

NCHRP Project 23-10, “Evaluation and Synthesis of V2X Technologies”

## **V2X COMMUNICATIONS IN THE 5.9 GHZ SPECTRUM: MARCH 2020 UPDATE**

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March 2020

The information contained in this report was prepared as part of NCHRP Project 23-10, National Cooperative Highway Research Program.

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## Acknowledgments

This study was conducted for AASHTO, with funding provided through the National Cooperative Highway Research Program (NCHRP) Project 23-10, Evaluation and Synthesis of Vehicle-to-X Technologies. The NCHRP is supported by annual voluntary contributions from the state Departments of Transportation. The report was prepared by WSP USA. The work was guided by a technical working group that included:

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# V2X COMMUNICATIONS IN THE 5.9 GHZ SPECTRUM: MARCH 2020 UPDATE

## Executive Summary

This white paper is focused on the 5.9 GHz spectrum and the important role it has played—and will continue to play—in achieving the many safety and efficiency goals originally established when 75 MHz of the band was first set aside for intelligent transportation system (ITS) services.

Connected vehicle applications made possible by the existence of this dedicated radio frequency band can—and will—be a difference-maker in future transportation systems. The National Highway Traffic Safety Administration (NHTSA) has publicly stated that vehicle-to-everything (V2X) communications “will provide drivers with the tools they need to anticipate potential crashes and significantly reduce the number of lives lost each year.”<sup>1</sup>

As we pass through the 20-year anniversary of that initial decision by the Federal Communications Commission (FCC) to allocate the spectrum, this paper will provide a high-level overview of the timeline and major milestones. The chronology can best be described as beginning with a Foundational Development period, then moving from Development to Deployment, and concluding here in the year 2020 with a period of both Progress and Uncertainty. The uncertainty, in large part, is being driven by a recent Notice of Proposed Rulemaking (NPRM) from the FCC to change the allocation of the 5.9 GHz spectrum, resulting in a significantly smaller dedicated portion for transportation safety purposes.

The timeframe of this white paper coincides with the recent close of the initial comment period for the NPRM, and the authors provide an overview of comments received from various stakeholder groups. In total, 268 comments were received after the NPRM was published on February 6, 2020 and prior to the March 9, 2020, deadline. Of those 268 comments, 89% voiced their opposition to the proposed actions in the NPRM, while only 9% were in support and 2% were neutral or did not take a clear position. Almost all submittals in opposition highlighted safety as their primary motivation for opposing the NPRM. There were a wide variety of arguments presented, and this paper will summarize several of them in more detail.

The current NPRM and the comments that have been received by the FCC also include many terms and research conclusions that may not be familiar to those who are not following it closely. This paper will assist by identifying and defining many of those technical elements, while also summarizing recent and relevant research and test activities that are critical to understanding the impact this NPRM might have on safety-related applications. In particular, radio interference testing was raised frequently in opposition to the FCC’s proposal, and this paper will summarize the outcomes from several different research efforts published recently.

Additional technical information on the technology, testing, and results of that testing can be found in the appendix. For more information on the NCHRP 23-10 project, please visit the project page at: <https://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=4902>

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<sup>1</sup> <https://www.nhtsa.gov/technology-innovation/vehicle-vehicle-communication>

## Introduction

Connected Vehicle (CV) technologies enable all types of vehicles, roadways, and mobile devices to communicate and share vital transportation information. Several new and evolving mediums can provide high-speed low-latency communication that will enable a host of applications categorized as vehicle-to-vehicle (V2V), vehicle-to-infrastructure (V2I), and vehicle-to-pedestrian (V2P) communications—collectively known as vehicle-to-everything (V2X).

This next generation connectivity, enabled by dedicated short-range communications (DSRC) and cellular vehicle-to-everything (C-V2X), will help us achieve significant safety and mobility benefits, both on their own and as complementary technologies when combined with in-vehicle sensors supporting advanced driver assist functions.

This white paper is focused on the 5.9 GHz spectrum and the important role it has played—and will continue to play—in achieving the many safety and efficiency goals originally established when 75 MHz of the band was first set aside for intelligent transportation system (ITS) services and applications.

More specifically, this paper will include a high-level chronology of the spectrum dating back to the 1999 allocation specifically for ITS use—introducing the reader to an overview of “how we got here.” As noted in the documented timeline, we are currently in a state of regulatory uncertainty as the Federal Communications Commission (FCC) has issued a Notice of Proposed Rulemaking (NPRM) that suggests reallocating a majority portion of the current 5.9 GHz spectrum for other non-transportation purposes. This paper will therefore also include a comprehensive summary of public comments received on the NPRM to date, providing an overview for those who are both engaged or not engaged in the process.

Following the NPRM update and summary, this paper will provide additional technical information for both DSRC and C-V2X. The intent is to give an overview on current spectrum usage, licensing rules, and where both technology solutions are heading in the future. We will also briefly cover an important technical debate currently in the spotlight given the FCC’s proposed change—radio frequency interference, and whether this is a barrier to future V2X applications.

Written in March 2020 as part of the National Cooperative Highway Research Program (NCHRP) Project 23-10, “Evaluation and Synthesis of Vehicle-to-X Technologies,” this white paper is intended for use by its project panel and state department of transportation (DOT) leaders. The objectives of NCHRP 23-10 are to help inform state DOT efforts for policy development, strategic planning, and infrastructure investment decisions. The project includes an evaluation of implications for state DOTs of the FCC proposal to reallocate portions of the 5.9 GHz bandwidth to other purposes. For more information, visit the project web page at: <https://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=4902>.

NCHRP produces ready-to-implement solutions to the challenges facing transportation professionals. NCHRP is sponsored by the individual state DOTs of the American Association of State Highway and Transportation Officials (AASHTO), in cooperation with the Federal Highway Administration (FHWA). NCHRP is administered by the Transportation Research Board (TRB), part of the National Academies of Sciences, Engineering, and Medicine. Any opinions and conclusions expressed or implied in resulting research products are those of the individuals and organizations who performed the research and are not necessarily those of TRB; the National Academies of Sciences, Engineering, and Medicine; or NCHRP sponsors.

## Section 1 - 5.9 GHz Spectrum Time Line

As an investment in the development of a safer transportation network to further the goals of Congress, the U.S. Department of Transportation (USDOT), and the ITS industry, the FCC allocated 75 MHz of spectrum in the 5.9 GHz band for intelligent transportation services in 1999. This was envisioned to improve traveler safety, decrease traffic congestion, and facilitate the reduction of air pollution while conserving fossil fuels. The FCC understood this was an investment that would require further effort and investigation from several stakeholders.<sup>2</sup>

As shown in Figure 1 below, the timeline for the 5.9 GHz spectrum evolution has passed through several major milestones over the past two decades. They can best be described as the Foundational Development period, Moving from Development to Deployment, and Progress Versus Uncertainty.

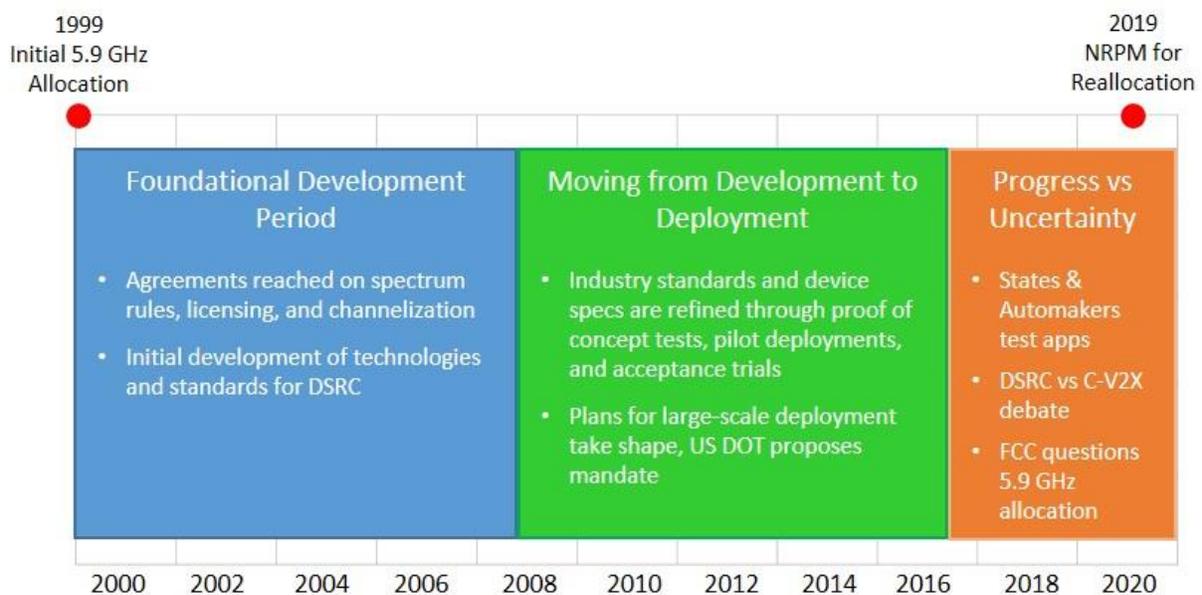


Figure 1 - Graphical Representation of the 5.9 GHz V2X Timeline (source: WSP USA)

### Foundational Development Period

Based on industry work and ITS America proposals, the FCC published an NPRM in November 2002 to develop rules and use of the 5.9 GHz Band.

In December 2003, the FCC adopted a Report and Order establishing service rules for licensing and use of the band.<sup>3</sup> Then FCC Chairman Michael Powell noted that “DSRC provides critical communications links for ITS and is essential to achieving a top priority of the DOT, that of reducing fatalities.”

It is important to note that in the Report and Order, the FCC acknowledged that “our action today is by no means the only prerequisite of DSRC deployment in the 5.9 GHz Band.”

<sup>2</sup> <https://www.fcc.gov/wireless/bureau-divisions/mobility-division/dedicated-short-range-communications-dsrc-service>

<sup>3</sup> <https://docs.fcc.gov/public/attachments/FCC-03-324A1.pdf>

The FCC began accepting applications for licenses and issued the first DSRC licenses in October 2004. (Note that despite the first license being issued, deployment was still not possible until 2008 as noted below).

From 2004 to 2006, the industry continued working with USDOT and the FCC on the designation of two channels within the 5.9 GHz Band for the highest priority vehicle safety communications, specifically using DSRC. During this period the USDOT also began aggressively pursuing a “proof of concept” test in Southeastern Michigan, to work through various deployment issues including system architecture and the design of systems, subsystems, and components, as well as the public sector applications developed to prove some of the system concepts.

The FCC Explicitly noted a spectrum sharing agreement had not yet been reached between the transportation industry and incumbents, in its July 2006 Memorandum Opinion and Order regarding the channel designation. This was the one remaining regulatory barrier to actual DSRC deployment.

Led by ITS America and AASHTO, an agreement between the transportation industry and Satellite Industry Association was submitted to the FCC in February 2008. Almost 10 years after the initial spectrum allocation, this agreement marked the first time that V2X technologies could be deployed unencumbered by a lack of standards or the threat of interference.

### Moving from Development to Deployment

From 2008 through 2017 many critical industry standards, product specifications, and security protocols were developed for DSRC. Some were accomplished through numerous USDOT-funded research and prototype programs to standardize safety-critical infrastructure elements, such as signal phase and timing and maps, as well as safety/mobility applications that further the role and value of DSRC. Many of these were public-private partnerships or brought in significant private industry engagement to assure that the technologies, applications, and standards would be industry-ready quickly. Simultaneously, USDOT was actively engaged with private sector Standards Developing Organizations (SDOs) to develop DSRC-based architectures and standards to support interoperable V2V and V2I deployments.<sup>4</sup>

In 2010-2011, the industry conducted acceptance trials in several different geographic locations, confirming that the technology would be one that infrastructure owner-operators and different types of travelers wanted. This included the formation of a Connected Vehicle Pooled Fund Study, where a group of state DOTs worked on shared-funding projects dedicated to advancing CV research and development.<sup>5</sup> Early test-bed efforts in California and Arizona evolved as a result of this effort.

From 2011-2013, the industry and the USDOT conducted the first large-scale testing and pilot program, the Safety Pilot Model Deployment in Ann Arbor, MI. Led by the University of Michigan Transportation Research Institute (UMTRI), the focus of this effort was to verify the maturity of the standards, the interoperability of the technology, and the safety benefits of mass deployment. This pilot’s impacts were substantial, as it brought forward important lessons learned and refinements to industry standards that brought us closer to a stage of “industry-ready” status.<sup>6</sup> A graphic representation of the project is shown in Figure 2.

