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 QUALCOMM INCORPORATED

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May 28, 2013

SUMMARY

Qualcomm is pleased to offer the FCC comments on the *5 GHz NPRM* specifically focused on whether it is possible to achieve two important policy objectives: 1) facilitating the rapid rollout and proliferation of innovative and potentially life-saving Dedicated Short Range Communications ("DSRC") services in the upper portion of the 5 GHz band, that is, the band of spectrum that was allocated for this purpose many years ago; and, 2) exploring the possibility of whether any portion of the 75 MHz now allocated for DSRC can be shared by the latest generation of Wi-Fi, *i.e.*, 802.11ac, on a secondary and completely non-interfering basis, thereby ensuring the absolute protection of any and all DSRC safety-of-life communications.

Qualcomm is strongly committed to providing wireless technology and chipsets to enable the speedy deployment of DSRC services, which have tremendous potential to improve vehicular safety. Qualcomm Atheros ("QCA") has long been an active developer and proponent of DSRC technology, and the DSRC research and trials conducted to date have largely used equipment containing Qualcomm chips. Because safety applications using DSRC technology can provide tremendous benefits to the American public, it is crucial that DSRC services be deployed as quickly and as broadly as possible. As the FCC notes in the *NPRM,* DSRC "involves vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communications [that] can save lives by warning drivers of an impending dangerous condition or event in time to take corrective or evasive actions." *NPRM* at ¶ 93. The FCC, therefore, should not take any action that will delay or jeopardize achieving these important objectives, which have been a key area of focus for the National Highway Traffic Safety Administration ("NHTSA") and other agencies within the U.S. Department of Transportation ("DOT"). Specifically, the FCC proceeding should not result in any delay in NHTSA's current schedule to make a regulatory decision regarding DSRC by the end of 2013.

By the same token, Qualcomm also is a leading supplier of chips for Wi-Fi, including chips that are enabling the rapid proliferation of 802.11ac — the latest Wi-Fi technology that offers greater throughput and improved quality of service. Given the proliferation of Wi-Fi devices and services and the positive impact that Wi-Fi has had on so many facets of American life, it is important to provide sufficient spectrum for 802.11ac to support its growth. It is important to highlight that 802.11ac uses wide contiguous swaths of spectrum — up to 160 MHz — and, this technology is ideal for higher bands, such as 5 GHz, because Wi-Fi is used for short range connectivity, where radio signals need not propagate over large distances. Indeed, providing a wider contiguous swath of spectrum for 802.11ac at 5 GHz will help fulfill an important objective of the Commission's multi-faceted efforts to ease the spectrum crunch.

Qualcomm is interested in exploring whether these two important policy objectives can be harmonized — that is, whether it is possible to fully enable and protect from harmful interference DSRC services, especially the incumbent DSRC safety services, while providing additional contiguous spectrum for 802.11ac at 5 GHz on a compatible, secondary, and absolutely non-interfering basis. It is no answer to the spectrum crunch to order spectrum sharing between the two services if doing so will result in harmful interference to DSRC. But it is also no answer to the spectrum crunch to simply rule out ideas for how to arrange the spectrum more efficiently if it is clear that this can be done in a manner that guarantees the absence of harmful interference to safety communications and avoids any adverse impact upon the rollout of DSRC. Qualcomm submits these comments in the hopes of achieving the closely interrelated goals of both ensuring the quickest possible deployment of DSRC vehicle safety services, and enabling the major portion of the 75 MHz currently allocated for DSRC services to be made available on a secondary, completely non-interfering basis to create wider swaths of contiguous spectrum at 5 GHz for 802.11ac-based Wi-Fi.

The *5 GHz NPRM* proposes to make the entire DSRC service band at 5.850 to 5.925 GHz available for shared Wi-Fi use and seeks comment on how spectrum sharing can be accomplished between Wi-Fi and DSRC communications technologies. It is clear that were the FCC simply to order that the entire 75 MHz shall be shared, it would place DSRC safety services at risk of harmful interference. Also, the NTIA report referenced in the *NPRM* specifies an entirely reasonable research plan to analyze the untested proposition that spectrum sharing between the two services within the entire DSRC band is possible. Qualcomm is nonetheless concerned that the passage of time and uncertain resolution to following this plan could significantly delay any rollout of DSRC, a result that should be unacceptable to the Commission, NHTSA and DOT, and all other stakeholders, given the potential safety benefits of DSRC. Qualcomm therefore offers an option for consideration that will allow DSRC-based safety applications to be rolled out in a portion of the DSRC spectrum in which they will have exclusive use. This suggestion would significantly reduce the time and effort for NTIA to analyze co-existence with DSRC safety applications and should allow the DSRC roll-out to proceed without delay. By taking this portion of the spectrum off the table for sharing, the rollout of DSRC safety services should occur broadly, rapidly, and without any threat of interference. The suggestion also creates a path for 802.11ac to operate on a shared basis in another portion of the DSRC spectrum on a secondary basis, if and only if this spectrum sharing can be proven to work successfully on a completely non-interfering basis.

Thus, the idea is to take spectrum sharing off the table for DSRC safety-related services, and to consider it for non-safety related services, but only if the absence of interference can be verified. Doing so would allow the DSRC roll-out to proceed unabated and enable 802.11ac to operate in a wider swath of contiguous spectrum if it can do so without impairing DSRC.

