Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, DC 20554

In the Matter of	)	
	)	
Revision of Part 15 of the Commission's Rules to Permit Unlicensed National Information Infrastructure (U-NII) Devices in the 5 GHz Band	)	ET Docket No. 13-49

COMMENTS OF BROADCOM LTD.

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Broadcom Ltd. ("Broadcom") submits these comments in response to the Public Notice issued by the Commission to update and refresh the record on the status of potential sharing solutions between proposed Unlicensed National Information Infrastructure ("U-NII") devices and Dedicated Short Range Communications ("DSRC") operations in the 5.850-5.925 GHz ("U-NII-4") band.[1/] Broadcom applauds the Commission's action, which it hopes will ultimately lead to expanded use of the U-NII-4 band for unlicensed use to support important growing business and consumer demands for larger Wi-Fi channels. Broadcom supports sharing of the band through adoption of the re-channelization sharing proposal described in the *Public Notice* and further discussed here. Re-channelization is the best approach to advance the Commission's twin goals of increasing the spectrum available for unlicensed devices while also protecting incumbent DSRC safety-of-life communications.[2/]

I. INTRODUCTION AND SUMMARY

Broadcom is a global leader in wired and wireless communications semiconductors. It ships well over seven million chips on a daily basis, has a meaningful presence in nearly all

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1/ *See The Commission Seeks to Update and Information Infrastructure (U-* , Public Notice, ET Docket No. 13-49 (rel. June 1, 2016) ("*Public Notice*");
Permit Unlicensed National Information Infrastructure (U-NII) Devices in the 5 GHz Band, Notice of Proposed Rulemaking, 28 FCC Rcd. 1769 (2013) ("*NPRM*").

2/ *See Public Notice* at 5 (citing *NPRM* ¶¶ 75-77).

categories of products that require communications chips, and has one of the broadest portfolios in the industry. Broadcom estimates that at least 99.98% of all Internet traffic goes through at least one of its chips. Because of its diversity in the market, Broadcom has a unique understanding of the overall communications ecosystem and the various technologies used to transmit data. Broadcom is innovating to ensure a smooth flow of data from the data center, to the Internet service provider, to the home gateway or router, and to the client device that is used to watch movies or surf the web. It is an active member of all the relevant standards bodies addressing Wi-Fi and licensed wireless technologies.

As the *Public Notice* states, the purpose of this proceeding is to make broadband technologies available in the 5 GHz band while protecting federal and non-federal users.[3/] The principal non-federal designation of the band is for DSRC systems, a component of the Intelligent Transportation System ("ITS") radio service. While spectrum for DSRC was allocated over 15 years ago and licensing and service regulations were adopted over a decade ago, there are no commercial DSRC operations today in the United States. During that same period, there has been explosive growth in Wi-Fi, which has driven, in part, the need for more unlicensed spectrum.

The Commission appropriately seeks to protect DSRC traffic, while providing much needed additional unlicensed wireless capacity to meet rising consumer demand. The best way to accomplish that is through the re-channelization approach. Under that plan, as envisioned by Broadcom, 30 megahertz of spectrum at 5895-5925 MHz would be dedicated exclusively for more delay sensitive, safety-of-life ITS applications, such as for Basic Safety Messaging

3/ *See id.* at 5 (citing *NPRM* ¶¶ 75-77).

("BSM"). The remaining 45 megahertz would be available for all other ITS applications and unlicensed use on a shared basis.[4/]

This re-channelization would provide maximum spectral separation from the hundreds of millions of 5.725-5.850 GHz ("U-NII-3") enabled devices in the market today, and preserve, on an exclusive basis, some of the U-NII-4 spectrum for the most delay-sensitive elements of the DSRC service. Moreover, under Broadcom's proposed plan, DSRC traffic on channels shared with unlicensed operations could be prioritized if required by the Commission by adjusting the algorithm based on the classification and criticality of the DSRC communications.[5/] This approach will provide the spectrum necessary to create additional 20, 40, 80, and 160 megahertz wide Wi-Fi channels.

