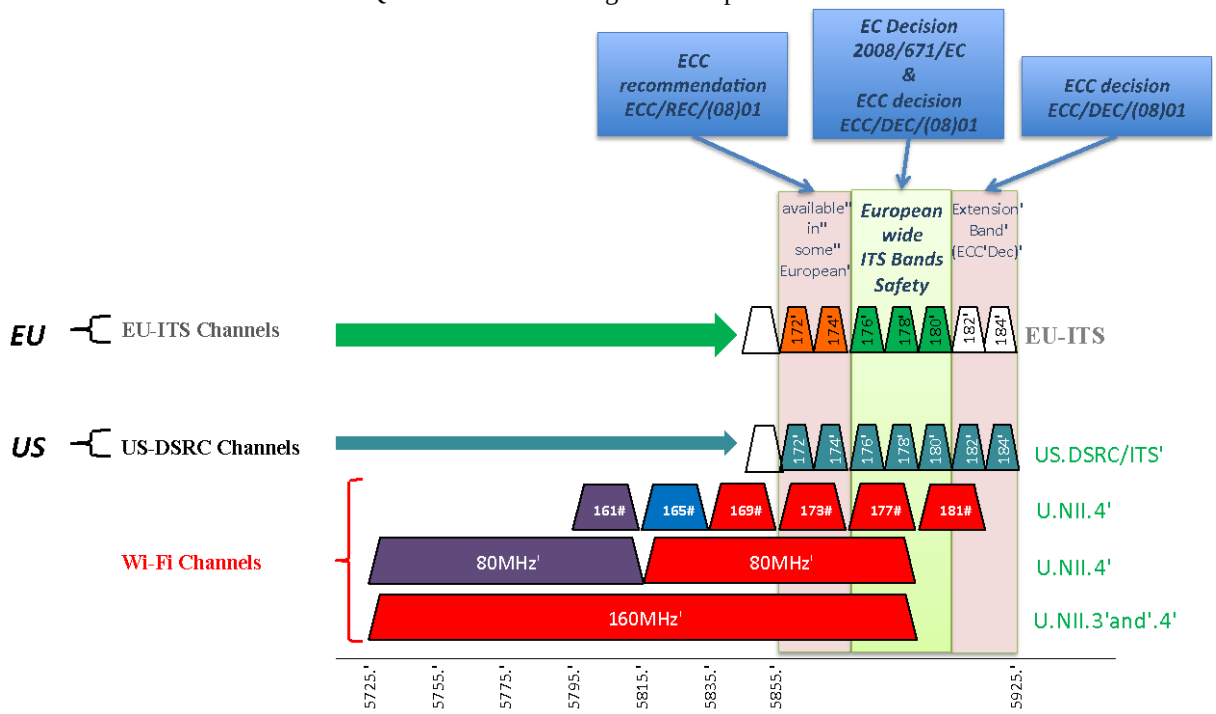

Figure C-1: European cooperative ITS spectrum allocation

Mitigation requirements

In Europe an activity on potential mitigation techniques and procedures to protect existing services have been initiated by the EU commission with a mandate to the CEPT.
As an initial result of this mandate (see CEPT Report A to the EU commission), work on mitigation techniques has been initiated to enable the compatibility between individual RLAN[7] devices and ITS. These studies have focussed on "listen-before-talk" process, where the potential interferer tries to detect whether a channel is busy before transmitting a data packet.
Two possible approaches are under study:

- Generic Energy Detection without any consideration of the interferer and victim signal frames: preliminary analysis indicated that a detection threshold of the order of -90 dBm/10 MHz would be required for a reliable detection of ITS. Further consideration is required, including on the feasibility of such a detection threshold and its impact on the RLAN operation.

[7] European regulators generally refer to WLAN as RLAN

- Combination of energy detection and carrier sensing, such as one of the Clear Channel Assessment (CCA) modes defined in 802.11 standards. Further studies are required to assess the applicability to ITS of the interference avoidance techniques currently employed in 5 GHz RLAN systems under dynamic multipath fading conditions.