As noted previously, 802.11ac uses channels of up to 160 MHz of contiguous bandwidth. Under the Wi-Fi channelization of the 5 GHz band, the uppermost 20 to 30 MHz of the DSRC spectrum would fall outside any 40/80/160 MHz channel; thus, there would be little, if any, tangible benefit in attempting to use this spectrum for 802.11ac since that technology is designed to use 40/80/160 MHz channels. Thus, Qualcomm believes that placing the uppermost 20 to 30 MHz spectrum off limits for Wi-Fi and providing exclusive use for DSRC safety services within that portion of the spectrum will provide absolute protection for the DSRC safety services without sacrificing any spectrum useful for 802.11ac-based Wi-Fi. In this way, the roll out of the DSRC safety services can and should proceed unabated, and the FCC and NTIA can focus their efforts on whether the lower 45 to 55 MHz may be shared by non-critical DSRC uses and Wi-Fi without harmful interference.

The virtues of this potential solution are that it: (i) simplifies the necessary spectrum sharing R&D and verification testing; and (ii) takes off the table the notion of sharing the spectrum on which DSRC safety services operate without impacting 802.11ac-based Wi-Fi because the uppermost 20 or 30 MHz of the 5850 to 5925 MHz band will not be used for any 40/80/160 MHz channel. Furthermore, it can be implemented with minimal adverse impact on the rollout of critically important DSRC safety services, which, again, is a crucial policy objective. If this proposal can be implemented successfully, as we believe it can, it would still allow the creation of up to four contiguous 160 MHz blocks of spectrum in the expanded 5 GHz band that the 802.11ac standard was designed to use, while limiting the impact on DSRC services.

To allow for successful spectrum sharing between non-critical DSRC services and 802.11ac in the lower 45 to 55 MHz, both services should use 20 MHz-wide transmissions and consider implementing the priority mechanism in the IEEE 802.11e standard to prioritize DSRC transmissions against 802.11ac services. Undoubtedly, the options presented herein must be further studied and tested before such sharing is ordered, but any such testing should be much simpler than testing sharing in the entire DSRC band because it would be limited to sharing with non-critical DSRC services, as DSRC safety services would operate exclusively in the uppermost 20 or 30 MHz of the DSRC band.

Qualcomm looks forward to continued discussions with the FCC and all interested stakeholders as they review the technical options presented in these comments.

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COMMENTS OF QUALCOMM INCORPORATED

QUALCOMM Incorporated ("Qualcomm") is pleased to comment on the Commission's *5 GHz NPRM*[1] to explore whether it is possible to dedicate the upper 20 or 30 MHz portion of the 5850 to 5925 MHz DSRC band for the exclusive operation of DSRC safety services while sharing the lower 55 or 45 MHz of the band between DSRC non-critical services and unlicensed Wi-Fi operations operating under the 802.11ac standard.

As the Commission explains in the *5 GHz NPRM*, enabling U-NII device operation within the two proposed additional bands, *i.e.*, the U-NII 2B band at 5350 to 5470 MHz and U-NII 4 band at 5850 to 5925 MHz, would provide two additional 160MHz-wide Wi-Fi channels (to create a total of four 160 MHz-wide channels) to help achieve multi-gigabit per second Internet access at 5 GHz. At the same time, licensed DSRC operations at 5850 to 5925 MHz are designed to support critical vehicle safety and other transportation-related broadcast message services. If methods to mitigate interference between the Wi-Fi and DSRC services can be

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1 *See* 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, *Notice of Proposed Rulemaking*, FCC 13-22 (rel. Feb. 20, 2013) ("*5 GHz NPRM*" or "*NPRM*").

successfully implemented, both the commercial Wi-Fi and vehicle safety uses at 5850 to 5925 MHz can be realized in a timely manner.

Qualcomm is deeply committed to DSRC and to the widespread availability of high speed Wi-Fi for purposes of offloading traffic from today's powerful and ubiquitous 3G and 4G cellular networks. There is no question that both DSRC and Wi-Fi technologies can benefit from technically viable, cost-effective, and near-term solutions. Qualcomm suggests in these comments that the community of stakeholders consider approaches that fully protect DSRC safety services, such as by giving them exclusive use of 20 to 30 MHz that 802.11ac-based Wi-Fi will not use, and by sharing the remaining 55 to 45 MHz of spectrum between non-critical DSRC services and Wi-Fi by providing priority to the incumbent DSRC services.

Qualcomm believes this option can allow the current DSRC technology validation programs to move forward more quickly and thus minimize the risk that the rollout of DSRC will be delayed by studies of sharing the entire DSRC band with Wi-Fi, while enabling all the spectrum that the FCC has identified for 40/80/160 MHz-wide Wi-Fi applications. To be clear, the spectrum that Qualcomm identifies to be allocated exclusively for DSRC use will not affect any of the additional 40, 80, or 160 MHz-wide channels that the FCC is proposing to allocate for 802.11ac-based applications.