In contrast, the alternative "detect and avoid" proposal[6/] does not adequately protect delay-sensitive DSRC traffic, nor does it promote efficient use of the spectrum. Further, detect and avoid would not provide reliable access to U-NII-4 spectrum, and would impair the U-NII-3 spectrum, because it would require unlicensed devices to vacate part of U-NII-3 and all of U-NII-4 in the presence of *any* DSRC use, no matter how minimal. Because cars are everywhere, the detect and avoid approach would ultimately make U-NII-4 useless and limit the utility of wider U-NII-3 channels for portable Wi-Fi devices.

4/ *See* Letter from Christopher Szymanski, Director, Product Marketing and Government Affairs, Broadcom Ltd. to Marlene H. Dortch, Secretary, FCC, ET Docket No. 13-49, Attachment at 4 (filed May 5, 2016) ("Broadcom Sharing Proposal").

5/ *See id.* at 2, 5.

6/ *See Public Notice* at 6; *see also* Letter from Mary L. Brown, Senior Director, Government Affairs, Cisco Systems, Inc. to Marlene H. Dortch, Secretary, FCC, ET Docket No. 13-49, at Attachment (filed Dec. 23, 2015) ("Cisco Ex Parte Letter"). Under this sharing proposal, unlicensed devices would monitor the existing 10 megahertz-wide DSRC channels established in the *DSRC Report and Order* in 2004. *See Public Notice* at 6 (citing *Amendment* - *Range Communication Services in the 5.850-5.925 GHz Band (5.9 GHz Band), et al.*, Report and Order, 19 FCC Rcd. 2458 (2004) ("*DSRC Report and Order*")).

II. ADDITIONAL UNLICENSED CAPACITY AT 5 GHZ IS NEEDED

Wi-Fi is the default medium for connectivity today.[7/] As of last October, Wi-Fi carried about half of all Internet traffic and 10 times more traffic than cellular.[8/] And the demand for Wi-Fi continues to grow exponentially. According to AT&T, over 80% of mobile traffic goes over Wi-Fi.[9/] There are over 7 billion installed Wi-Fi devices today, with total cumulative Wi-Fi shipments expected to surpass 15 billion units by the end of 2016.[10/] The 5 GHz band has become an increasingly important focus for unlicensed operations due to growing Wi-Fi congestion in the 2.4 GHz band, which cannot support larger Wi-Fi channelization.[11/] Wi-Fi Alliance and other commenters have pointed out that "the 5 GHz band is particularly attractive for new Wi-Fi deployments given that it provides a large amount of unlicensed spectrum and is compatible with existing Wi-Fi standards."[12/] The Commission has also noted that it "expect[s]

7/ Kevin Robinson, *Wi-Fi and the Rise of Smart Cities*, WI-FI ALLIANCE (Oct. 30, 2015); *available at* http://www.wi-fi.org/beacon/kevin-robinson/wi-fi-and-the-rise-of-smart-cities.

8/ *Id.*

9/ *See* Bill Smith, President, Technology Operations, AT&T Services Inc., Keynote Address at the Wells Fargo 2016 Convergence & Connectivity Symposium (June 21, 2016) (transcript available at http://www.streetcove.com/2016/06/at-inc-at-wells-fargo-convergence.html).

10/ *Wi-Fi® Device Shipments to Surpass 15 Billion by End of 2016*, WI-FI ALLIANCE (Jan. 5, 2016), *available at* http://www.wi-fi.org/news-events/newsroom/wi-fi-device-shipments-to-surpass-15-billion-by-end-of-2016; *see also Wi-Fi To Carry Up To 60% of Mobile Data Traffic By 2019*, FIERCEWIRELESS (June 16, 2015) (reporting that a study by Juniper Research "has forecast that Wi-Fi networks will carry almost 60% of smartphone and tablet data traffic by 2019, reaching over 115,000PB (Petabytes) by 2019, compared to under 30,000PB [in 2015] - representing almost a four-fold increase."); *available at* http://www.fiercewireless.com/press-releases/wi-fi-carry-60-mobile-data-traffic-2019.