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<sup>4</sup> <https://www.standards.its.dot.gov/>

<sup>5</sup> <https://www.pooledfund.org/Details/Study/431>

<sup>6</sup> <http://safetypilot.umtri.umich.edu/>; [https://www.its.dot.gov/research\\_archives/safety/cv\\_safetypilot.htm](https://www.its.dot.gov/research_archives/safety/cv_safetypilot.htm); <http://www.aacvte.org/>

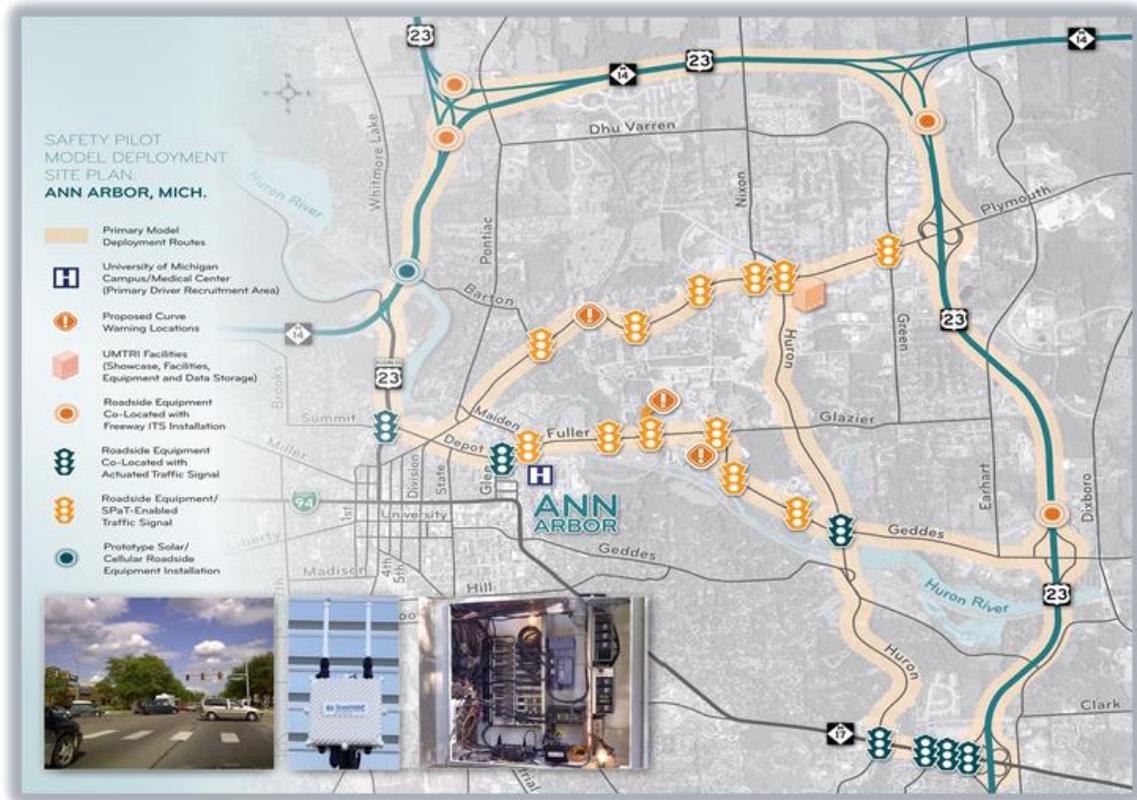


Figure 2 - Safety Pilot Model Deployment Overview (source: UMTRI)

At the same time the Safety Pilot Model Deployment was showing great promise, in February 2012, Congress passed the Middle-Class Tax Relief and Job Creation Act of 2012. This Act included a provision requiring the National Telecommunications and Information Administration (NTIA) to submit a report to the FCC and relevant Congressional committees studying the operation of unlicensed devices in the 5.9 GHz Band. NTIA released the initial study on the potential sharing of spectrum in January 2013, and the FCC released a NPRM seeking comment on sharing the 5.9 GHz spectrum band with unlicensed devices in February 2013.

The prospect of spectrum sharing did not have an impact on development and deployment progress, however, as the USDOT and industry continued to move ahead. In fact, the September 2014 ITS World Congress, a global event held in Detroit, MI, offered an opportunity for the world to see how far the United States had advanced. More than 25 live demonstrations took place on Belle Isle, where automakers, infrastructure owners and operators, academicians, and technology vendors demonstrated a variety of applications that would be made possible by V2X communications. This was an important launching point as many infrastructure agencies around the nation began to contemplate V2X deployments in their states.

While DSRC progress was rapidly expanding, in 2014 the 3rd Generation Partnership Project (3GPP), a collaborative project aimed at developing globally acceptable specifications for third generation (3G) mobile systems, began studying ITS services using the protocol defined for cellular networks documented in Release 12 of the 3GPP specification.

Soon after, in 2015, the USDOT announced it would fund three large-scale DSRC pilot deployments in Wyoming, New York City, and Tampa.<sup>7</sup> They were focused on “uncovering what barriers remain and how to address them, documenting lessons learned, and serving as a template assisting other early CV technology deployments,” and doing so in real-world environments, solving real-world problems. That year also saw the formation of the V2I Deployment Coalition, a multi-disciplinary industry coalition bringing together infrastructure owners and operators, automakers, vendors, and academia toward the goal of sharing knowledge and advancing V2X deployment.

In 2016, Columbus Ohio was awarded the Smart City Challenge Grant, which included plans for the single largest DSRC deployment to date. That same year, the National Highway Traffic Safety Administration (NHTSA) introduced a Notice of Proposed Rulemaking that would have mandated DSRC (or alternative technology that could meet the same performance standards) in all light-duty vehicles.

### Progress Versus Uncertainty

In June 2016, the FCC released a Public Notice seeking additional comment to update and refresh the record on sharing the 5.9 GHz Band. This led to an agreement between the FCC and USDOT to undertake three phases of testing to determine whether spectrum could be safely shared between V2X technologies and unlicensed devices. The first phase of this testing began in October 2016.

Despite some uncertainty with spectrum sharing and no additional action having been taken on NHTSA’s proposed mandate, in 2017 the first DSRC-enabled production vehicles hit the United States market, offered by General Motors in their Cadillac CTS vehicles. That same year, the 3GPP published Release 14 of their specification, updated based on the results of the Release 13 Study. Cellular vehicle-to-everything (C-V2X) was suddenly seen as a potential alternative to DSRC that may soon become available. C-V2X quickly gained momentum as it could benefit from years of pilot development invested in DSRC technology.

The V2I Deployment Coalition also announced a joint effort toward closing final gaps in deployment knowledge with the National Signal Phase and Timing (SPaT) Challenge. This was aimed at encouraging each of the 50 states to instrument at least one corridor with DSRC and to broadcast SPaT messages in standard SAE J2735 formats.

At some point in late 2017, the proposed rulemaking by NHTSA was put on a longer-term action list and it became clear it would not be advanced by the new administration. However, in April 2018 Toyota announced it would begin the installation of DSRC technology by model year 2021 “with the goal of adoption across most of its lineup by the mid-2020s.”

Not long after Toyota’s announcement, two FCC Commissioners issued an unprecedented letter to Toyota signaling the FCC’s interest in opening the 5.9 GHz band for unlicensed use.<sup>8</sup> Later in 2018, the FCC released its Phase I Testing Report, and sought comments on the report, in October 2018. The next month, the 5G Automotive Association (5GAA) petitioned the FCC for a waiver to allow C-V2X to operate in Channels 182 and 184, the upper 20 MHz of the 5.9 GHz band, leaving the remaining channels for DSRC. And the Ford Motor Company announced plans for widespread installation of C-V2X in upcoming model years. More than any other year, 2018 represented the “progress versus uncertainty” period.

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<sup>7</sup> <https://www.its.dot.gov/pilots/>

<sup>8</sup> <https://www.fcc.gov/document/orielly-and-rosenworcel-letter-james-lentz-ceo-toyota-motor-na>

During several speeches in 2019, FCC Chairman Ajit Pai referred to the 5.9 GHz spectrum as “lying fallow,” and to DSRC as a “promise unfulfilled.”<sup>9</sup> And in April of that year, Toyota announced it would halt its plans to install DSRC across its vehicle fleet as announced only a year earlier. Toyota said the decision was based on “a range of factors, including the need for greater automotive industry commitment as well as federal government support to preserve the 5.9 GHz spectrum band for DSRC.”<sup>10</sup>

In late 2019, FCC Chairman Pai announced that the Commission intended to release a Notice of Proposed Rulemaking (Docket 19-138) that would reallocate more than half of the 5.9 GHz safety spectrum for unlicensed uses. It also stopped awarding licenses for DSRC deployments.

### Special Temporary Authority

During early 2020, while the proposed rulemaking was still in progress, an unprecedented global pandemic swept through the United States (COVID-19). As part of its response to this national crisis, the FCC granted a 60-day temporary authority for selected wireless internet service providers (largely in rural communities) to access the lower 45 MHz of the band.

On March 27, 2020, the FCC’s Wireless Telecommunications Bureau granted temporary spectrum access to 33 wireless Internet service providers serving 330 counties in 29 states to help them serve rural communities facing an increase in broadband needs during the COVID-19 pandemic. The Special Temporary Authority (STA) allows these companies to use the lower 45 megahertz of spectrum in the 5.9 GHz band for 60 days.<sup>11</sup>

This act was the result of a joint request filed one week earlier by the wireless internet service providers named in the grant, who stated this was needed to provide relief during the state of emergency caused by the spread of COVID-19 throughout the country.

The STA allows wireless ISPs to operate in the 5850-5895 MHz portion of the band, as long as they are not within 2km of an existing licensee, or within 75km of specific “government wireless” installations as noted in the official release by the FCC.<sup>12</sup>

In addition to maintaining at least 2km of distance from an existing licensee, the STA notes that service providers granted this exemption are “responsible for ensuring that it does not cause interference to existing licensees.” The providers must contact any potentially affected license owners before beginning operation, but if a “complaint of interference cannot be timely resolved, operation under this STA must cease.”

At the conclusion of the 60-day STA, providers must “cease operating in the 5.9 GHz band and retune equipment to operate in compliance with the Commission’s equipment certifications.”

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<sup>9</sup> <https://docs.fcc.gov/public/attachments/DOC-360918A1.pdf>

<sup>10</sup> <https://www.reuters.com/article/autos-toyota-communication/toyota-halts-plan-to-install-u-s-connected-vehicle-tech-by-2021-idUSL1N22816B>

<sup>11</sup> <https://docs.fcc.gov/public/attachments/DOC-363358A1.pdf>

<sup>12</sup> <https://docs.fcc.gov/public/attachments/DOC-363358A2.pdf>

## Section 2 - FCC NPRM to Reallocate the 5.9 GHz Spectrum

In December 2019, the FCC approved a Notice of Proposed Rulemaking (NPRM) that would reduce the safety spectrum set-aside for CV technologies from 75 MHz to only 30 MHz, establish specific technology requirements within that allocation, and open the rest of the spectrum to unlicensed Wi-Fi devices (FCC ET Docket No. 19-138).<sup>13</sup>

Specifically, the NPRM recommends:

Utilize the lower 45 megahertz of the band (5.850-5.895 GHz) for unlicensed operations to support high-throughput broadband applications.

- Unlicensed device operations in the 5.850-5.895 GHz band be subject to all of the general Part 15 operational principles in the Unlicensed National Information Infrastructure (U-NII) rules.
- Adopt technical and operational rules (e.g., power levels, out-of-band emissions limits) similar to those that already apply in the adjacent 5.725-5.850 GHz (U-NII-3) band.
- Unlicensed devices include objects like cordless phones, baby monitors, garage door openers, and other communicating devices.

Dedicate spectrum in the upper 30 megahertz of the 5.9 GHz band (5.895-5.925 GHz) to support ITS needs for transportation and vehicle safety-related communications.

- Revise the current ITS rules for the 5.9 GHz band to permit Cellular Vehicle-to-Everything (C-V2X) operations in the upper 20 megahertz of the band (5.905-5.925 GHz).
- Seek comment on whether to retain the remaining 10 megahertz (5.895-5.905 GHz) for DSRC systems or whether this segment should be dedicated for C-V2X.
- Require C-V2X equipment to comply with the existing DSRC coordination rules for protection of the 5.9 GHz band Federal Radiolocation Service.
- Retain the existing technical and coordination rules that currently apply to DSRC, to the extent that we allow DSRC operations in the 5.895-5.905 GHz band.

### Summary of the Process

The initial stages of an NPRM are structured, but the overall time line, possible actions, and potential outcomes are highly variable and subject to many different factors. Initial steps for the NPRM to reallocate the 5.9 GHz Spectrum include:

- NPRM was published in Federal Register—February 6, 2020.
- 30-day comment period ended—March 9, 2020.
- 30-day reply comment period ends—April 27, 2020 (submitters can address other comments).

All comments, reply-comments, petitions, and *ex parte* communications are published on the FCC website under the reference of the docket number (19-138).

The time from closing of comment windows to FCC action can vary greatly, with both internal and external factors influencing the timing. Likewise, the volume and nature of comments may or may not impact timing.

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<sup>13</sup> <https://www.federalregister.gov/documents/2020/02/06/2020-02086/use-of-the-5850-5925-ghz-band>

During this period, FCC staff continues to take meetings with interested parties to have additional discussions. Summary briefs of these meetings will be published as *ex parte* communications on the FCC website.

There are many possible outcomes from the NPRM, but the most likely actions by the FCC are:

1. Issue a revised Report and Order that causes an action to be adopted that may or may not track exactly with all that is included in the NPRM;
2. Take partial action, leaving additional clarifications needed to the service rules;
3. Issue a further notice of inquiry that could include another comment and reply period; or
4. Take no action, letting the issue sit on the back burner for an undefined amount of time.