Hence, the approach described in these comments is intended for the Commission's consideration and to facilitate discussion among the affected stakeholders. As a stakeholder itself in both DSRC and Wi-Fi technology camps, Qualcomm offers what it hopes is a viable and minimally disruptive suggestion in the hopes of achieving the expeditious delivery of both critical driver safety communications technologies via the DSRC service and expanded Wi-Fi benefits via additional U-NII spectrum. As a well-established wireless chipset and technology provider to consumers and many commercial industries, including the transportation industry, Qualcomm believes that it is important to offer a potential solution that addresses the requirements posed by the *NPRM*[2] with the lowest possible risk and a better chance of successful near-term deployment.

Qualcomm's approach is comprised of the following elements:

1. Retain the exclusive right for use for DSRC safety services in the upper 20 or 30 MHz portion of the current DSRC band;

2. Enable sharing of spectrum between Wi-Fi and DSRC non-safety services in the lower 55 or 45 MHz portion of the 5850 to 5925 MHz band; and

3. Encourage the use of 20 MHz -wide transmissions in the shared portion of the band and appropriate priority mechanisms, including those provided in the IEEE 802.11e standard, to prioritize DSRC transmissions.

Qualcomm believes that this option: (i) is straightforward and simple; (ii) can be readily manufactured extrapolating from existing chip designs; and (iii) eliminates the need to develop and test complex and new spectrum sharing techniques and protocols that would be necessary if the entire DSRC band is opened to shared Wi-Fi use. Qualcomm's proposed approach limits risk and uncertainty, and timely provides the benefits of advanced DSRC and Wi-Fi technologies.

BACKGROUND

Founded more than a quarter century ago, Qualcomm has pioneered the development of many innovative wireless technologies. For example, the company invented the Code Division Multiple Access ("CDMA")-based cellular communications technology that is used around the globe for countless wireless voice and broadband communications devices, services, and

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2 *See NPRM* at ¶¶ 101, 112.

applications. Today, Qualcomm is the world's largest provider of multi-mode, multi-band 3G and 4G wireless chipset technology integrated into today's mobile phones and consumer electronic devices. The company also broadly licenses its technologies to hundreds of manufacturers worldwide that make wireless network equipment, handsets, and other consumer devices.

Qualcomm is redefining the way people incorporate wireless devices and services into everyday life. The company's innovations enable opportunities across the wireless and wired value chains by making devices and networks smarter and faster, content richer, and communications more personal and affordable to people everywhere. Qualcomm Atheros, which is part of the Qualcomm Mobile & Computing division of Qualcomm Technologies, Inc. (itself wholly-owned by Qualcomm Incorporated), provides a leading portfolio of connectivity technologies, including Wi-Fi, HomePlug Powerline, Location, Bluetooth, FM, NFC, Ethernet, and PON technologies for the mobile, networking, computing, automotive, and consumer electronics markets.

Qualcomm also has a strong commitment to the transportation sector. Qualcomm's roots in the connected vehicle space began with the launch of our OmniTRACS service in 1988. OmniTRACS pioneered mobile communication and geo-location tracking technology for trucking fleet management. To date, well over 1.5 million OmniTRACS units have been installed in 39 countries across 4 continents.

In addition, a decade ago, Qualcomm partnered with GM/OnStar to deliver the first widely deployed passenger car telematics system. Since then, Qualcomm has expanded its automotive footprint by offering its CDMA and UMTS modem chipsets to a majority of car makers around the world.

QCA's industry leading WLAN chips also are used in the majority of DSRC devices that have been tested to date, including those used by the Crash Avoidance Metrics Partnership ("CAMP") and DOT in Safety Pilot Driver Clinics and Model Deployment work. Building on that success, Qualcomm now offers state-of-the-art DSRC, WLAN, and CDMA/UMTS/LTE chipsets for Intelligent Transportation Systems ("ITS") systems.

Not surprisingly, the company's long-standing motor vehicle business provides a strong motivation to seek a coexistence solution for DSRC and Wi-Fi that can be deployed successfully and quickly. Hence, Qualcomm is working hard to enable a solution to timely enable the implementation of DSRC safety services while expanding the commercial benefits of Wi-Fi.

DISCUSSION

I. The FCC Should Consider Dedicating The Uppermost 20 or 30 MHz Of The Existing DSRC Band For Vehicle Safety Communications

A. The FCC's Proposed U-NII 4 Band

The *5 GHz NPRM* proposes to open the entirety of the 5850 to 5925 MHz DSRC band for U-NII Wi-Fi usage.[3] This new U-NII band is referred to as the U-NII 4 band and adopts the rules in FCC Rule Section 15.407. Figure 1 below shows the proposed spectrum allocation and Out-of-Band Emissions ("OOBE") rules relevant to DSRC.

[3] *See NPRM* at ¶¶ 2, 75-77, & 92-101.