In the further development of the detection mechanisms the mobile characteristics of the ITS environment has to be taken into account. This can be achieved by deploying dynamic multipath fading channel models in the evaluation process of the investigated mitigation techniques. These channel models are under development in ETSI TC ITS.
In face of the market deployment of ITS-G5 systems in 2015 the European channel allocation and the deployed bandwidth (10 MHz) in the ITS systems can no longer be changed at this point in time. All suggestions and mitigation techniques relying on reallocating spectrum or demanding the change of the channel bandwidth cannot be considered as a feasible solution.

Conclusion

In its report to the EU commission the European regulators have stated some important requirements for a potential coexistence between future RLAN deployment and ITS in the 5GHz band:

- The European channel allocation and the channel bandwidth of 10 MHz cannot be changed.

- Channel reallocation to avoid interference between C-ITS and 802.11 RLAN is not feasible. In Europe not all channels are allocated yet, therefore channel relocation is not supported by the European regulators.

- The detection of C-ITS signals should consider the sensitivity and dynamic conditions of C-ITS, i.e. a highly dynamic environment, including (Doppler/multipath) effects from moving signal sources on the transmitted and received signals.

A potential future RLAN spectrum regulation in Europe will be based on these basic assumptions. The further development of mitigation techniques for the European regulation is now under development and evaluation in ETSI TC BRAN in close cooperation.

Appendix D: USDOT Participation in IEEE Tiger Team re. 5 GHz Spectrum Sharing

US Department of Transportation (USDOT) staff participated in IEEE Tiger Team Meetings. USDOT's primary role was to monitor the progress of the team's work. When appropriate, USDOT provided clarifying information to the team and/or technical input based on their technical expertise. USDOT did not seek to advocate any specific outcome; rather USDOT sought to respect the value of the consensus processes of IEEE.

USDOT reviewed the two potential approaches to spectrum sharing made available to the Tiger Team; and offers the following initial evaluation, recognizing that insufficient detail was provided to reach any conclusions on either approach's risk to transportation safety use of the spectrum:

13/1449r2 proposal by Yucek:

1. The current proposal appears inconsistent with the premise of the spectrum sharing concept proposed in the FCC NPRM (FCC 13-22, February 20, 2013); namely, that unlicensed users would operate in the 5 GHz band on a non-interference basis with respect to the incumbent licensed systems. This proposal actually appears to be a reallocation of spectrum away from the current incumbent and thus appears to be outside the bounds of the NPRM.

2. Limiting the DSRC incumbent to primary use of only 30 MHz of spectrum is insufficient to support even a portion of all planned safety applications which include vehicle-to-infrastructure (V2I) as well as vehicle-to-vehicle (V2V) applications.

3. Moving the safety channel, the control channel, and the high powered public safety communications into adjacent channels would be expected to substantially increase adjacent channel interference levels, which places at risk the effectiveness of the safety critical applications that provide imminent crash notification alerts to drivers.

4. The proposed approach would effectively invalidate a substantial portion of the many years of safety application testing and international standards development and harmonization work undertaken by the USDOT and industry partners. This work has had European and Asian partners using both governmental and industry funding and support. It would require much of this research and testing work to be repeated; such additional work would delay availability of life-saving technologies and impose large costs.

5. The proposal does not provide sufficient detail to support analysis of potential impact on safety applications beyond the points made above.

6. As a result, this proposal as submitted appears problematic on many levels and is technically unsuitable to meet the non-interference criteria set forth in the NPRM.

13/0994r0 proposal by Ecclesine:

1. This proposal did not provide sufficient detail to support analysis to understand the impact on safety applications. Additional detail which would have been beneficial includes but is not limited to:
   - What is the 802.11ac back-off time if DSRC is detected?
   - What is the ability or sensitivity of 802.11ac to detect the DSRC 10 MHz channel?

USDOT looks forward to continuing cooperation in supporting research for successful sharing methodologies and is ready to actively participate in testing and evaluation when equipment becomes available.