Some of the external factors that might impact the eventual outcome include:

- Inquiries, interactions, and statements from members of Congress. Congress can also enact legislation that would directly impact FCC actions, but this is less common during election years.
- If an Order is issued, there can (and often will) be petitions for reconsideration. The FCC is under obligation to rule on petitions, but the timeliness and results of those petitions and rulings can be uncertain.
- If an Order is issued, it is also subject to appeal in a federal court of appeals—usually the D.C. Circuit Court. The timeliness and results of those appeals can be uncertain.

### Overview of Comments Submitted to the FCC on the Current NPRM

The timeframe of this white paper coincides with the recent close of the initial comment period on March 9, 2020. In total, 268 comments were received after the NPRM was published on February 6, 2020 and prior to the March 9 deadline.

As shown in Figure 3, of those 268 comments, 9% of submissions were in support of the NPRM, 2% were neutral or did not take a clear position, and 89% voiced their opposition to this proposed action.

Almost all submittals in opposition highlighted safety as their primary motivation for opposing the NPRM.

Many commenters also mentioned that the value of reduced fatalities and injuries can be measured, and if this is done, the potential value of V2X far exceeds the value of a relatively small amount of additional Wi-Fi capacity. Many suggested that the value of reduced fatalities and injuries be considered under the FCC's mandate to allocate radio spectrum in the "public interest".

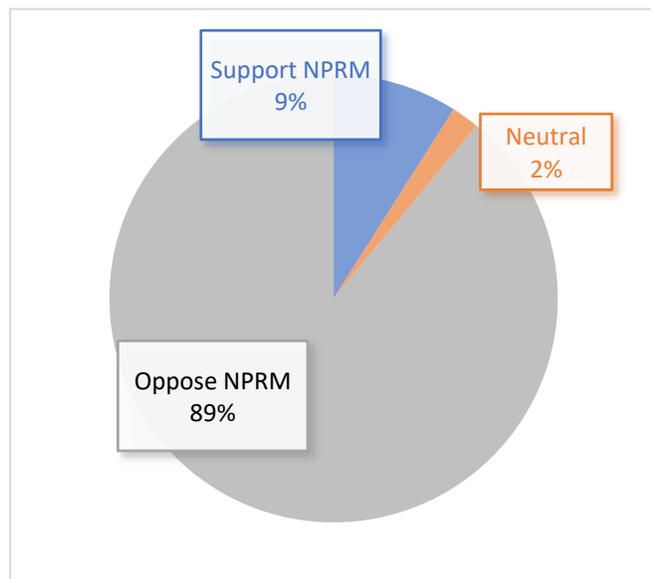


Figure 3 - Overview of Positions Taken on FCC NPRM

Notably, among submitters in the transportation industry who voiced opposition to the NPRM, 80% were either technology neutral, did not mention DSRC or C-V2X in their comments, or encouraged the provision of bandwidth for both technologies. Of the minority who expressed preference for a specific technology, 14% favored DSRC and 6% favored C-V2X.

### Submitters

A wide variety of submissions were received:

- The American Automobile Association, American Road & Transportation Builders Association, American Society of Civil Engineers, International Bridge, Tunnel and Turnpike Association, Institute of Transportation Engineers, ITS America, National Transportation Safety Board, Society of Automotive Engineers (SAE), and the National Safety Council all submitted comments.
- In addition to signing on to American Association of State Highway Transportation Officials' (AASHTO) remarks, 20 individual state DOTs and/or state representatives also submitted separate comments including Arkansas, California, Colorado, Connecticut, Georgia, Idaho, Kentucky, Maryland, Michigan, Minnesota, Montana, North Dakota, Oregon, Pennsylvania, South Dakota, Tennessee, Texas, Utah, Washington, and Wyoming.
- Comments were also received from a number of county DOTs or governments and regional MPOs, including: Gwinnett County (Georgia), Macomb County (Michigan), Maricopa County (Arizona), Orange County (California), St. Louis County (Missouri), the North Central Texas Council of Governments, the San Diego Association of Governments, and the Association of Metropolitan Planning Organizations.
- There were also submissions from the cities of Arlington, Texas; Columbus, Ohio; Eugene, Oregon; Fremont, California; Frisco, Texas; Medford, Oregon; and New York, New York.
- The Tampa Hillsborough County Expressway Authority, Contra Costa Transportation Authority, and Central Ohio Transit Authority also submitted comments, as did the National Association of City Transportation Officials, American Public Transportation, and American Public Works Association.
- The Alliance for Automotive Innovation, Automotive Safety Council, Motor & Equipment Manufacturers Association (MEMA), DSRC Auto Safety Coalition, 5G Automotive Association, and other automotive associations provided comments.
- Many individual automakers chose to weigh in separately, including Ford, General Motors, and Fiat Chrysler as well as BMW, Honda, Hyundai, Jaguar/Land Rover, Nissan, Toyota, Volkswagen, and Volvo. Automotive suppliers Bosch, Continental, and Denso presented comments as well.
- There were submissions from the trucking industry, including the American Trucking Associations, the Truck and Engine Manufacturers Association, Volvo Group, and UPS, as well as the Commercial Vehicle Safety Alliance.
- Various academics, consultants, and vendors provided comments, operating in their official and/or personal capacities.
- There were also a significant number of comments from individual amateur HAM radio operators and their representative associations, most focusing on their secondary use of the spectrum to support existing communication network infrastructures, particularly in emergency and disaster situations.
- Additional entrants in opposition to the NPRM included the National Sheriffs' Association, International Association of Fire Fighters, National School Transportation Association, various

bicycling and walking advocacy organizations, groups interested in the efficiency enhancements such as Securing America's Future Energy, industry groups like OmniAir, and safety organizations like the Vision Zero Network.

- USDOT submitted a significant amount of additional information in opposition to the NPRM, by way of the United States Department of Commerce National Telecommunications and Information Administration.
- Technology companies Broadcom, Facebook, Comcast, and Microsoft, and various associations including Citizens Against Government Waste, the Wireless Internet Service Providers Association, the Open Technology Institute, Public Knowledge, and the Internet & Television Association provided both comments and *ex parte* submissions in support of the NPRM.

#### Key Issues from Infrastructure Owners and Operators

Submissions from state and local transportation agencies and other key associations were strongly united in opposition to this NPRM. They frequently raised several common issues. Some of these include:

- This action is short-sighted, given that 37,000 people are dying annually on our nation's roadways and this technology has the potential to reduce that number by up to 80%. Many jurisdictions are committed to Vision Zero goals; this action is in direct contradiction.
- Public safety should be valued over potential commercial advancement. The safety, as well as mobility and efficiency benefits, of using this spectrum for V2X need to be more carefully considered and analyzed. Rather than only considering the potential economic opportunities of opening the spectrum to unlicensed use, the FCC should also weigh the direct costs associated with crashes (estimated at over \$800 billion in 2017) and traffic congestion (\$140 billion).
- The FCC should assume the burden of proof to justify why the spectrum should be taken away, rather than shifting the burden of proof to incumbent users of the spectrum.
- Many agencies presented the investments they had already made in V2X technology—both in terms of local and federal monetary costs as well as number of intersections, vehicles, or other infrastructure equipped—and stated that the deployment timelines would have been more aggressive had there not been so much regulatory uncertainty during the preceding years.
- Critical safety applications take more time to develop than consumer electronics, so the statement that 20 years is an excessively long time is not accurate.
- There has not been enough research on signal interference to show that the proposed 30 MHz is feasible for critical safety applications.
- The FCC should continue its testing of band sharing between V2X and unlicensed devices, rather than abandoning it for this proposal.
- Most commented that the FCC should take a technology-neutral approach. A few displayed a slight preference to DSRC due to the anticipated costs involved with reconfiguring and/or replacing existing radios, redesigning existing systems, and retesting. Some also expressed that moving to C-V2X could cause further delays as it has not been validated and does not have mature standards like DSRC does, though they seemed open to testing dual-units or following a phased approach that allows new technology to be adopted without sacrificing existing investments during the lifetime of existing equipment.

### Key Issues from Other Transportation and Infrastructure Stakeholders

Many vendors, consultants, and academics echoed those of state and local DOTs, and included the following highlights:

- Safety is the top priority, and the benefit to society of 45 MHz of additional Wi-Fi spectrum is small compared to the value of additional road safety.
- 30 MHz is not enough, and more research needs to be done on potential spectrum interference.
- The proposed changes undermine American competitiveness in the global market and compromise international interoperability. While other regions in the world see the need to allocate more dedicated spectrum for ITS, the Commission's proposal goes in the opposite direction.
- Had the U.S. government mandated DSRC technology in new vehicles, this band would be in full widespread use now. The unclear regulatory environment introduced uncertainty, which delayed the market, and even caused a few carmakers to cancel their planned deployments.
- Vehicles will never be fully automated without V2V, V2I, and V2X. Connectivity does not require line of sight and adds additional information to a vehicle system beyond what its sensors could detect.

### Key Issues from Original Equipment Manufacturers (OEMs) and Suppliers

Automakers, their associations, and their suppliers were united in their opposition to this NPRM. Within this group, some voiced that they appreciated the Commission's opening of spectrum to C-V2X over DSRC, but many remained technology neutral and focused primarily on the need to protect the full spectrum and leave the exact technology as a different conversation. Many explicitly voiced their commitment to deploy V2X in the United States, assuming we could achieve regulatory certainty.

Comments included:

- Slashing 60% of the 75 MHz 5.9 GHz band and therefore limiting ITS technologies to only 30 MHz will strand already-deployed V2X units and users, foreclose advanced safety features of the future, and compromise the technology's lifesaving potential.
- The full 75 MHz will be needed to allow use cases to operate fully in a busy environment, anything less would restrict the true potential of V2X technology.
- Several cited research done in Europe recommending that "the minimum basic spectrum needs for these known message types is 67 MHz for urban environments and 72 MHz for suburban and rural environments."
- Denso stated that one 10 MHz channel will become saturated at ~2,000 safety messages per second and, for platooning, a 10 MHz channel may become saturated when ~20 platooning vehicles are within communications range. This led to the conclusion that at least 47 MHz of spectrum is needed to provide safety-critical communications in typical urban scenarios, and 77 MHz in more challenging urban scenarios.
- Ford suggested that applications requiring larger payloads than the 20-30 MHz could provide include sensor sharing, intent/trajectory sharing, vulnerable Road User (VRU) safety, and other advanced ITS applications including platooning, traffic flow coordination for congestion management, and automated valet services for parking management.

- The opportunity to use the enormous supply of data of CAVs to save lives is what has motivated an estimated \$80-billion of investment in automated vehicles between 2014 and 2017 alone. This proposal risks stifling technological innovation.
- Toyota points out that in the NPRM, the FCC proposes repurposing at least 20 MHz away from DSRC to C-V2X. However, it does not specify whether the C-V2X technology that it is proposing to be used is LTE V2X or 5G NR V2X. Since 5G NR V2X is not capable of same-channel coexistence with LTE V2X (and is not backwards compatible), a decision to permit LTE V2X in a channel locks in LTE V2X as the only C-V2X technology that can be used in that channel—now and into the future.
- Sufficient bandwidth is not optional, or nice-to-have, it is essential to automotive safety in this context. When it comes to saving American lives, we should clearly strive to be the global leader.

#### Key Issues from the Trucking and Commercial Vehicle Industry

The trucking industry raised many of the same points as other stakeholders, including:

- Utilizing advanced vehicle technology will enhance both the safety of employees and of the general public, particularly in today's challenging operating environment for large trucks.
- One of the near-term applications of these technologies is platooning of two or more tractor-semitrailer combination vehicles. This could help decrease traffic congestion, reduce emissions and air pollution, and enhance safety.
- This proposal will harm highway, road, and bridge safety.
- Recommend coordinating more closely with USDOT to study implications.
- While some previous estimates of the timing of transportation-related use of these technologies may have been overly aggressive, the future widespread benefits of the technologies should not be underestimated.

#### Key Issues from Technology Companies Also in Opposition to the NPRM

Beyond infrastructure and automotive stakeholders, several wireless and technology companies also came out in opposition to the NPRM as currently structured. Their comments included:

- Qualcomm continued its support for C-V2X over DSRC, but agreed that 30 MHz is not enough to deploy potential applications fully.
- Panasonic supported a technology-neutral approach as it has supported both DSRC and C-V2X deployments and urged the FCC to undergo a more rigorous analysis that considers the billions of dollars in economic impact provided by lifesaving V2X technologies, for which there are no currently viable substitutes.
- T-Mobile and AT&T agreed that the public interest would be best served by designating the full 5.9 GHz band to ITS, though T-Mobile voiced support for C-V2X while AT&T remained technology neutral. Their justification included:
  - The Commission has already made sufficient additional spectrum available for unlicensed use. The U.S. is an outlier in making substantially more spectrum available on an unlicensed and shared basis than other countries.
  - This can help enable important improvements in safety, traffic efficiency, mobility, and energy efficiency on America's roads.

- Reallocating the lower 45 MHz of the 5.9 GHz band for exclusively unlicensed Wi-Fi use would deliver only incremental public benefits and have a minimal impact on investment in the unlicensed device ecosystem.