11/ *See, e.g.*, Reply Comments of Wi-Fi Alliance, ET Docket No. 13-49, at 5 (filed July 24, 2013) (stating that "[a]dditional access to 5 GHz spectrum in particular is necessary to meet congestion caused by the increased adoption of Wi-Fi") ("Wi-Fi Alliance Reply Comments"); *NPRM* at Statement of Commissioner Mignon L. Clyburn (emphasizing the need for additional spectrum to support unlicensed technologies because "[t]he 2.4 GHz band, while critical to the success of Wi-Fi and other unlicensed technologies, is increasingly congested").

12/ *See* Wi-Fi Alliance Reply Comments at 5 (citing Comments of the National Cable & Telecommunications Association, ET Docket No. 13-49, at 7-10 (filed May 28, 2013); Comments of the Telecommunications Industry Association, ET Docket No. 13-49, at i (filed May 28, 2013); Comments of

that more and more devices with even wider bandwidths will continue to be introduced in the 5 GHz band in the not too distant future as a result of new technical standards."[13/] These wider channels will provide super-fast throughput and enable the next generation of Wi-Fi communications.

The proliferation of Wi-Fi devices capable of operating in the 5 GHz bands is well beyond what was conceived in 1999 when the Commission designated spectrum for DSRC use. The rules governing DSRC must be updated to account for spectrum utilization as it exists in 2016, as opposed to what was projected over 16 years ago.

III. RE-CHANNELIZATION WILL BEST PROTECT PUBLIC SAFETY

In 1999, the Commission designated the 5.850-5.925 GHz band for DSRC-based ITS applications and adopted basic technical rules for DSRC operations.[14/] In 2004, the Commission established licensing and service rules for DSRC in the 5.850-5.925 GHz band.[15/] The Commission's action was necessarily based on the Commission's and auto industry's understanding of spectrum use at that time. This plan was designed to provide maximum spectral separation between the primary BSM channel (172), the high power control channel (178), and the higher power alternative BSM as showi-o0044>5 4e3o8005700-3(e)-5(rna)7(ti)-3(ve)4( )-9(B)7(S)

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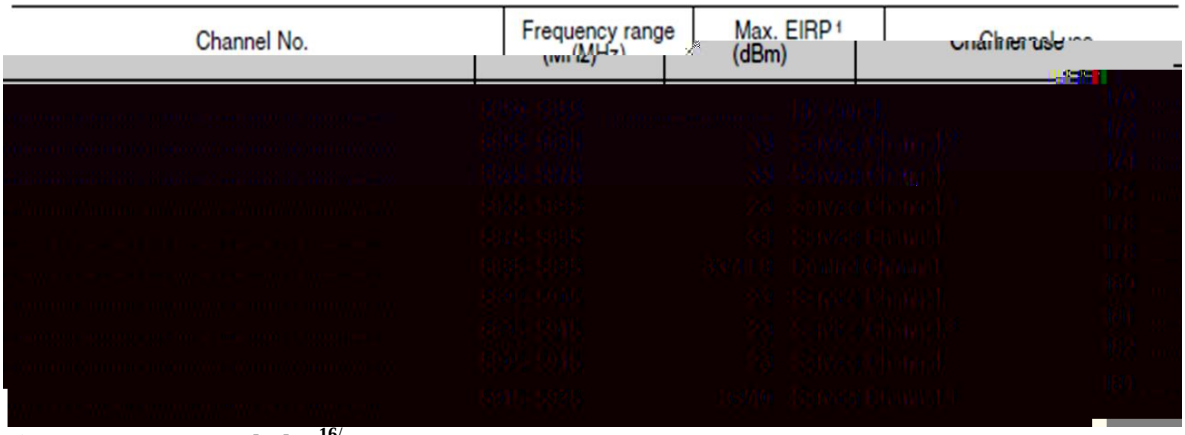