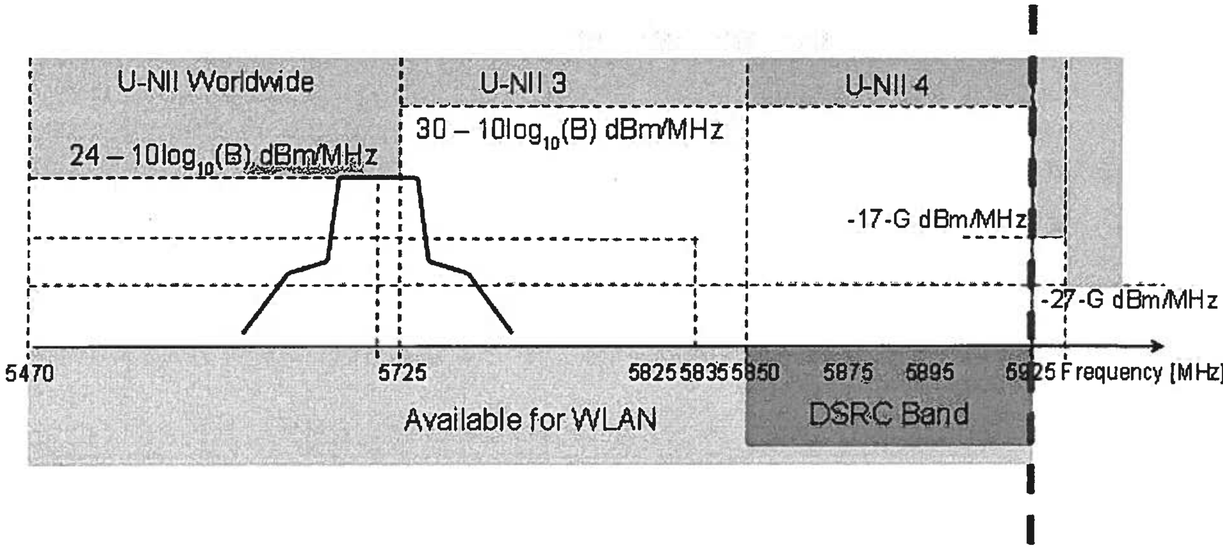

Figure 1. *NPRM* proposed spectrum allocation and OOBE requirements

The FCC proposes to adopt for the U-NII 4 band the current rule for the U-NII 3 band, *i.e.,* OOBE must be less than - 17 - G dBm/MHz (where G is the transmit antenna gain) within 10MHz from the U-NII 4 boundary and must be less than - 27 – G dBm/MHz beyond 10 MHz from the band edge.

B. <u>Problems With Sharing The Entire DSRC Band With Wi-Fi</u>

The main challenge to DSRC use as proposed in the *5 GHz NPRM* is that Wi-Fi devices would operate on the same channels as DSRC devices even though all DSRC testing and deployment studies to date have been predicated on exclusive, non-interfering use by DSRC. While the *NPRM* stipulates DSRC as the primary user in this spectrum, it is virtually impossible to completely eliminate interference from the wide deployment and use of Wi-Fi devices throughout the DSRC band, especially because Wi-Fi usage within vehicles via mobile hotspots and vehicle cellular connectivity is growing every day.

The FCC's *5 GHz NPRM* proposal introduces particular problems for DSRC Channel 172, where critical safety message communications reside — and where virtually all vehicle-to-vehicle ("V2V") and vehicle-to-infrastructure ("V2I") safety applications have been tested.[4] The *NPRM* proposes to share this channel with U-NII devices, thus introducing the potential for harmful interference. Following through on this proposal would invalidate previous safety testing results and necessitate additional rounds of interference studies.

Another complication introduced by sharing the entire DSRC band is that DSRC services currently are designed to operate with a 10 MHz clock,[5] which means that DSRC channels would not be detectable by existing Wi-Fi devices. To address this problem, new signal detection techniques would have to be developed and tested, consuming time and energy from both the Wi-Fi and DSRC industries. To be clear, underlying any real solution is the practical implementation of sharing/priority-yielding rules. This may be quite difficult, for example, if a different time delay is imposed on Wi-Fi transmissions when DSRC signals are detected because uniform conformance of U-NII devices to any such priority scheme may be difficult to enforce.

In light of the aforementioned issues, there is well-justified concern about the potential adverse impact of this proceeding on the DSRC rollout. Indeed, the development of new types of spectrum sharing techniques and the NTIA testing schedule, which runs through December 2014, also introduce uncertainty to the viability of the safety proposition, as these issues and testing will not be resolved in 2013 or even 2014.[6] Also, if there is high market penetration of

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4 *See* F. Ahmed-Zaid, et. al., "Vehicle Safety Communications – Applications (VSC-A) Final Report," DOT HS 811 492A, National Highway Traffic Safety Administration (Sept. 2011); U.S. Dep't of Transportation Safety Pilot Program, *available at* http://www.its.dot.gov/safety_pilot/index.htm.

5 *See* IEEE Std. 802.11p, 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 (July 2010); ETSI ES 202 663: European Profile Standard for the Physical and Medium Access Control Layer of Intelligent Transport Systems Operating in the 5GHz Frequency Band (2010).

6 *See NPRM* at ¶ 103.

DSRC for vehicle safety purposes, DSRC priority needs may obviate any use and thus any benefit from expanding Wi-Fi to DSRC spectrum where there is appreciable vehicular traffic.

C. Allocating The Uppermost 20 or 30 MHz Exclusively For DSRC Use Would Protect DSRC Safety Services from Harmful Interference

In light of the concerns discussed in Section I.B above, Qualcomm offers two options for how to enable the rapid roll out of DSRC and the full protection of DSRC safety services while making available additional spectrum for Wi-Fi on a non-interfering basis. Allocating the uppermost 20 or 30 MHz for DSRC usage exclusively would allow for the successful deployment of DSRC systems and the timely use of the majority of the proposed U-NII 4 band for 802.11ac-based Wi-Fi and its associated high-capacity 80 and 160 MHz-wide channels. A summary of the two options is provided in Table 1 below.