#### Key Issues from Current Secondary Spectrum Users

Because the current legislation also allows secondary uses of the spectrum, some comments were not about the ITS use and rather focused on these uses.

- Of 82 submissions from individual amateur HAM radio operators and their representative associations, all except one (who remained neutral) were in opposition to the NPRM. Most focused on their secondary use of the spectrum to support existing communication network infrastructures, particularly in emergency and disaster situations, and some mentioned the value of protecting the Safety Band for safety-critical ITS services as well.

### Comment Spotlight: Keep the Spectrum, but Consider a New Approach

While the automakers were not uniform on technology preferences (DSRC, C-V2X, or both), several of their submissions did state the need for stakeholders to coalesce around the broader goal of interoperability and focus on resolving any technical differences, while keeping the full 75 MHz.

- General Motors suggested that the FCC allow the transportation community (vehicle manufacturers and infrastructure owner-operators) a brief period to define an industry-wide V2X deployment plan in the ITS-dedicated 75 megahertz of the 5.9 GHz band.
- Toyota proposed that the USDOT be charged with identifying to the Commission within a specified period (perhaps 12-18 months) a single communication protocol that automakers and infrastructure providers will utilize going forward. At that point in time, the Commission would incorporate the identified protocol into its rules. If the USDOT identifies either DSRC or 5G NR V2X, the Commission should draft its rules to also permit into the band any future technology that is interoperable and backwards compatible in the same channel with the identified protocol. Such a requirement would not be necessary if the U.S. Department of Transportation identifies LTE V2X since future C-V2X technologies will not be backwards compatible to LTE V2X.
- Honda suggested that the best and most efficient path forward at this time is for the FCC and USDOT to appoint an independent arbiter panel or oversight board to manage and oversee use of the 75 MHz allotment. In order for V2X Basic Safety Messages (BSM) to have the intended widespread benefit, it remains essential to have a single communication protocol for all vehicles.
- Volkswagen was clear in stating that they favor a technology-neutral approach to V2X technologies in the 5.9 GHz band, but went on to suggest the FCC should let the automotive manufacturers decide on the most suitable technology. Safety communications operating in the 5.9 band require highly reliable transmission; there is a great concern that the current proposal could result in significant adjacent channel interference, unless adequate protection is guaranteed for V2X systems in the ITS spectrum.

In comments submitted through the NTIA, the USDOT strongly encouraged the FCC to work cooperatively toward a solution.<sup>14</sup> The USDOT stated in their submission:

“One well-established means of facilitating such an approach would be through a negotiated rulemaking, which provides federal agencies with a structured but supple process for bringing all stakeholders to the table in instances like this one, where there are deeply held disagreements on fundamental underlying issues that could be better resolved through a robust dialogue rather than a written public comment period. FCC could partner with USDOT safety experts to work with stakeholders from the telecommunications and automotive industries; states and local authorities; transportation safety advocates; other relevant public interest entities; and interested federal agencies in a collaborative endeavor to share resources and identify solutions. As part of this process, FCC and USDOT could work to promote agreement among V2X stakeholders on the appropriate "cooperative" technology or blend of technologies, including DSRC, cellular, and/or other forms.”

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<sup>14</sup> <https://ecfsapi.fcc.gov/file/10313251510165/5.850-5.925%20GHz%20Band%2C%20ET%20Dkt%20No.%2019-138.pdf>

## Comment Spotlight: Legal Arguments

Several submissions that opposed this NPRM have introduced legal arguments, suggesting that the FCC may lack the legal authority to implement this action. While these arguments might (or might not) influence the initial action taken by the FCC, they could potentially arise later as the basis of legal appeals if the NPRM should move forward as currently proposed.

Legal Reference	Issue Summary from Submitted Comments	Submitters
<p>The NPRM represents a “fundamental change” to existing DSRC licenses, which violates Sect 316 of the Communications Act (47 U.S.C.)</p>	<ul style="list-style-type: none"> <li>• The Supreme Court previously ruled that the FCC’s power to modify existing licenses means “moderate” and “minor” changes. This proposal would substantially modify Part 90 and 95 DSRC licenses to reduce available operating bandwidth from 75 MHz to 10 MHz, which would represent a fundamental change to existing DSRC licenses.</li> <li>• The outcome of the NPRM would also likely prevent DSRC licensees from providing safety-critical communications using V2X technologies. The Commission has previously ruled that a fundamental change occurs when a licensee cannot provide substantially the same services under very similar terms.</li> </ul>	<p>Submitters:</p> <ul style="list-style-type: none"> <li>• ITS America</li> <li>• Utah DOT</li> <li>• AASHTO</li> <li>• Alliance for Automotive Innovation</li> </ul>
<p>The NPRM could potentially eliminate DSRC completely, which violates Sect 312 of the Communications Act (47 U.S.C.)</p>	<ul style="list-style-type: none"> <li>• If no spectrum is set aside for DSRC, the licenses effectively will be revoked. Section 312 permits the FCC to revoke a license only upon the occurrence of specific circumstances, such as making “false statements” to the Commission or “willful or repeated violation” of Commission rules.</li> <li>• Because the current license holders have satisfied the conditions of their licenses and are not in violation of the FCC’s character and fitness policies, there is no basis to revoke their licenses.</li> </ul>	<p>Submitters:</p> <ul style="list-style-type: none"> <li>• ITS America</li> <li>• Utah DOT</li> <li>• Alliance for Automotive Innovation</li> </ul>
<p>The NPRM has been advanced against the advice of safety experts and the USDOT, which violates Sect 1 of the Communications Act (47 U.S.C.)</p>	<ul style="list-style-type: none"> <li>• Section 1 of the Communications Act notes that the FCC, among other matters, was created to “promote safety of life and property through the use of wire and radio communications.”</li> <li>• The FCC has advanced this proposal with no analysis or evidence to show successful operation of V2X technologies in the remaining 30 MHz and without completing research to determine if the lower 45 MHz could be shared between V2X technologies and unlicensed devices.</li> <li>• The USDOT, the expert agency on transportation safety, and dozens of other transportation experts and organizations, have presented evidence that contradicts the FCC’s proposal.</li> </ul>	<p>Submitters:</p> <ul style="list-style-type: none"> <li>• ITS America</li> </ul>
<p>The NPRM is a significant departure from prior policy, offers little data on the ability of DSRC to function in a single 10 MHz channel, therefore it violates the Administrative Procedure Act (5 U.S.C.).</p>	<ul style="list-style-type: none"> <li>• Under the Administrative Procedure Act, agency orders will be held unlawful and set aside if they are “arbitrary and capricious.” This is defined when the agency “entirely failed to consider an important aspect of the problem, or offered an explanation for its decision that runs counter to the evidence.”</li> <li>• The Commission has not acknowledged out-of-band interference that will result from the realignment, which will likely render the small amount of spectrum unusable.</li> <li>• The USDOT, the expert agency on transportation safety, and dozens of other transportation experts and organizations, have presented evidence that contradicts the FCC’s proposal.</li> </ul>	<p>Submitters:</p> <ul style="list-style-type: none"> <li>• DSRC Auto Safety Coalition</li> </ul>

## Key Issues in Support of the NPRM

As noted earlier, a small number of commenters did support the NPRM as currently structured.

Technology Associations	Policy and Watchdog Organizations	Private Companies
<ul style="list-style-type: none"> <li>• NCTA - The Internet &amp; Television Association</li> <li>• Wireless Internet Service Providers Association</li> <li>• Dynamic Spectrum Alliance</li> <li>• Wi-Fi Alliance</li> </ul>	<ul style="list-style-type: none"> <li>• Citizens Against Government Waste</li> <li>• Open Technology Institute</li> <li>• The Free State Foundation</li> <li>• R Street Institute</li> <li>• Competitive Enterprise Institute</li> <li>• Consumer Action for a Strong Economy, Inc.</li> <li>• Institute for Policy Innovation</li> <li>• TechFreedom</li> <li>• Open Technology Institute and Public Knowledge</li> </ul>	<ul style="list-style-type: none"> <li>• Comcast Corporation</li> <li>• Microsoft Corporation</li> <li>• Broadcom/Facebook</li> </ul>

Comments that support the NPRM see economic opportunity in opening the spectrum, suggesting that this action will support next generation gigabit Wi-Fi, advance 5G, and address the strain on today's overburdened Wi-Fi frequencies. Several of the commenters also suggested that the NPRM's proposed band split approach will protect any future crash-avoidance ITS applications that may rely on 5.9 GHz spectrum, because splitting the band eliminates the possibility of co-channel operation.

A subset of the commenters described this action as a compromise that did not go nearly far enough, and favored an approach that would allocate the entire 75 MHz to unlicensed use. For example, NCTA – The Internet & Television Association stated:

- “The Commission can make the most efficient and effective use of this valuable mid-band spectrum by permitting unlicensed operations in the entire band, and letting ITS services operate either in (1) another dedicated spectrum band (such as 4.9 GHz), or (2) flexible-use licensed or unlicensed spectrum in the same way that countless other technologies do—including services that contribute to automotive safety.”

Two of the commenters identified interference could potentially be an issue, but did not offer empirical evidence that their proposed solutions would make a difference.

- One comment noted that as the majority of Wi-Fi use is indoors, the Commission may want to examine having different out-of-band emissions (OOBE) limits depending on whether the unlicensed device is operated indoors or outdoors to maintain robust protection for ITS communications where it is used.
- The other comment stated that the Commission needs to reexamine the OOBE limit at the upper U-NII-4 band edge in a manner that protects the Vehicular Safety Service but does not restrict commercially important Wi-Fi use cases. The proposed rule would significantly reduce or even eliminate the possibility of Wi-Fi deployments in the band, and so the OOBE limit should be changed to match that of U-NII-3 devices.

## Section 3 - Overview of Critical Terms and Testing Outcomes

The current NPRM and the comments that have been received by the FCC related to this proposed rulemaking include many terms and technologies that may not be familiar to those who aren't following it closely. Terms like U-NII-3 and U-NII 4, interference and spectral masks, decibels (dB), adjacent channels and re-channelization, detect and vacate, and sensitivity—to name just a few. Further, the reports documenting the results of testing activities that have been performed by the FCC, USDOT, CAMP, 5GAA and others introduce even more new terms and concepts.

This section will serve to identify and define those elements which are key to understanding the issues and concerns of the proposed rulemaking. It will also summarize important features of the current legacy spectrum and give an overview of recent and relevant test activities critical to understanding the impact this NPRM might have on safety-related applications.

The high-level discussion presented in this section is the result of detailed research and review of multiple sources representing many different entities and different viewpoints. Additional information related to these topics, the technology, testing, and results of that testing can be found in the appendix.

### Terms and Concepts

**Dedicated Short-Range Communications (DSRC)** is a wireless technology operating in the 5.9GHz spectrum used for secure, low-latency, highly-reliable communications between vehicles, and between vehicles and infrastructure.

**Cellular Vehicle-to-Everything (C-V2X)** is a device-to-device communications technology, developed by the 3GPP, and based on current LTE cellular standards. C-V2X is not 5G, nor is it interoperable with DSRC.

**Radio Frequency (RF)** delineates the range of frequencies available for use by wireless devices that include DSRC, C-V2X, Cellular, and unlicensed Wi-Fi. It is generally considered to be the entire range above audible frequencies and below infrared.

**Spectrum** is the range of frequencies associated with certain attributes, (i.e., audio spectrum, visible light spectrum, RF spectrum). For purpose of this discussion, the term 5.9 GHz spectrum refers to the 75 MHz of RF spectrum between 5.850 and 5.925 GHz.

**Channel (or Band)** is a term used to identify how a portion of the wireless spectrum is allocated. DSRC uses 10 MHz channels, C-V2X uses 20 MHz channels and U-NII devices use 20, 40, 80 and potentially 160 MHz channels.

**Guard Band** is a frequency range whose purpose is to provide isolation between two adjacent channels. Presently there is a 5MHz guard band at the lower end of the 5.9 GHz spectrum. It provides a buffer between current U-NII operations and DSRC.

**U-NII** or Unlicensed National Information Infrastructure defines the range of frequencies allocated for Wi-Fi devices. **U-NII-3** is the band immediately below the 5.9 GHz spectrum. **U-NII-4** is the band that would be created by the current NPRM, utilizing spectrum up to 5.895 GHz and allowing for 160 MHz wide channel.

**Interference** is defined by any external source whose output overlaps the channel of the intended transmission and produces undesired effects in that band. Interference can be in one of three forms: ambient or background noise, packet collision, and transmitter message suppression.

**Ambient noise** is the culmination of all unwanted signals, both in-band and adjacent, which reduces the ability of weak signals from distant transmitters to be received. Ambient noise is typically a result of unlicensed devices transmitting in or near the DSRC channel.

**Packet collision** occurs when a receiver receives packets simultaneously from two or more sources and the message cannot be properly interpreted, rendering them useless. These packets are discarded by the receiver. These are essentially transmitted messages that are lost.

**Transmitter message suppression**, also known as Clear Channel Assessment, is a feature of DSRC whereby the transmitter waits until the channel is idle before transmitting. If the channel is not idle, the transmitter will wait a random period and then re-try the transmission. In the case of DSRC, if secondary transmitters are continually using the channel and no idle period can be detected, the message transmission by the primary device will effectively be suppressed. While in this case the wireless radio is truly operating as designed, the effects are not desirable.