Figure 1: DSRC Band Plan[16/]

This plan design may have made sense for DSRC operations in 2004, with limited adjacent channel communications emitting energy into the band, and no U-NII devices operating in the same bands. Similarly, as noted above, neither the Commission nor the auto industry could have predicted the number of unlicensed devices that would be placed in operation under rules already in place long before 1999, when the DSRC allocation was created.[17/] However, as shown in Figure 2 below, the 125 megahertz of U-NII-3 spectrum directly adjacent to the DSRC has since been allocated for unlicensed use and there are hundreds of millions of devices operating in the band.

16/ 47 C.F.R. § 90.377(b), Table.

17/ In particular, devices operating in what is now considered the U-NII-3 band were authorized as early as 1985. *See Authorization of Spread Spectrum and Other Wideband Emissions Not Presently Provided for in the FCC Rules and Regulations*, First Report and Order, 101 FCC 2d 419 ¶ 24 (1985). And, in 1997, the Commission made the 5.725-5.825 GHz band available for U-NII. *See Amendment of NII Devices in the 5 GHz Frequency Range*, Report and Order, 12 FCC Rcd. 1576 (1997). The Commission subsequently extended the upper edge of the U-NII-3 band from 5.825 to 5.850 GHz.
to Permit Unlicensed National Information Infrastructure (U-NII)Devices in the 5 GHz Band, ET Docket No. 13-49, First Report and Order, 29 FCC Rcd 4127, 4153-54, ¶¶ 91-94 (2014), *recon. denied, Revision ion Infrastructure (U-NII) Devices in the 5 GHz Band*, Memorandum Opinion and Order, 31 FCC Rcd. 2317, ¶¶ 17-23 (2016).