Features	Option No. 1	Option No. 2
Dedicated DSRC spectrum	**20 MHz** (5905-5925 MHz)	**30 MHz** (5895-5925 MHz)
Shared Wi-Fi/DSRC spectrum with DSRC using 20MHz service channels (Ch173/177)	**55 MHz** (5850-5905 MHz): • Wi-Fi uses a 10MHz guard band (5895-5905 MHz)	**45 MHz** (5850-5895 MHz) • No explicit guard band defined • Need a more restrictive OOBE rule
OOBE rule	• - 17 - G dBm/MHz at 5905 MHz • - 27 – G dBm/MHz at 5915 MHz where G is the Tx antenna gain	• - 5 - G dBm/MHz at 5895 MHz • - 17 - G dBm/MHz at 5905 MHz • - 27 – G dBm/MHz at 5915 MHz

Table 1. Technical Features of Two Potential Solutions

The main features of these options include dedicated DSRC safety and control channels, 20 MHz DSRC service channels in the shared spectrum, and facilitation of Wi-Fi devices to satisfy OOBE rules. Each of these features is discussed in greater detail below.

Both options would allocate the upper (20 or 30 MHz) portion of the original 75 MHz DSRC spectrum to dedicated DSRC use and allow the lower portion (55MHz or 45MHz) to be shared with Wi-Fi rather than open the entire DSRC spectrum.[7] In implementing either approach, DSRC critical safety channels would be moved to the dedicated DSRC spectrum (Channels 182/184, and possibly Channel 180) to minimize the impact of spectrum sharing to the current V2V/V2I testing programs. Since all these channels have the same channel bandwidth and virtually identical physical layer properties as the well-tested Channel 172, both options minimize the need for a large body of channel propagation and, importantly, additional V2V/V2I safety studies.[8] And, importantly, all the identified 40/80/160 MHz -wide channels for Wi-Fi would be made available, and only a single 20 MHz channel (Channel 181) would be excluded.

A key result from Qualcomm's testing and analysis is that Wi-Fi chipsets may have difficulty satisfying the more stringent OOBE rule in the *5 GHz NPRM* if U-NII channels are

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7 It should be noted that 20 MHz-wide IEEE Channel 181 runs from 5895 to 5915 MHz, and Channel 181 is not part of any IEEE-defined 40, 80, or 160 MHz block. Also, the 10 MHz-wide 5915 to 5925 MHz portion of the DSRC band, which sits directly above Channel 181, is not part of any IEEE channel. Thus, the above options impact only a single 20 MHz Wi-Fi block that would not be used for wideband (*i.e.*, 40/80/160 MHz-wide) IEEE 802.11ac operation. *See, e.g.,* Dep't of Commerce, "Evaluation of the 5350-5470 MHz and 5850-5925 MHz Bands Pursuant to Section 6406(b) of the Middle Class Tax Relief and Job Creation Act of 2012" at 3-3 ("NTIA Report") (Jan. 2013).

8 While moving safety Channel 172 may require a channel definition change, the physical characteristics of Channel 172 and upper part of the spectrum are very similar. And, while some testing may be needed, it will be substantially less than developing a new hardware capability in 802.11ac and testing the co-existence afterwards – as would be required if the entire DSRC band is shared with Wi-Fi.

adjacent to DSRC channels. Therefore, the above options are designed to facilitate U-NII devices satisfying stringent OOBE rules while protecting DSRC operation from interference.

Figure 3 and Figure 4 below illustrate the two above options by showing the spectrum allocation and OOBE requirements. Both Figures 3 and 4 define the same OOBE levels at 5905 MHz and higher frequencies; the only difference is whether the U-NII 4 band ends at 5905 MHz (as shown in Figure 3) or at 5895 MHz (as shown in Figure 4).

Option No. 1 (from Table 1 above) is illustrated in Figure 3 below. With the current IEEE channel list definition,[9] a 10 MHz guard band (5895-5905 MHz) is placed between the highest WLAN channel and the DSRC channels. Currently, there is a 10 MHz guard band placed at the lower end of the U-NII 3 band (5725-5735 MHz), and it is subject to the same OOBE requirements (*i.e.*, Section 15.407 rules) as the *NPRM* proposes for the U-NII 4 band. With that guard band, Wi-Fi devices can satisfy the U-NII 3 OOBE requirements, and thus Option No. 1 will not impose on Wi-Fi devices extra performance loss or any additional burden of hardware modification to satisfy the more stringent Section 15.407 OOBE rule proposed in the *NPRM*.

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9 IEEE 802.11-2012 Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications. IEEE, 2012.