**Cross-Channel Interference**, also known as **Adjacent Channel Interference**, is another way to describe interference caused by out-of-band emissions infringing overlapping the channel of the intended transmission.

**Spectral Mask** is a term used to define the shape of an RF transmission, including the relative power levels in and out of band. A more detailed discussion is included in the appendix.

**Signal Power** is the amount of energy used to radiate (i.e., push) an RF signal. Power is measured in decibels (dB) and is logarithmic, meaning a measured 10 dB increase equates to an order of magnitude (10x) increase in power.

**Out-of-Band Emissions** (OOBE) is a measure of the energy (interference) from overlapping adjacent channel transmissions.

**Sensitivity** is the ability of a receiving device to receive 'hear' an RF signal. The more sensitive a device, the fainter a signal it can receive.

**Digital Certificates** and the underlying Certificate Authority provide a way to ensure the authenticity of messages exchanged in a connected vehicle environment.

### Current 5.9 GHz Spectrum and its Utilization

When the spectrum was first allocated to USDOT for ITS, engineers were very purposeful in their design of DSRC devices to maximize the use of the spectrum and minimize the effects of interference. The result is that current DSRC devices rely on having seven (7) channels (10 MHz each) with the option of combining certain channels into two 20 MHz channels.

The design intentionally spread the critical services—Safety, Control, and Public Safety—across the full spectrum. This isolation protects the channels from cross-channel interference. As shown in Figure 4, Safety messages, located in the lowest channel, Ch. 172, are protected from external interference on the lower end by a 5 MHz guard band. The Public Safety Channel, Ch. 184, at the upper edge of the

band is afforded higher-power transmission, negating the impact of adjacent channel interference. The Control Channel, Ch. 178, sits in the middle of the spectrum and given its role facilitating the management of the remaining four channels, mitigates interference as part of its channel use strategy.

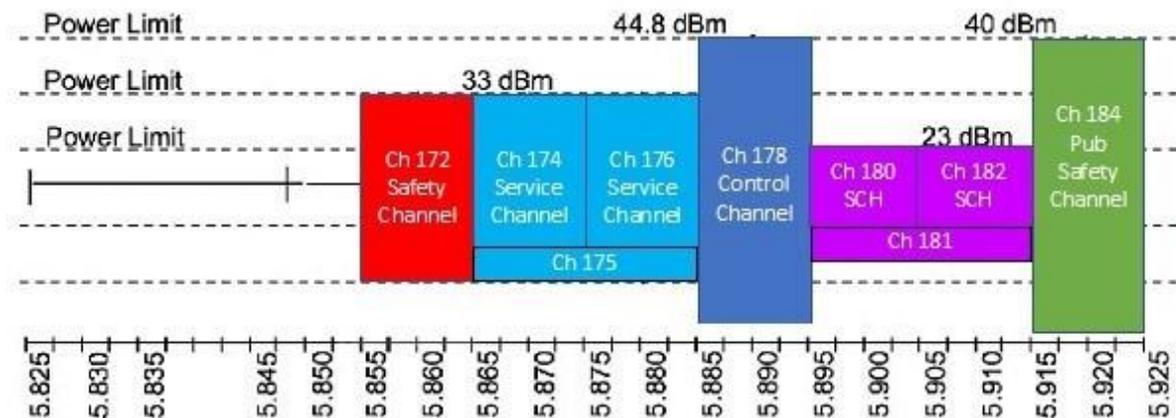


Figure 4 - Channel Allocation for the 5.9 GHz Spectrum (source: WSP USA)

Often overlooked when discussing spectrum utilization, the security elements, and the robust environment that has been developed to support security, have a critical need for a reliable way to exchange, renew, and revoke digital certificates. Without the ability to authenticate messages, the value of safety data is minimized. The use of service channels as prescribed in the present architecture allow for security and other critical operational features to be implemented without negatively impacting the exchange of safety-critical information.

#### Introduction of C-V2X

With the release of 3GPP Release 14 (R14) in 2017, a new technology supporting device-to-device communications was introduced. Known as Cellular Vehicle to Everything (C-V2X), the technology leverages the same hardware as traditional cellular, but does not require a data plan or account.

C-V2X is backed by the 5G Automotive Association (5GAA), a global cross-industry organization of companies from the automotive, technology, and telecommunications industries developing end-to-end solutions for future mobility and transportation services. In 2018, 5GAA submitted a waiver to the FCC to allow C-V2X operations in the upper portion of the DSRC band.<sup>15</sup> Since all transmissions occur in the same 20 MHz channel, there is no requirement for a service channel in C-V2X, as devices simply listen for available messages. Note: the FCC NPRM as currently written has set aside this 20 MHz channel for C-V2X.

Testing to evaluate the shared used of this spectrum by DSRC and C-V2X in this configuration had only recently begun and conclusive results, positive or negative, are not yet available.

<sup>15</sup> <https://ecfsapi.fcc.gov/file/104030451515194/5GAA%20Band%20Plan%20Ex%20Parte%20-%20FINAL.pdf>

## How the Post-NPRM Spectrum Appears

If the recommendation of the FCC in the current NPRM is accepted, the channel configuration will undergo a significant change. As shown in Figure 5, the lower 45 MHz, which includes the 5 MHz guard band, and the first four DSRC channels, including both the Safety Channel, Ch. 172, and the Control Channel, Ch. 178, will all be re-allocated to use by unlicensed Wi-Fi. The upper 20 MHz of the spectrum will be dedicated to C-V2X consistent with the waiver 5GAA filed with the FCC for initial use. That leaves a single, 10 MHz channel, Ch. 180, offered for either DSRC or C-V2X operations, to be determined.

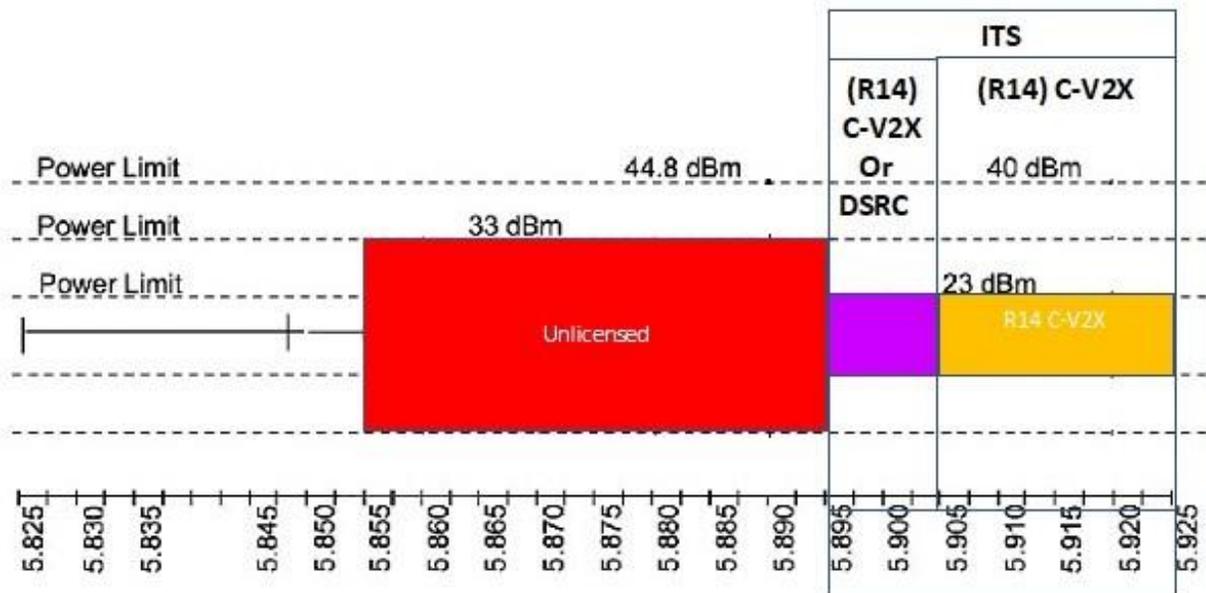


Figure 5 - FCC NPRM Channelization of Spectrum Reallocation (source: WSP USA)

From the DSRC perspective, the thoughtful engineering to minimize adjacent channel interference is no longer possible; the ability to maximize spectrum use for all of the services envisioned for DSRC is not possible; and what remains is the possibility of a single channel that (according to USDOT research) will likely be overloaded by having to combine all of the crash-imminent safety messages with the necessary system management and security messages.

DSRC and C-V2X would now be adjacent to 20MHz or wider channels, both of which could have significant negative interference implications. When 5GAA first generated the waiver request to FCC, the 20 MHz channel they requested had a level of isolation from DSRC with the lesser-used Ch. 180 separating the two.

With this proposed change by the FCC, DSRC and C-V2X are now immediately adjacent, and immediately above C-V2X is additional unlicensed spectrum.

## Published Test Results on Interference

Exploration and testing of the 5.9 GHz and surrounding spectrum for interference and mitigating strategies is nothing new. In fact it was identified as early as 2010 when the notion of possible spectrum sharing came to light. FCC NPRM 16-68, issued in June 2016, was the first FCC action to identify this need for testing.<sup>16</sup>

NPRM 16-68 specifically identified three phases of testing. Phase I was to be conducted by the FCC in their labs. Its primary purpose was to determine the ability of U-NII devices to detect and avoid transmitting in cases where DSRC was sharing the spectrum. Phase II was to be conducted in USDOT labs and field settings, and its purpose was to evaluate the efficacy of the Phase I approach to interference avoidance in real-world controlled conditions. Finally, Phase III was to explore more robust, dynamic real-world scenarios, again, as defined by the USDOT Test Plan.

Since NPRM 16-68 was published, numerous test results related to the coexistence with and interference affects from unlicensed Wi-Fi on DSRC have been made available. This includes testing performed by both FCC and USDOT. With the recent introduction of C-V2X as a possible alternative to DSRC, and with the publication of the current NPRM (19-138), many of the test scenarios were revisited and updated, resulting in revised versions of many of the test reports. We have identified five (5) reports/whitepapers as most relevant to this white paper:

- FCC Report TR 17-006 [\[link\]](#)
- USDOT Impairing Traffic Safety from Changes in the Safety Band: Introduction of Interference from Unlicensed Users [\[link\]](#)
- USDOT DSRC-U-NII-3 Sharing & Spectrum Interference Testing – Draft Report [\[link\]](#)
- USDOT Analysis of FCC Phase I Sharing Report Out-of-Band Emissions for U-NII Adjacent and Next Adjacent Channel [\[link\]](#)
- CAMP DSRC & Wi-Fi Baseline Cross-channel Interference Test and Measurement Report [\[link\]](#)

The appendix includes a more detailed review of each report.

The following is a summary of known facts and observations specific to interference, to be considered when evaluating additional research and testing needs in the wake of the FCC NPRM.

### Facts:

- Interference testing to date has been performed primarily with Wi-Fi devices only. The proposed rulemaking will however allow any device operating under FCC Part 15 to use this spectrum. In the absence of testing devices which fall into this category, no determination of their impact can be made, but it cannot be assumed to have no impact.
- U-NII-4 devices only exist in prototype or as modified U-NII-3 form, mostly complying with current U-NII-3 rules. As such, there is no real basis to validate U-NII-4 performance or impacts.
- Specification for U-NII-4 devices do not yet exist.
- The design, test and activities necessary to engineer a robust environment with sufficient confidence to support ITS safety using DSRC required tens of thousands of hours and data points to produce.

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<sup>16</sup> <https://www.fcc.gov/document/59-ghz-public-notice>

### Observations:

- Adjacent channel interference from high-power Wi-Fi (36 dBm EIRP) and only 15% traffic load caused significant interference at a distance of 200 meters from DSRC.
- Interference from Wi-Fi in an adjacent channel typically resulted in significant packet errors 200-350 meters away for traffic loads of 15% and higher.
- Interference is far more sensitive to the traffic load transmitted by the Wi-Fi than the power level.
- A regular periodic distribution of Wi-Fi traffic caused about 10-20% more packet errors than a more random Poisson distribution.
- Self-Interference and adjacent channel interference will likely affect the ability of a re-channelized spectrum to deliver safety messages.
- Loss of Control Channel would increase complexity of delivering necessary safety-related support messages.
- Cross-channel test results showed the potential for cross-channel interference, having an impact on DSRC performance up to a range of 500 meters or more, but typically between 200 and 300 meters.
- The 10 MHz and 20 MHz channels proposed for transportation safety-critical applications under the current NPRM could see interference from above and below if both proposed allocations become regulation.

It is clear from the results of even just this small number of real-world, over-the-air tests that wireless devices operating in the 5.9 GHz spectrum negatively affect the performance of DSRC, thus limiting its ability to perform the safety-critical role it was designed to perform. The effects, coupled with the proposed re-channelization of DSRC and the addition of C-V2X as a potential technology companion, is anticipated to even further diminish the connectivity performance of the 5.9 GHz spectrum.

### Published Benefits Analyses

The current NPRM and the comments submitted also frequently refer to costs and benefits, in particular how important CV technology is to future safety needs. Observational data is often used in making the case that CV technology has distinct advantages over simple reliance on vehicle-only commercially available sensors today. Specifically:

- Lidar does not work in heavy rain, fog, or snow.
- Cameras have reduced performance when dirty, at nighttime, and in heavy sun-load conditions.
- Radar has trouble identifying stopped objects.