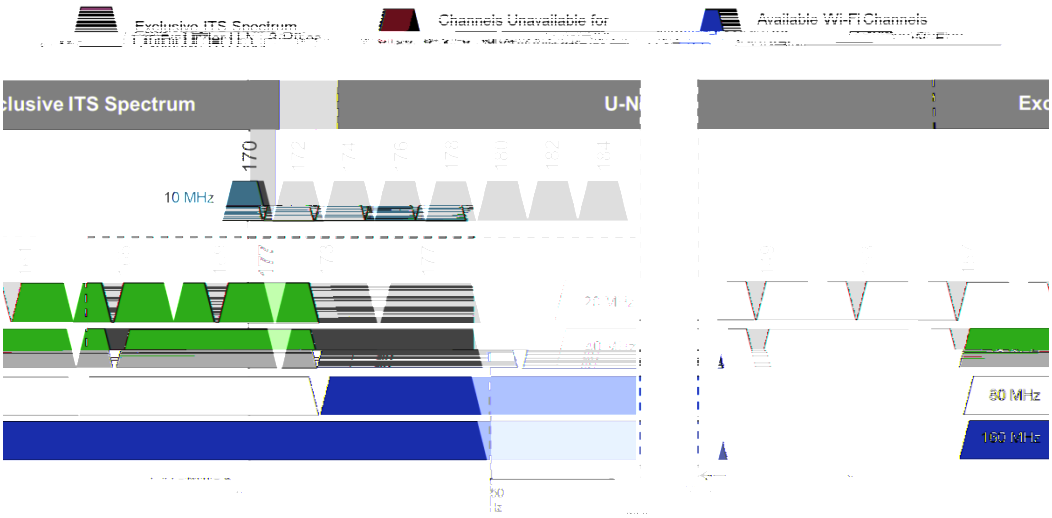

Figure 2: U-NII-3 and U-NII-4 Spectrum

The five 20 megahertz, two 40 megahertz, and one 80 megahertz channels that can be supported in the U-NII-3 band are the most intensely employed for 5 GHz Wi-Fi devices. An IEEE 802.11 and FCC compliant Wi-Fi device operating at 20 megahertz, 40 megahertz, and 80 megahertz bandwidths in channels 161, 159, and 155 respectively, cumulatively emit much higher out of band emissions ("OOBE") into channel 172 than into channel 180 as shown in Figure 3 below. If three U-NII-3 devices were operating with 20, 40, and 80 megahertz channels, the cumulative OOBE would be 6.6 dBm/10 MHz emitted into channel 172 versus -5.2 dBm/10 MHz emitted into channel 180.

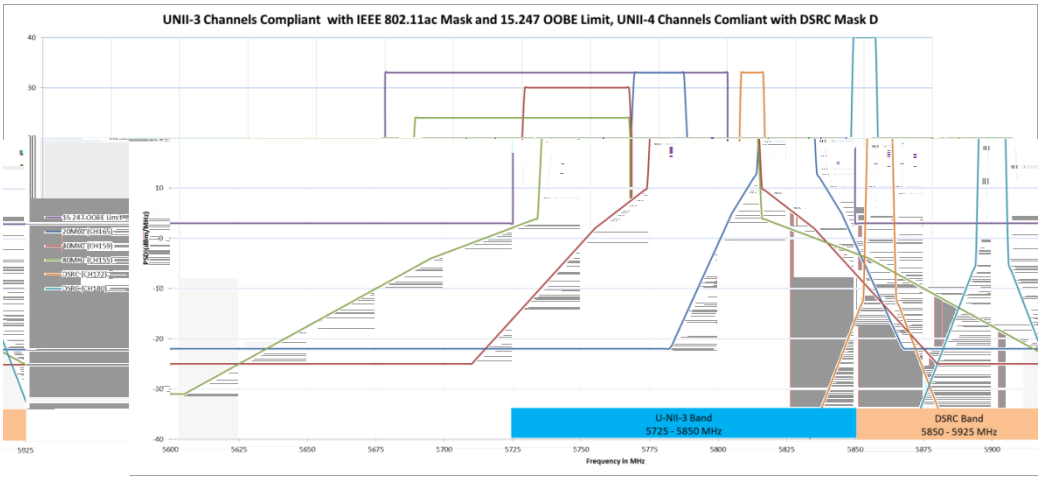

Figure 3: Graph depicting OOBE of U-NII-3 devices authorized under current FCC rules

In the past, automakers have claimed that "*as few as three outdoor U-NII devices could cause serious, har*

DSRC-based safety systems."[18/] This claim was based on the -8.9dBm/10 MHz allowed under the uniform rules adopted in 2014 for the U-NII-3 band (see Figure 4 below),[19/] which is 15dB below the limits for devices in the U-NII-3 band permitted under Section 15.247 of the rules before 2014.[20/]