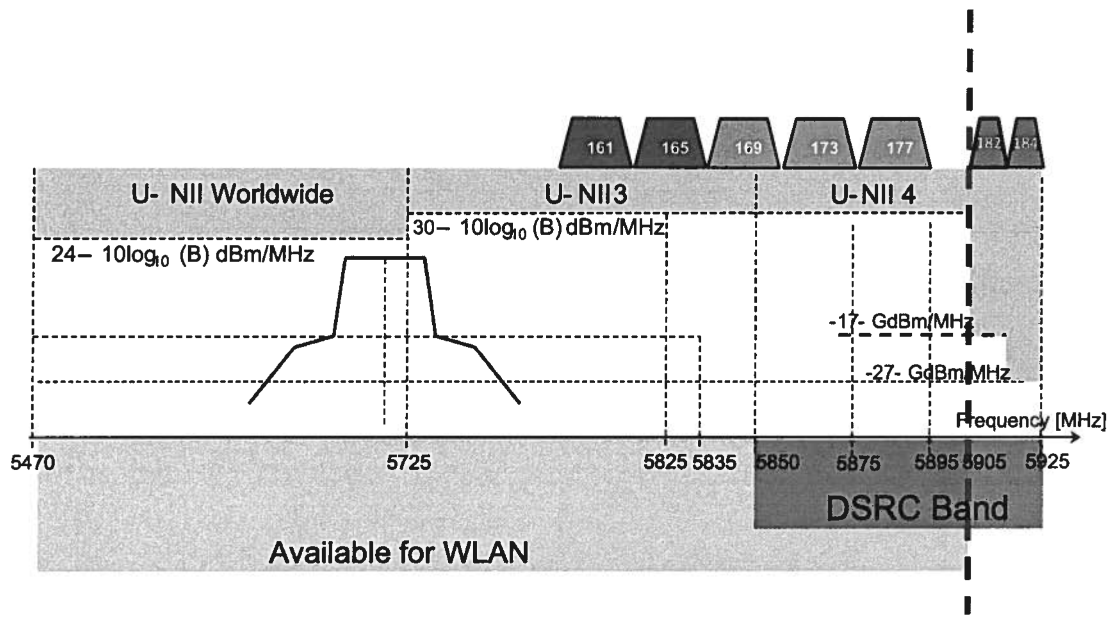

Figure 3. Option No. 1: 20 MHz dedicated to DSRC with the same OOBE requirements as proposed in the *NPRM*

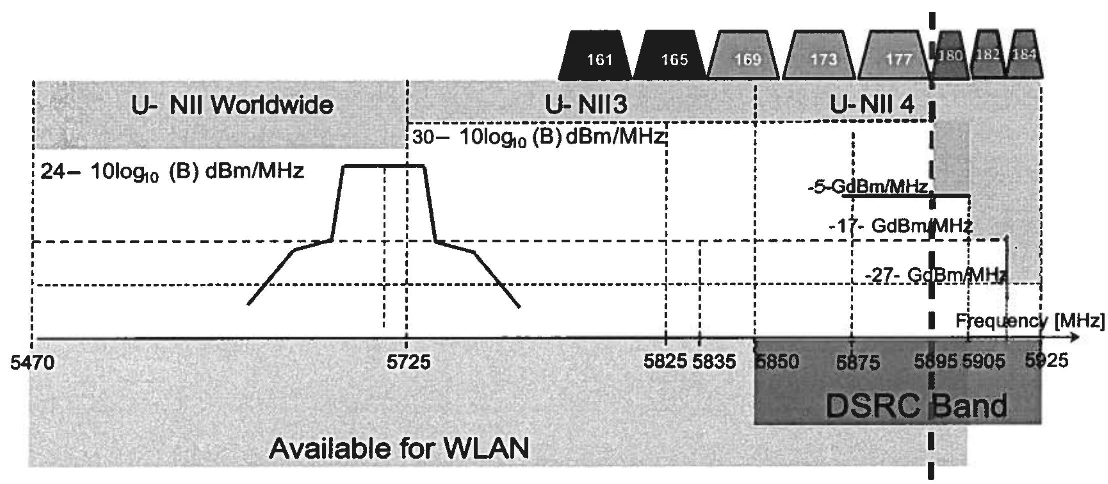

Figure 4. Option No. 2: Dedicating 30 MHz to DSRC and relaxing the OOBE requirements

Option No. 2, shown in Figure 4 above, gives an additional dedicated 10 MHz channel (*i.e.*, Channel 180) to DSRC but relaxes OOBE requirements for U-NII devices on that channel (5895-5905 MHz). Qualcomm's simulation and testing results show that even with the OOBE at the band edge relaxed to - 5 - G dBm/MHz (where G is the transmit antenna gain), if Wi-Fi devices use channels close to the proposed U-NII 4 upper band edge, they will need to lower their maximum transmission power to approximately 20 dBm for VHT40/80/160 packets and 12 dBm for VHT20 packets. Although Option No. 2 essentially caps the transmission power for Wi-Fi, the maximum allowed transmission power levels are still sufficient for the intended low-power short-range communication Wi-Fi use cases for this band.

D. It Is Possible to Use Most Of the Identified Spectrum for Both DSRC and Wi-Fi

The above options would have DSRC and Wi-Fi share the lower portion of the DSRC band and have the DSRC service channels operate with a 20 MHz bandwidth for several reasons beneficial to both Wi-Fi and DSRC devices.