Furthermore, most sensors have limited range as compared to the 300m minimum performance requirement of DSRC. CV technology can address many scenarios that today's sensors cannot, including:

- Intersection movement assist;
- Left turn assist;
- Emergency electronic brake light;
- Red light violation warning;
- Curve speed warning;
- Reduced speed/work zone warning; and

- High-speed platooning.

In terms of quantifying the benefits of connected vehicle technology, most analyses focus on its potential to improve safety, mobility, and sustainability. For example, the SPaT data that is broadcast at an intersection can address all three.

- Safety: The OBU can assess the vehicle will run a red light and warn the driver.
- Environment: Using the SPaT information from a corridor of RSUs, the OBU can direct the driver to maintain a specific speed such that the driver does not need to accelerate or brake while traversing a corridor. This increases fuel economy and decreases the carbon footprint.
- Mobility: Based on connected vehicle data, the traffic signal controller can dynamically adjust the SPaT to improve traffic flow and reduce congestion.

Most benefit analyses that have been conducted to date, focus on the benefits of connected vehicle technology, but very few focus on the costs.

Volpe completed an analysis in April of 2014<sup>17</sup> and found that V2I applications have a very large safety benefit potential, even when viewed as an incremental add-on to V2V safety systems. They also found that V2I provides additional benefits during the years when OBU penetration is low because it can be available when only one vehicle (rather than both) is equipped. However, the cost-benefit discussion in the document only included safety benefits.

In December 2015, NHTSA published the results of the independent evaluation of V2V safety applications from the Safety Pilot Model Deployment.<sup>18</sup> Volpe, the independent evaluator, concluded that overall, the Safety Pilot Model Deployment demonstrated that V2V technology can be deployed in a real-world driving environment and that the safety applications issued warnings in the safety-critical driving scenarios that they were designed to address.

Several other research documents provide safety-based deployment assistance location for curve speed warning,<sup>19</sup> stop-sign gap assist,<sup>20</sup> and red light violation warning<sup>21</sup> applications. The purpose of each of the documents is to give state and local agencies guidance on how to select locations for deployment for each of the three applications to derive the greatest benefit-to-cost ratios.

Another study from the University of Michigan Transportation Research Institute<sup>22</sup> illustrates the negative consequences of delaying deployment of DRSC. It also reinforces the need for FMVSS 150, the

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<sup>17</sup> Volpe, Connected Vehicle Deployment Decision-Support Analysis and stakeholder Impact Analysis: Summary of findings. April 11, 2014. [https://www.transportation.gov/sites/dot.gov/files/2020-03/CV%20Deployment%20Decision%20Support%20-%20Summary%20Report%20final\\_0.pdf](https://www.transportation.gov/sites/dot.gov/files/2020-03/CV%20Deployment%20Decision%20Support%20-%20Summary%20Report%20final_0.pdf)

<sup>18</sup> Nodine, E., Stevens, S., Lam, Andy, Jackons, C. and Najm, W. Independent Evaluation of Light-Vehicle Safety Applications Based on Vehicle-to-Vehicle Communications Used in the 2012–2013 Safety Pilot Model Deployment. NHTSA. December 2015. DOT HS 812 222.

<sup>19</sup> Safety-Based Deployment Assistance for Location of V2I Applications Pilot: Curve Speed Warning Application.

<https://www.transportation.gov/research-and-technology/safety-based-deployment-assistance-location-v2i-applications-pilot-curve>

<sup>20</sup> Safety-Based Deployment Assistance for Location of V2I Applications Pilot: Stop-Sign Gap Assist Application.

<https://www.transportation.gov/research-and-technology/safety-based-deployment-assistance-location-v2i-applications-pilot-stop>

<sup>21</sup> Safety-Based Deployment Assistance for Location of V2I Applications Pilot: Red-Light Violation Warning Application.

<https://www.transportation.gov/research-and-technology/safety-based-deployment-assistance-location-v2i-applications-pilot-red>

<sup>22</sup> James R. Sayer, Carol A. C. Flannagan, Andrew J. Leslie. The Cost in Fatalities, Injuries and Crashes Associated with Waiting to Deploy Vehicle-to-Vehicle Communication. May 2018.

<http://umtri.umich.edu/sites/default/files/The%20Cost%20Associated%20with%20Waiting%20to%20Deploy%20DRSC.pdf>

proposed regulation that would have mandated V2V technology in all light weight vehicles, but was put on long-term action list during an administration change.

In addition to the technical research mentioned in the previous section, a significant difference of opinion is growing in terms of cost-benefit analysis concerning the use of this spectrum. A number of commenters to the FCC NPRM noted that the benefits and costs section of the NPRM is “extraordinarily one-sided,” focusing almost exclusively on the benefits of making additional spectrum available to unlicensed use while largely ignoring the benefits that are lost by reallocating 45 MHz away from transportation safety.

The FCC references a RAND study’s estimates in terms of consumer surplus and revenue growth (the same as GDP, fn. 96). At \$17.7 billion for 75 MHz, this estimate is much smaller and by implication smaller still for 45 MHz at \$10.6 billion ( $\$17.7 \text{ billion} \times 0.6$ ). The NPRM does not adjust any of the estimates down for 45 MHz. The USDOT found considerable fault with this approach and concludes that a “rigorous analysis” of the benefits should be conducted.<sup>23</sup>

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<sup>23</sup> <https://www.transportation.gov/research-and-technology/preliminary-technical-assessment-fcc-59-ghz-nprm>

## Conclusions

V2X applications enabled by the 5.9 GHz spectrum have traversed a deliberate time line that featured a developmental period, testing period, and the current period of regulatory uncertainty.

Feedback submitted to the FCC concerning their proposed reallocation of the 5.9 GHz spectrum was significantly in opposition, with safety and radio interference raised by many submitters. This white paper summarized comments from several different stakeholder groups, and highlighted several areas that might be of interest (including suggestions for how to move forward, and information on possible legal challenges that could be pursued by some of the submitters).

The current NPRM and the comments that have been received by the FCC have also brought new technical research and terminology to the dialogue, and this white paper has provided an overview that demonstrates the need for additional radio interference research, as well as cost/benefit analyses.

Additional technical information on the technology, testing, and results of that testing can be found in the appendix.

## Appendix - Technical Information

Section 3 of this white paper provides a high-level discussion on several key elements related to the technologies operating (or planning to operate) in the 5.9 GHz spectrum. To support the understanding of those discussions, Section 3 also defines many key terms using familiar terminology. The background and detailed information in this appendix is intended to provide additional depth to the conversation, taking a deeper dive on some or all of those supporting elements, elements that were fleshed out in great detail during the drafting of this paper.

The order generally follows the order of Section 3, expanding on many of the summary items documented in the main body, and including additional information that was purposefully omitted from the body of the paper. Some repetition is necessary in order to ensure the context of the original language is maintained. While not meant to be standalone document, a majority of the subsections in this appendix are able to be read as such.

### Current 5.9 GHz Spectrum and its Utilization

When the 5.9 GHz spectrum was first allocated to USDOT for ITS, engineers were very purposeful in their design of DSRC devices to maximize the use of the spectrum and minimize the effects of interference. Message exchanges needed to work well in an environment where the sender and a receiver may be moving toward or away from one another at speeds greater than 100 miles per hour, or where vehicles are moving at varied speeds in the same environment. To maximize the number of vehicles that can reliably communicate with each other and with the infrastructure, engineers considered the entire 75 MHz of the 5.9 GHz band. The result is the current DSRC design with seven (7) channels (10 MHz each) and the option of combining certain channels into 20 MHz channels.

This design intentionally spread the critical services—Safety, Control and Public Safety—across the full spectrum. This isolation protects the channels from cross-channel interference.

- Safety messages, located in the lowest channel, Ch. 172, are protected from external interference on the lower end by a 5 MHz guard band.
- The Public Safety Channel, Ch. 184, at the upper edge of the band is afforded higher-power transmission, negating the impact of adjacent channel interference.
- The Control Channel, Ch. 178, sits in the middle of the spectrum and, given its role facilitating the management of the remaining four channels, mitigates interference as part of its channel use strategy.

The design effort also considered which functions could be supported in each channel, depending on safety-criticality and other priorities.

Table 1 depicts the channel numbers along with a few examples of SAE J2735 messages that are broadcast on each channel.

Table 1. Channel Use by DSRC (Source: WSP USA)

<b>172 (Safety Channel)</b>	<b>174 (Service Channel)</b>	<b>176 (Service Channel)</b>	<b>178 (Control Channel)</b>
Basic Safety Messages used by Vehicle-to-Vehicle safety applications  Signal Phase and Timing (SPaT)/MAP messages used by Vehicle-to-Infrastructure applications  Personal Safety Messages used by Vulnerable Road User applications	Signal Request Messages (SRMs) and Signal Status Messages (SSMs) used by Signal Priority and Signal Preemption applications  On-Board Unit (OBU) IEEE 1609.2 Certificate update requests  OBU Over-the-Air firmware updates and other OBU IPv6 Services	SRMs and SSMs used by Signal Priority and Signal Preemption applications  OBU IEEE 1609.2 Certificate update requests  OBU Over-the-Air firmware updates and other OBU IPv6 Services	IEEE WAVE Service Advertisements (WSAs) used to advertise services available at a given Roadside Unit  Traveler Information Messages/Road Safety Messages used by Traveler Information/services applications
<b>180 (Service Channel)</b>	<b>182 (Service Channel)</b>	<b>184 (Public Safety Channel)</b>	
SRMs and SSMs used by Signal Priority and Signal Preemption applications  OBU IEEE 1609.2 Certificate update requests  OBU Over-the-Air firmware updates and other OBU IPv6 Services	SRMs and SSMs used by Signal Priority and Signal Preemption applications  OBU IEEE 1609.2 Certificate update requests  OBU Over-the-Air firmware updates and other OBU IPv6 Services	SRMs and SSMs used by Signal Priority and Signal Preemption applications  Other messages for Public Safety applications	

### DSRC Roadside Units

In April of 2017, the USDOT released version 4.1a of their DSRC Roadside Unit (RSU) Specification, describing the minimum requirements an RSU should support to provide effective V2I communication. A DSRC RSU is the wireless access point deployed in the infrastructure to communicate with approach vehicles.

A typical DSRC RSU contains two radios supporting three 10 MHz channels. One radio is utilized to broadcast SAE SPaT and MAP messages on the Safety Channel 172, using IEEE 1609.4 continuous channel access (CCA). CCA is addressed later in the subsection on interference, but the basic concept is that the radio listens and waits for an opening before it broadcasts.

The second radio utilizes 1609.4 alternating channel access to broadcast messages on the Control Channel (CCH) 178, and then broadcast and receive messages on another service channel (SCH) as designated by Ch. 178.

The IEEE 1609.3 Wireless Access for Vehicle Environments (WAVE) Service Advertisements (WSA) and SAE J2735:2016 travel and roadway messages, such as the Traveler Information Message (TIM) are also

typically broadcast on the control channel. Other SAE DSRC messages, such as Signal Status Messages (SSM), as well as IPv6 Services are available on the SCH. The services listed in the WSA include the SCH utilized by the RSU.

Since all RSUs utilize Ch. 178 (CCH) and Ch. 172 (Safety Channel), that leaves five other service channels to choose from for other SAE messages and IPv6 Services. The other SCH for each RSU is selected as part of an overall System Channel Plan. The Channel Plan is intended to minimize SCH overlap between RSUs to maximize the number of vehicles that can utilize RSU services (e.g., IPv6) simultaneously. The IPv6 Services enable OBUs to download firmware updates and top off IEEE 1609.2 certificates, over-the-air.

RSU Owners must obtain a license from the FCC to operate each device. FCC Licenses are issued for a region as well as for specific locations within the region. For a regional license, a center point and radius are provided to the FCC. For a location specific license, the latitude, longitude, and elevation of the location as well as the RSU Antenna manufacture, model number, antenna gain, and installation height, and the hardware make, model, FCC ID number, FCC Class, service channel, and transmit power, among other things, are provided to the FCC. Prior to the issuance of the current NPRM, RSUs could be licensed for all channels within the 5.9 GHz spectrum.

#### *DSRC On-Board Units*

Similar to RSUs, typical On-Board Units (OBUs) contain two radios. OBUs broadcast and receive SAE J2735 Basic Safety Messages (BSMs) on Channel 172 as well as receive SPaT and MAP messages broadcast by RSUs. OBUs also listen to the CCH for WSAs and travel and roadway messages. OBUs may broadcast other messages, such as the SAE Signal Request Message (SRM), if an authorized vehicle such as transit, fire or police is properly equipped. OBUs may also request firmware and security certificate updates using the SCH contained in the WSA.

OBUs are presently "licensed by rule," which can mean as long as OBUs comply with applicable FCC rules (pass FCC certification), they do not require an individual license. However, language in the current NPRM intends to remove this licensing option.