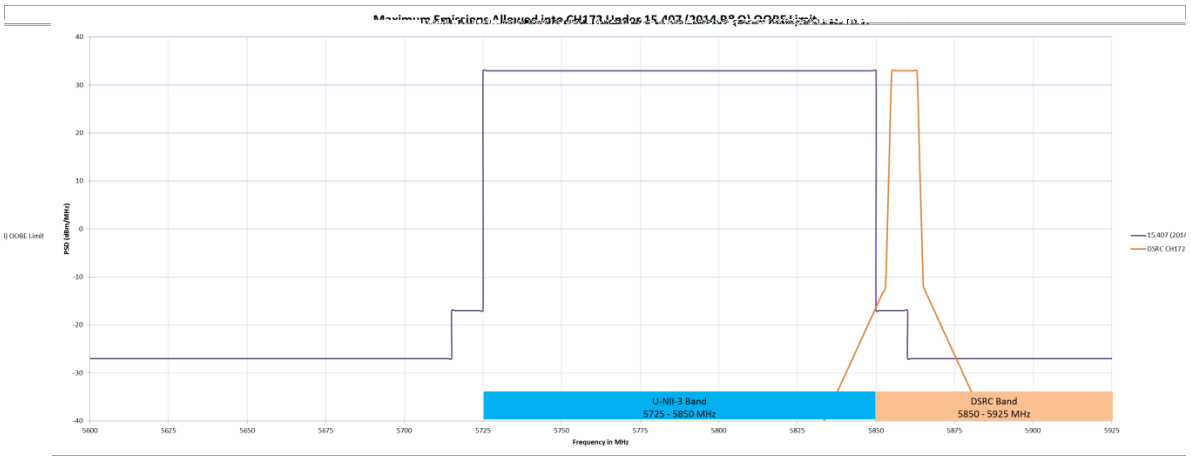

Figure 4: Graph depicting maximum energy emitted into channel 172 from 2014 R&O compliant device

As Broadcom and others have demonstrated, the recently modified U-NII-3 rules will reduce OOBE into the DSRC channels as new devices are introduced into the market over

18/ *See* Association of Global Automakers, Reply to Oppositions to Petition for Partial Reconsideration, ET Docket No. 13-49 (filed Sept. 2, 2014) (citing Mehdi Alasti & Mehran Nazari, *The Potential Interference Between Newly Proposed U NII3 Band & the Currently Assigned DSRC Band*, White Paper, AdGen Telecom Group, Inc., at 3 (Aug. 27, 2014) (") (emphasis in original)).

19/ *See Interference Analysis* at 13-18.

20/ Devices in the U-NII-3 band could previously be approved under the parameters specified in either Section 15.247 or Section 15.407 of the rules. In 2014, the Commission adopted regulations that required devices to be approved under Section 15.407.

time.[21/] Nevertheless, this more stringent requirement does nothing to address the massive deployment of U-NII-3 Wi-Fi devices that are already in the market and were approved to operate under Section 15.247 of the regulations. Therefore, the only feasible way that the Commission can provide any protection for delay-sensitive BSM DSRC traffic from OOBE caused by existing devices is to move the BSM from channel 172 to the top part of the DSRC band. The automakers' own analysis of devices manufactured and sold under the U-NII-3 rules previously in effect require that the Commission act immediately to move channel 172 before any DSRC devices are commercially deployed.

Broadcom therefore encourages the Commission to move the primary BSM from channel 172 to one of the three top most DSRC channels. The Commission should do this even while it considers and tests the various proposals that will enable U-NII-4 devices to operate with DSRC as discussed in this proceeding. The Commission should then act quickly to finalize the process outlined in this Public Notice to provide additional needed unlicensed spectrum for wireless operations.

Under Broadcom's proposal, DSRC channels 180, 182, and184 would be dedicated on an exclusive basis for delay-sensitive safety-related applications. The Commission may even wish to consider designating channel 184 as the primary BSM channel because it would be the furthest away from U-NII-3 traffic. Channel 180 could then be designated for normal- and higher-power safety messages. Finally, the bottom service channels would be designated to operate in 20 megahertz wide bandwidths as shown in Figure 4 below.

21/ *See* Opposition of Aerohive Networks, Inc., Broadcom Ltd, *et al.*to Petition for Reconsideration of the Association of Global Automakers and the Alliance of Automobile Manufacturers, ET Docket No. 13-49 (filed June 23, 2016).

Figure 4: Proposed DSRC Band Plan

As Broadcom has explained, separating DSRC safety-of-life channels from other channels is optimal from a planning and implementation perspective.[22/] Moving the safety channels to the top of the U-NII-4 band would allow them to operate on an exclusive basis. Applications such as collision avoidance systems should always be on, in a listening and receive mode, and with the ability to transmit real-time vehicle status. In contrast, applications such as

deploying DSRC vehicle-to-vehicle ("V2V") devices that can reliably operate alongside the hundreds of millions of authorized U-NII-3 devices already in the market.