It is easier for Wi-Fi devices to detect DSRC activities and yield priority to them when DSRC uses the same 20 MHz operation basic to all Wi-Fi OFDM standards.[10] Given that both Wi-Fi and DSRC "speak" the same 20 MHz "language," Wi-Fi devices can detect DSRC preambles, and even decode DSRC packets and check for bits that identify them, without additional hardware changes. And, by using existing Quality of Service ("QoS") enhancement mechanisms in Wi-Fi, DSRC can be treated with higher priority. In particular, the enhanced distributed channel access ("EDCA") mechanism defined in IEEE 802.11e is a possible candidate, as this has been adopted in many existing Wi-Fi products and tested in the field. This would allow packet-by-packet channel sharing and maximize the spectrum usage for both DSRC and Wi-Fi devices. Moreover, because 20 MHz DSRC packets occupy only half of the air time of the 10 MHz alternative, this approach provides Wi-Fi greater access to the shared spectrum.

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[10] Although the IEEE 802.11n standard defines new 40 MHz OFDM channels and the IEEE 802.11ac standard further defines 80/160 MHz OFDM channels, all of these new channels have the same subcarrier spacing (312.5 kHz) as that of the basic 20 MHz channel first defined in the IEEE 802.11a standard. In contrast, the 10 MHz OFDM channels basic to the IEEE 802.11p standard used by DSRC have a subcarrier spacing of 156.25 kHz; the 10 MHz channels are in a "half-clocked" operation mode with double symbol times.

On the other hand, coexistence between 20 MHz (and possibly wider bandwidth) Wi-Fi operation and 10 MHz DSRC operation is likely to be much more challenging. For example, Wi-Fi devices may need additional hardware to detect 10 MHz DSRC packets and new spectrum sharing techniques would need to be developed and tested through concerted effort from both Wi-Fi and DSRC experts. The development and deployment of a viable solution would require considerable time, effort and expense.

Packet error rate ("PER") performance is the main concern in using 20 MHz channelization for DSRC for two main reasons: (i) the pilot tone spacing of the 20 MHz channel doubles that of the 10 MHz channel, which may increase the channel tracking errors in challenging mobility environments; (ii) the delay spread in some mobility environments can be larger than the guard interval of the 20 MHz channel and create inter-symbol interference, which degrades the Signal-to-Noise Ratio ("SNR").

DSRC channels present the twin challenges of mobility and multipath for channel estimation. Higher mobility means coherence times as short as 0.25 to 0.30 ms for vehicular safety applications.[11] This requires channel tracking over time since the initial channel estimate from the preambles becomes obsolete even before the packet duration is comparable to the coherence time. Rich multipath brings in frequency selectivity and narrows the coherence bandwidth to as low as 410 kHz for DSRC channels.[12] The combination of these two effects requires good channel tracking in both time and frequency.

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11 *See* L. Cheng *et al.*, "A Measurement Study of Time-Scaled 802.11a Waveforms over the Mobile-to-Mobile Vehicular Channel at 5.9GHz," IEEE Communications Magazine, pp. 84-91 (May 2008); Tan *et al.*, "Measurement and Analysis of Wireless Channel Impairments in DSRC Vehicular Communications," Technical Report, U.C. Berkeley (Apr. 2008).

12 *See* Cheng *et al.*,

The 20 MHz channels encounter more frequency selectivity across the doubled bandwidth and their doubled pilot tone spacing means larger channel estimation errors when the same number of pilots is used as in 10 MHz operation. Fortunately, 20 MHz operation overcomes this with a shorter packet duration (half that of 10 MHz operation), which alleviates tracking errors that would accumulate over time. Since 20 MHz operation has the above two conflicting effects on channel tracking, its impact on decoding performance depends on the channel scenario: whether the channel tracking errors accumulated over time dominate those over frequency. Figure 5(a) on page 15 below shows the PER comparison between 10/20 MHz operations under an equal-strength two-tap channel model with a maximum excess delay of 0.5 μs, which is smaller than both the Guard Intervals ("GIs") of 10/20 MHz operations (1.6 μs and 0.8 μs, respectively). The PER curves of the two channelization methods have a crossover at a relative velocity of 110 km/h (or 68.4 mph), with 20 MHz operation outperforming 10 MHz operation at higher mobility.

Consider also the impact of using the 20 MHz channelization under excessive delay spread, where the channel impulse response has significant energy with 0.8 μs or larger delay after the first arrival path. In this case, the resulting inter-symbol interference ("ISI") and inter-carrier-interference ("ICI") will introduce a SNR cap and hence an error floor. These will degrade the PER performance. However, such effects are small in most communication scenarios where the energy outside the GI is small, and this will not be the bottleneck for decoding, especially at low modulation rate options. This is illustrated in Figure 5(b) with simulation results using the ITU VehA model[13] with an extreme excess delay spread of 2.51 μs. Here we observe moderate performance degradation of 20 MHz channelization at lower speeds

13 ITU-R Recommendation M.1225, "Guidelines for Evaluation of Radio Transmission Technologies for IMT-2000" (1997).

when compared to 10 MHz channelization. When mobility is higher, the difference becomes smaller, and eventually 20 MHz operation performs even better than 10 MHz operation, again due to the shortened packet duration. Note that the ITU VehA channel model has much larger root mean square and maximum delay spreads than the measured delay statistics of DSRC channels reported by several groups of researchers.[14] Hence the results in Figure 5(b) show a worst case scenario for 10/20 MHz operations in DSRC channel conditions. For most mobility channel scenarios, the difference between the two is smaller and the crossover in performance may happen at much smaller relative velocities.