#### *DSRC Security*

Cybersecurity is an important part of any communication system to protect user data against unauthorized and malicious use. There are two (2) major components to cybersecurity: protecting data and protecting privacy. "Data protection" ensures personally identifiable information (PII), such as social security numbers or driver license numbers, are only accessible to those we authorize. "Privacy protection" ensures our habits, such as travel shopping, work, or school, are only known to those we trust.

V2X communication is no different. In most cybersecurity systems the user (data owner) knows who they are communicating with and agrees to share certain information about themselves for the benefit of the transaction. For example, most smartphone users agree to share location, travel habits, shopping habits, and other information with their application provider to enjoy the always connected world we have grown accustomed to; our application providers know us better than we know ourselves in some respects. With V2X, however, much information can be gleaned from the data our vehicles broadcast. Since most of the data broadcast by our vehicles are critical to the operation of vehicle safety

applications and broader mobility applications, V2X security focuses on privacy protection—protecting the identity of the vehicle operator and owner.

V2X messages do not contain PII or vehicle identifiable information (VII), such as vehicle make, model, model year, or vehicle identification number (VIN). However, vehicle, and infrastructure, applications must still be able to “trust” the data they are receiving to ensure the integrity of the data (i.e., be sure it is coming from a legitimate source and not from a malicious [bad] actor). To enable privacy while still being able to “trust” a data source, all V2X messages (data) are signed with a digital certificate from a known Certificate Authority (CA) (certificate issuer). These certificates as well as the overall Security Credential Management System (SCMS) are based on IEEE 1609.2. The premise being, if my vehicle trusts the CA and the CA trusts your vehicle, then my vehicle can trust your vehicle. This mechanism enables vehicles to exchange data with each other and the infrastructure while remaining anonymous.

Both RSUs and OBUs sign messages with IEEE 1609.2 certificates. To obtain certificates, devices must be enrolled in a SCMS. Enrollment requires device manufactures to provide evidence that devices meet specific requirements and adhere to specific standards, such as the IEEE 1609 suite of standards and SAE J2735 and the J2945 suite of standards, depending on the certificates they are requesting.

There are typically three types of certificates utilized in a DSRC system: Application, Identity and Pseudonym. Application Certificates are generally utilized by RSUs which do not require anonymity. RSUs typically have one certificate per application, with that certificate being valid for one week. Two weeks of certificates, this week and next, are maintained on the RSU at all times, with RSUs topping off (requesting new certificates) every week.

OBUs utilize Identity Certificates when anonymity is not required, such as broadcasting SAE SRMs to request Signal Priority or Preemption. Similar to Application Certificates, Identify Certificates have a one-week validity period with OBUs maintaining two weeks of certificates, this week and next. OBUs top off Identity Certificates once a week.

OBUs also utilize Pseudonym Certificates when anonymity is required, such as broadcasting BSMs. Pseudonym Certificates are valid for one week, but OBUs typically contain up to 20 certificates for a given week and rotate the certificate used during the week such that OBUs cannot be tracked by their certificate. OBUs typically maintain up to three years of certificates on board. Device top-off frequency is defined via system owner policy and can range from every week to every 18 months.

#### *OmniAir DSRC Device Certification*

The OmniAir Consortium certifies DSRC devices to ensure the devices meet relevant IEEE, SAE, and other standards and requirements. OmniAir provides a third party independent assessment of functionality, interoperability, and reliability. OmniAir's certification program provides confidence to federal, state, and local agencies that devices meet independent testing requirements, in addition to the manufacturer's proprietary "self-certification" test methods.

Specialized test equipment and laboratories are required to test RSUs and OBUs to ensure they meet the standards and overall functionality requirements. OmniAir qualifies test tools and laboratories to perform Device Certification.

Twice a year, OmniAir hosts a "PlugFest", in which device manufactures, test laboratories, and test equipment manufactures come together to evaluate their devices against OmniAir's certification test

processes. PlugFest enables device manufactures and test equipment providers to conduct certification dry runs in a safe and secure environment, prior to submitting devices for certification.

## Introduction of C-V2X

With the release of 3GPP Release 14 (R14) in 2017, a new technology supporting device-to-device communications was introduced. Known as Cellular Vehicle to Everything (C-V2X), the technology leverages the same hardware as traditional cellular but is not part of the cellular network. C-V2X does NOT require a SIM card or a data plan and utilizes a device-to-device architecture. And C-V2X is sometimes erroneously referred to as 5G. Today, C-V2X operates in the same 5.9 GHz band as DSRC and is based in current 4G (4th Generation cellular technology) Long Term Evolution (LTE) technology.

C-V2X is backed by the 5G Automotive Association (5GAA), a global cross-industry organization of companies from the automotive, technology, and telecommunications industries developing end-to-end solutions for future mobility and transportation services. In 2018, 5GAA submitted a waiver to the FCC to allow C-V2X operations in the upper portion of the DSRC band.<sup>24</sup> Since all transmissions occur in the same 20 MHz channel, there is no requirement for a service channel in C-V2X, as devices simply listen for available messages. Note: the FCC NPRM as currently written has set aside this 20 MHz channel for C-V2X.

### *C-V2X Devices*

Pre-production versions of C-V2X devices presently only contain a single radio supporting a single 20 MHz channel. C-V2X transmissions only use the bandwidth needed to broadcast the data, unlike DSRC which utilize the entire 10 MHz channel regardless of the packet size transmitted.

Several Standards Development Organizations are developing standards for C-V2X devices. For example, National Electrical Manufactures Association (NEMA) is developing Specification TS-10, which incorporates C-V2X technology into RSUs and SAE is developing J3161, which defines the minimum performance requirements for C-V2X BSMs, similar to SAE J2945/1 for DSRC BSMs.

According to current FCC rules, it is illegal to operate C-V2X devices in the 5.9 GHz (DSRC) band. Infrastructure owners wishing to operate C-V2X devices must obtain an Experimental license from the FCC. In addition to the parameters required for a DSRC License, the FCC requires an Experimental Description document that defines the purpose and other relevant technical criteria of the “experiment,” and verification that the requested spectrum is vacant (or will be vacated), among other items, when requesting an Experimental license.

Figure 6 - C-V2X Proposed Spectrum Plan (source: WSP USA)Figure 6 shows the C-V2X channel allocation contained in the 5GAA Waiver Request. Since all transmissions occur in the same 20 MHz channel, there is no requirement of a WAVE Service Advisement in C-V2X, as devices simply listen for available messages. C-V2X employs Hybrid Automatic Repeat Request (HARQ) for packet re-transmission to improve overall reliability in a 20 MHz channel. Details of HARQ are beyond the scope of this white paper.

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<sup>24</sup> <https://ecfsapi.fcc.gov/file/104030451515194/5GAA%20Band%20Plan%20Ex%20Parte%20-%20FINAL.pdf>

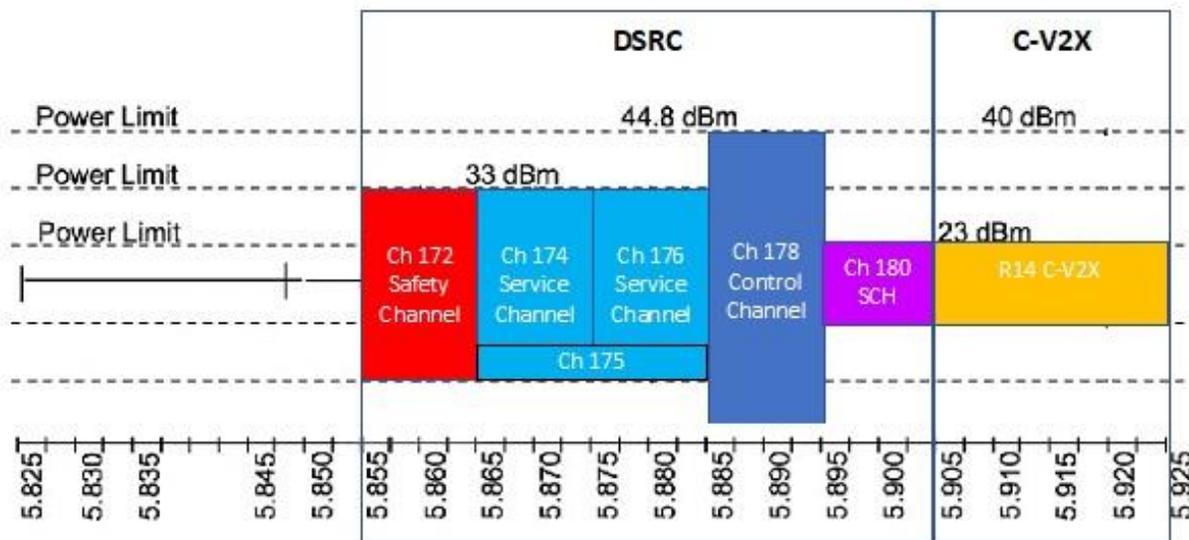


Figure 6 - C-V2X Proposed Spectrum Plan (source: WSP USA)

#### C-V2X Security

C-V2X devices utilize the same IEEE 1609.2 certificates as DSRC devices. There is no difference between enrolling a DSRC device or a C-V2X device in a SCMS or in the way the certificates are utilized by the devices and applications.

#### OmniAir C-V2X Device Certification

The OmniAir Consortium is developing a C-V2X certification program similar to their existing DSRC program. They are working with device manufactures, test laboratories, test tool manufactures, and other industry stakeholders to develop appropriate test cases, leveraging existing DSRC test cases and developing new test cases to meet relevant 3GPP R14, SAE J3161, and other requirements. OmniAir has been evaluating C-V2X test cases since the 2019 spring PlugFest and plans to roll out the official program in the fall of 2020.

#### Differences Between DSRC and C-V2X

The principal difference between DSRC and C-V2X is the communication stack Radio (physical) Layer; DSRC uses IEEE 802.11/1609.4 standards tailored through SAE J2945/1 V2V Performance Requirements, and the USDOT RSU specification version 4.1a whereas C-V2X uses 3GPP R14 specifications tailored via the draft SAE J3161 V2V Performance Requirements and the NEMA TS10 RSU specification. The remaining stack components (IEEE 1609.2, 1609.3 and SAE messages) are consistent between the two technologies.

Figure 7 shows a comparison of the DSRC and C-V2X communication stacks. All other external interfaces to the Roadside Unit (i.e., Signal Controller, Backhaul) remain the same. Messages and applications remain the same as well.

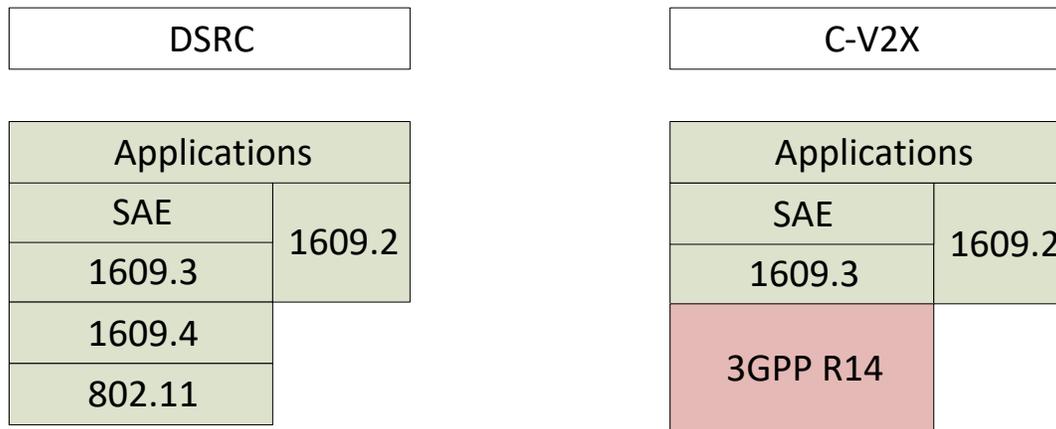


Figure 7. Comparison of DSRC and C-V2X Network Stack

## V2X Support for Automated Vehicles

As previously discussed, V2X devices are omnidirectional (i.e., offer 360 degrees of coverage). Communicating via radio signals allows two equipped vehicles to “hear” each other and exchange critical information—regardless of whether the vehicles are in view, around a corner, or behind a building or even a cornfield. This is a significant benefit for enhancing the safe operation of automated vehicle functionality and reliability.

Without connectivity, automated vehicles are islands, much like traditional human driven vehicles are today. They do not coordinate their actions, nor do they cooperate with each other for the overall benefit of the "system." Vehicles with Radar, LiDAR cameras, and other sensors need to sense, or “see” their environment. They must:

- See (detect) an object;
- Determine if it is a vehicle, animal, pedestrian, or tree;
- Track the object;
- Predict the object’s behavior based on what it sees;
- Determine if the object poses a threat; and
- React to potential threats.

But the USDOT recently pointed out that vehicle-based sensors are unlikely to be able to address many crashes adequately that occur at intersections. This is because the vehicles involved in such crashes often “reveal” themselves to each other (establish a line-of-sight condition) very late in the crash scenario, such that there is insufficient time for onboard crash-avoidance systems to assess crash probabilities and then warn the driver appropriately.<sup>25</sup>

With connectivity, automated vehicles:

- Coordinate and cooperate with each other to improve overall traffic flow;
- Are no longer islands, they’re part of a “system” (collective);

<sup>25</sup> <https://ecfsapi.fcc.gov/file/10313251510165/5.850-5.925%20GHz%20Band%2C%20ET%20Dkt%20No.%2019-138.pdf>

- Have enhanced situational awareness (visibility of environment);
- “Hear” as well as “see,” and
- Hear long(er) distances.