Re-channelization will far better protect the relocated BSM traffic than the "detect and avoid" approach which does not address the OOBE from U-NII-3 devices as described above, and will likely create additional co-channel interference into the primary BSM channel 172 as outlined below. In particular, under the detect and avoid approach, DSRC devices would continue to operate in 10 megahertz wide channels, even when operating co-channel with other U-NII-4 devices. DSRC devices operating in a 10 megahertz wide channel would only be capable of detecting preamble signals of other transmitters operating with 10 megahertz wide channels, therefore forcing such DSRC devices to rely on energy detection for sharing purposes with non-DSRC devices. Generally, preamble detection is far more reliable at much lower energy levels than simple energy detection. Energy detection is typically limited to signals at -72 dBm or stronger, and preamble detection is reliable at levels that are close to the noise floor (*e.g.*, below -85 dBm). This difference in detection capability would allow a DSRC device to hear a Wi-Fi device at a least 2 to 4 times farther away. This occurs regardless of whether the Wi-Fi device is operating in a 20, 40, 80, or 160 megahertz wide signal configuration because all Wi-Fi preambles contain an integer multiple of copies of a single 20 megahertz preamble (*e.g.*, a 80 megahertz Wi-Fi signal contains four 20 megahertz Wi-Fi preambles).

Reliable DSRC detection of the presence of active Wi-Fi transmitters is important because a device that attempts transmission into a channel where interference is present has a lower probability of successful transmission. A channelization scheme where the lower DSRC traffic operates in 20 megahertz wide channels would enable mutual DSRC and Wi-Fi recognition at very low signal levels. Without mutual recognition, there would be scenarios

where the DSRC device would attempt to transmit because it believed the medium was idle, but in fact there were active Wi-Fi transmissions, leading to lower probabilities of successful DSRC transmissions.

In addition, a lack of alignment in DSRC and Wi-Fi transmissions may obscure the preambles of DSRC devices, which would result in a DSRC detection rate by Wi-Fi that is equal to the ratio of idle airtime to busy airtime. This may thereby lead to a delay in detecting the presence of DSRC devices. While issues caused by a DSRC 10 megahertz wide channel can be resolved in future versions of the Wi-Fi and/or DSRC standards, as previously demonstrated by Broadcom,[23/] this would not immediately enable intensive use of the U-NII-4 spectrum with today's Wi-Fi devices, nor could it be fully tested within the Commission's proposed time frame. In contrast, the Broadcom proposal outlined here enables more rapid sharing by moving the most delay sensitive DSRC traffic to non-shared channels and ensuring mutual recognition of the shared traffic.

IV. PRIORITY ACCESS FOR DSRC CAN BE PROVIDED EVEN ON SHARED CHANNELS

If the Commission determines that DSRC should be provided priority in the 45 megahertz of shared DSRC spectrum, that can be accomplished through current Enhanced Distributed Channel Access ("EDCA") technologies. DSRC traffic can be protected in the lower 45 megahertz of the U-NII-4 band because DSRC and Wi-Fi are both IEEE 802.11 standards, enabling sharing through similar medium access mechanisms (provided the mutual preamble recognition as described above). Under Broadcom's proposal, Wi-Fi would be able to detect low-level DSRC signals based on a combination of energy detection and carrier sensing,

23/ *Id.* at 4, 6.

including DSRC signals as low as -85 dBm.[24/] If a DSRC transmission is detected in a channel, then the Wi-Fi device would protect DSRCs by modifying the controlling parameters of its access mechanisms, providing priority for the DSRC device for at least two seconds in that channel. It would also be possible to vary the prioritization levels based on modifications to the EDCA as necessary.