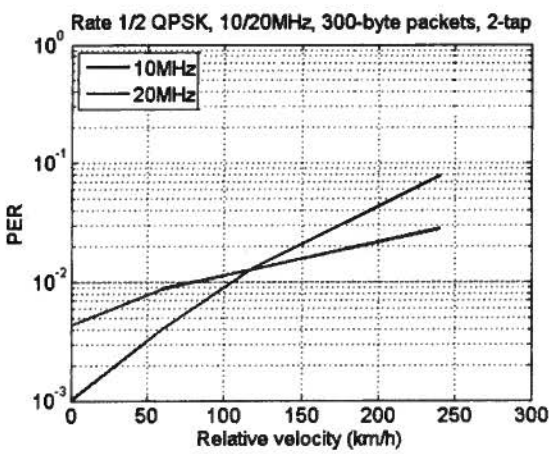

Figure 5(a)

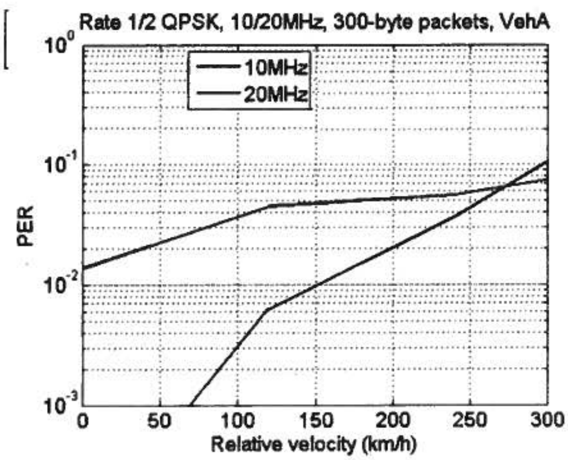

Figure 5(b)

To summarize, the key OFDM parameters of 10 MHz and 20 MHz DSRC packets and their impact on decoding performance are provided in Table 2. 20 MHz channelization has an advantage in high mobility environments and 10 MHz channelization behaves better in larger delay spread scenarios. However, even at a difficult channel condition, the 20 MHz operation

[14] *See* Cheng *et al, supra*; Tan *et al. supra;* ITU-R Recommendation M.1225, "Guidelines for Evaluation of Radio Transmission Technologies for IMT-2000," 1997; L. Cheng et. al., "Mobile Vehicle-to-Vehicle Narrow-Band Channel Measurement and Characterization of the 5.9 GHz Dedicated Short Range Communications (DSRC) Frequency Band," IEEE JOURNAL ON SELECTED AREAS IN COMMUNICATIONS, Vol. 25, No.8, pp.1501-1516 (Oct. 2007).

suffers only a minor performance loss at lower relative velocities. In all cases with either 10 MHz or 20 MHz channelization, our simulations show reasonable performance (<10% in PER) with our Wi-Fi-enhanced receiver.

PHY parameters	10 MHz	20 MHz	Impact to decoding performance
OFDM GI	1.6 μs	0.8 μs	Longer GI better covers delay spread
Carrier spacing	156.25 kHz	312.5 kHz	Smaller carrier spacing leads to better channel tracking
Packet duration*	0.44 ms	0.22 ms	Shorter transmission leads to better channel tracking

Table 2. OFDM parameters of 10 MHz and 20 MHz DSRC packets

* Assuming ½ QPSK for 300-byte basic safety message (BSM) payload

* * *

As a long-time wireless chip and solutions provider for all types of users, including the users of our nation's transportation systems, Qualcomm has a vested interest in ensuring the successful deployment of both DSRC and Wi-Fi within the existing DSRC service band. Qualcomm intimately understands the significant benefits to automotive safety that the widespread use of DSRC communication technologies can provide. At the same time, Qualcomm fully appreciates the benefits of expanding the available spectrum for 5 GHz unlicensed Wi-Fi devices. Thus, the company is motivated to provide a solution with the lowest risk to all stakeholders and the nearest term deployment potential.

The two options detailed above, which: (i) retain the upper fraction of the 5850 to 5925 MHz spectrum band for exclusive DSRC use, (ii) open the majority of DSRC band to satisfy the growing needs of Wi-Fi, and (iii) encourage 20 MHz operation in the shared spectrum to enable spectrum sharing, represents a potential path forward that reduces uncertainty and shortens development and deployment timelines. The two options maintain the exclusive right of DSRC in part of the spectrum to support highly promising, safety-of-life vehicle DSRC communications and enable sharing on the rest of the spectrum on a non-interfering basis. Importantly, they eliminate the need for complex and new spectrum sharing techniques and testing because they offer the assurance of safety and can be easily manufactured by extrapolating from current chip designs.

We look forward to continued discussion of these potential solutions with the FCC and all industry stakeholders.

CONCLUSION

Qualcomm is pleased to offer the FCC two potentially viable options to enable the successful deployment of DSRC systems at 5.850 to 5.925 GHz while opening up the majority of the proposed U-NII 4 band for Wi-Fi systems. Qualcomm believes that the technical options described herein provide simple, viable, and clear solutions to most expeditiously and sensibly open the existing DSRC spectrum band for Wi-Fi use — specifically high-data-rate connectivity supported by the IEEE 802.11ac standard. They are offered to the Commission and to the DSRC and Wi-Fi stakeholder communities for their close consideration.

Respectfully submitted,

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Dated: May 28, 2013