Sharing can be best facilitated if the shared channels are 20 megahertz wide. This approach will take advantage of current and future 802.11ac and 802.11ax technologies because DSRC uses the same basic protocols. Mutual detection can most easily occur if the preamble fields are the same for unlicensed U-NII-4 and DSRC operations. Moreover, the Commission can test using existing 20 megahertz unlicensed devices to prove the feasibility of this concept. A 10 megahertz wide DSRC channel would still be used in the segment of the band dedicated for safety-of-life applications.

V. THE RE-CHANNELIZATION PROPOSAL BEST PROMOTES USE OF DEVELOPING WI-FI TECHNOLOGIES

The Commission has noted that the U-NII-4 band has the potential to "expand opportunities for innovative spectrum access models by creating new avenues for opportunistic and unlicensed use of spectrum and increasing research into new spectrum technologies."[25/] As noted above, under Broadcom's approach, the shared portion of the U-NII-4 band would extend from 5850 MHz to 5895 MHz, leading to an additional three 20 megahertz wide Wi-Fi channels, two 40 megahertz wide channels, a single 80 megahertz wide channel, and a single 160 wide

24/ *Id.* at 5-6.

25/ *NPRM* ¶ 75.

megahertz channel (see Figure 2 above). The Department of Transportation's proposed test plan contemplates the use of wider-band unlicensed channels.[26/]

The creation of the additional 80 and 160 megahertz channels is particularly important because there are only six 80 megahertz wide and two 160 megahertz wide channels currently available for operations in the US. Manufacturers must believe that their devices will be able to reliably access these larger channels before they build new use cases to take advantage of the spectrum. Going from two available 160 megahertz wide channels to three available channels may be the difference in whether such devices are widely deployed.

In contrast, the detect and avoid proposal would substantially limit unlicensed use of the U-NII-4 band, and even impair the UNII-3 band.[27/] The proposal dramatically restricts the amount of time available for Wi-Fi operations by requiring U-NII-4 devices to vacate the entire band and 25 megahertz of the UNII-3 band in the presence of even minimal DSRC use. So, even if DSRC traffic takes many years for adoption, or is never fully deployed, the detect and avoid method could prevent Wi-Fi systems from reliably accessing the U-NII-4 band.

Broadcom therefore urges the Commission to act quickly in allowing U-NII-4 shared access, which will create broader channels that will foster more flexible, efficient, and innovative Wi-Fi applications.

26/ *See DSRC-Unlicensed Device Test Plan*, Prepared for the Dep't of Transportation, Intelligent Transportation Systems – Joint Program Office, at 2.2.8 , 23-24(Aug. 2015). According to the test plan:

> "[T]he U-NII-4 band can overlap the 10 MHz DSRC channels with 20, 40, 80 and 160 MHz U-NII-4 channels. When the same energy is spread over a wider channel, the amount of energy available to interfere in the 10 MHz channel is less. Therefore it is possible that if the narrower U-NII-4 channels interfere in the DSRC channels, the wider U-NII-4 channels might not. This objective is to determine if such conditional sharing might be possible."

27/ *See* Cisco Ex Parte Letter at 5.

VI. CONCLUSION

Broadcom strongly supports the Commission's efforts to restart the process of making the U-NII-4 band available for unlicensed operations. The re-channelization approach will lead to that result more quickly and with greater protection of safety-of-life DSRC applications than the detect and avoid plan. The re-channelization proposal will designate spectrum exclusively for safety-of-life purposes, and continue to allow the remainder of the U-NII-4 band for shared use, supporting less sensitive DSRC applications. The detect and avoid proposal is not likely to result in additional spectrum being available for reliable unlicensed use, especially with regard to larger channel configurations. Moreover, pursuant to Broadcom's recommendation for moving the BSM channel, there will be less potential for interference to that channel than under the detect and avoid approach.

Respectfully submitted,

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