The National Transportation Safety Board (NTSB) submitted comments to the FCC regarding the NPRM citing their investigations of (partial) automated vehicle crashes revealed that numerous crash scenarios are simply outside the capability of sensor based systems and that “V2V technology provides safety information beyond that of vehicle-based sensors, especially for occluded vehicles and objects or vehicles traveling on perpendicular paths.”<sup>26</sup>

In their submission to the FCC regarding the NPRM, Toyota pointed out that V2X can allow Automated Driving System (ADS) vehicles to easily and reliably communicate with emergency response vehicles, with traffic signals, and with other infrastructure messaging (such as location of work zones, temporary lane closures), and numerous other messages that can help an ADS vehicle navigate along its intended path and follow the trajectories of other nearby vehicles to assist in collision avoidance.<sup>27</sup>

## Next Generation V2X Technical Environment

Both DSRC and C-V2X are developing approaches for next generation products. Both assume the availability of the entire 75 MHz of the 5.9 GHz band. Next generation DSRC will operate across the entire band to accommodate today’s applications as well as emerging cooperative-automated applications such as platooning, cooperative perception, or cooperative maneuvering. 3GPP expects LTE C-V2X to continue to utilize the 20 MHz channel 183, with new 5G technologies occupying a greater portion of the spectrum.

### *DSRC*

IEEE is developing the "Next Generation" DSRC technology, designated as 802.11bd. The 802.11bd standard is being designed to be backwards compatible with 802.11p, the current DSRC technology. This infers 802.11bd and 802.11p devices can communicate with each other while operating on the same channel.

Just as 802.11p is based on the current Wi-Fi 802.11a specification with modifications to support vehicular speeds on up to 200 kph (124 mph), 802.11bd is based on the current Wi-Fi 802.11ac specification, with modifications to support vehicular speeds on up to 500 kph (310 mph). The 802.11bd specification will also add re-transmission capability to increase overall reliability.

The 802.11bd specification is designed to utilize the same channelization as 802.11p(DSRC): seven 10 MHz Channels. As a result, 802.11bd will require the entire 75 MHz of 5.9 GHz band.

### *C-V2X*

3GPP is developing a "New Radio" technology as part of Release 16, designated as "Advanced C-V2X." The NR V2X standard is likely to employ a similar approach to the previously developed New Radio standard for base station communication (uplink/downlink). However, the 3GPP decided in 2018 not to consider same-channel coexistence between NR V2X and LTE V2X. Therefore, NR V2X is not backward compatible. This means that for some period of time, devices will require a dual radio system, one for

<sup>26</sup> [https://ecfsapi.fcc.gov/file/10304962123988/64852\\_out.pdf](https://ecfsapi.fcc.gov/file/10304962123988/64852_out.pdf)

<sup>27</sup> <https://ecfsapi.fcc.gov/file/10309215237674/FCC%20NPRM%20COMMENTS%20TOYOTA%20FINAL%203.9.20.pdf>

R16 and one for R14, to support the new technology and the legacy LTE C-V2X technology until all devices and installations move to the 5G NR, R16 capability.

As with current DSRC and C-V2X technologies, these differences are only at the radio level; SAE defined V2X messages, interfaces to other devices (e.g., Traffic Signal Controllers) and back office systems (Traffic Management systems) will remain the same and evolve independent of the radio.

R16 is being designed for a 40 MHz channel. The 3GPP assumes Channel 172 will remain available for DSRC. This, along with the 20 MHz channel utilized by R14, implies C-V2X will require 60 MHz of the Band. When accounting for DSRC channel 172 (10 MHz) and the 5 MHz guard band, the entire 75 MHz of the 5.9 GHz band is required.

#### *Future Interoperability of V2X Technologies*

Interoperability is the ability of two or more devices to exchange, process, and act on data received from each other. DSRC (current or next generation) and C-V2X (3GPP R14 and NR V2X) technologies are designed to utilize the 5.9 GHz band differently, and appear as noise to each other. They cannot receive, process, nor act on data from one another, thus they are not interoperable. Consider the analogy of a person who can only speak English and a person who can only speak Russian. Both utilize spoken language to communicate, but the English-speaking person cannot understand the “information” the Russian speaking person is trying to convey and vice versa.

While each technology may be independently capable of meeting the performance requirements for safety-of-life applications, the lack of interoperability (or compatibility) between technologies means that the benefits of V2X will be limited solely to the interactions between vehicles and infrastructure equipped with each specific technology.

More specifically, it is not possible for a vehicle equipped with DSRC to exchange BSMs with a vehicle equipped with C-V2X. Vehicles would need both types of radios. While interoperability between DSRC and C-V2X is not possible, coexistence could be achieved through various spectrum sharing processes. One such process is “Detect and Vacate.” Detect and Vacate operates under the premise that one technology has a higher priority use of the spectrum and all other technology must concede the spectrum when a primary use device is present. For example, if DSRC had priority over the spectrum, C-V2X devices would need to “listen” to be sure DSRC was not utilizing a channel before broadcasting. If a C-V2X device “hears” (detects) that a channel was in use by DSRC, it would not be able to broadcast on that channel. If a C-V2X device was utilizing a channel and a DSRC device came into range, the C-V2X device would need to move to a different channel (vacate).

In general, reducing the spectrum for V2X technologies limits the safety, and other, benefits envisioned by the FCC. Through the standards, certification, and application development processes over the past several years, the industry has assumed V2X technology would have 75 MHz of bandwidth. Reducing the bandwidth now, just months away from full scale deployment, would require the entire industry to start over, losing several years of progress, while lives are continually lost due to vehicle crashes.

## Advanced Terms and Concepts

The primary source of concern for the proposed spectrum reallocation is the introduction of interference, interference that will limit the effectiveness of DSRC or C-V2X. The following is a detailed discussion of key terms and concepts related to the types of interferences and what constitutes interference versus a normal waveform.

#### *Overview of Radio Frequency Interference*

Radio Frequency Interference (RFI) is defined as any external source whose output overlaps a signal path and produces undesired artifacts in the signal along that path. The impact of RFI can be far ranging, resulting in an increase in error rate or in the worst case, a total loss of data. When safety of life is dependent on receipt of messages from other vehicles and from infrastructure, as is the case with the current V2X use cases, any loss of data can have a significant impact.

#### *Forms of RFI*

RFI is generally thought of in one of three forms: ambient or background noise, packet collision, and transmitter message suppression. Separate or in combination, these forms of RFI prevent the reliable exchange of data between a transmitter and a receiver. The following describes each and their specific impact.

- Ambient noise is the culmination of all unwanted signals, both in-band and adjacent, which reduces the ability of weak signals from distant transmitters to be received. Ambient noise is typically a result of unlicensed devices transmitting in or near the DSRC channel.
- Packet collision occurs when a receiver receives packets simultaneously from two or more sources and the message cannot be properly interpreted, rendering them useless. These packets are discarded by the receiver. These are essentially transmitted messages that are lost.
- Transmitter message suppression, also known as Clear Channel Assessment, is a feature of the Carrier Sense Multiple Access/Collision Avoidance (CSMA/CA) protocol used by the IEEE 802.11 protocol on which DSRC (and for that matter Wi-Fi) is based. As specified by the protocol, the transmitter waits until the medium (in the case the 10 MHz channel) is idle before transmitting. If the channel is not idle, the transmitter will wait a random period of time and then re-try the transmission. In the case of DSRC, if secondary transmitters are continually using the channel and no idle period can be detected, the message transmission by the primary device will effectively be suppressed. While in this case the wireless radio is truly operating as designed, the effects are not desirable.

#### *Spectral Mask*

A term that has been mentioned quite a bit in relationship to the recent FCC NPRM is that of a spectral mask. To understand spectral masks, the reader must first understand a few basic principles of radio frequency communications.

First, the term Signal Power (or simply power) is the amount of energy used to radiate (i.e., push) the signal. Power is measured in decibels (dB) and is logarithmic, meaning a measured 10 dB increase equates to an order of magnitude (10x) increase in power. When describing a spectral mask, relative power or dBr is used, with 0 dBr considered the maximum power of the transmitted signal. The zero power point or floor of the spectral mask is considered to be -40 dBr, a point where the power level has been reduced by 10,000 times.

The second principle is to understand the characteristic of a radio frequency (RF) signal. As seen in Figure 8, this is a waveform for a typical U-NII-3 802.11ac signal. The waveform of a transmitted RF signal does not behave like a square wave with an infinite (completely vertical) slope on the leading and trailing edges of the channel. Instead, as you move farther away from the center frequency of the signal, the power level decreases non-linearly, with varying slopes (rates of change), first gradually (nearly flat until just before the edges of the band, points A on **Error! Reference source not found.**) and then more precipitously, until you reach the lower measured limits (point D).

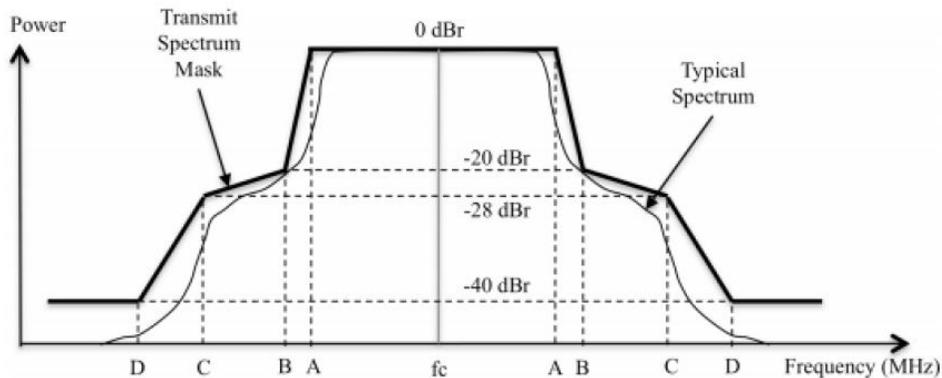


Figure 8 - Example of a Spectral Mask for Wi-Fi (source: National Instruments)

A spectral mask serves to characterize and bound the waveform by identifying what the maximum relative power is at each of these key points within the waveform consistent with the standards that govern the waveform’s protocol. In theory, a waveform will not exceed the power levels prescribed by the spectral mask.

The design of the spectral mask is such that the majority of power is concentrated within the band. In the example above points A are fully within the band and, represent the frequency over which maximum power is transmitted. As you move along from point A to point B, during which one crosses the edge of the band, power is decreased significantly (-20 dB). However, you will also notice that this -20 dB point is now outside of the band.

While a 20dB decrease in power would seem significant, there is evidence that when mixing-and-matching different RF protocols (DSRC, Wi-Fi, other), the interference caused by this remaining out-of-band transmission is still impactful.

More important to the current situation, the proposed changes in the FCC NPRM, which allows for the use of adjacent 160 MHz U-NII-4 channels, would effectively allow the out-of-band portion of the waveform (point C in the figure) of an adjacent U-NII-4 waveform, whether immediately above or below the proposed safety spectrum, to overlap the entirety of the 30 MHz spectrum.

### Published Test Results on Interference

As noted in the main body of the white paper, five (5) key reports white papers served as the basis of our summary of the state of testing. The following is a brief overview and relevant findings from each of the document reviewed. The summary of the facts and observations from each may be found in the main body of the white paper.

### *FCC Report TR 17-006 – Phase 1 Testing Results*

The first significant result of spectrum sharing tests is embodied in FCC Report TR 17-006, published in October 2018.<sup>28</sup> This report captures the results and summarization of the completed Phase I testing as recommended in NPRM 16-68 (June 1, 2016). Two spectrum sharing proposals were considered, Detect and Vacate and re-channelization. Under Detect and Vacate, DSRC and non-DSRC devices alike would share the spectrum, but the behavior of the non-DSRC device is intended to yield the spectrum to DSRC in the presence of DSRC transmissions by immediately moving to another part of the spectrum. Re-channelization involves repurposing the spectrum by moving the ITS safety to a different portion of the spectrum and allowing unlicensed Wi-Fi devices to occupy the channels that were freed.

Based on language in the current NPRM language, the FCC is clear that the recommended approach is re-channelization, and as such, the remaining outcomes summarized in this paper will focus on that approach as opposed to detect and vacate. Specifically, Section II.A.5 of the current NPRM states:

“Rather than further attempting to resolve questions about coexistence and sharing of spectrum by unlicensed operations and DSRC, the Commission propose to repurpose the lower 45 megahertz of the 5.9 GHz band (5.850–5.895 GHz) to allow unlicensed operations, and retain use of the upper 30 megahertz of the band (5.895–5.925 GHz) for ITS purposes, either solely for C–V2X or divided between C–V2X and DSRC technologies.”

The approach for re-channelization proposed to move the safety elements of DSRC to the upper 30 MHz of the 5.9 GHz spectrum, similar to the current NPRM approach, allotting 30 MHz in the upper band for ITS, but still maintaining the use of a 20 MHz channel in the lower spectrum. This approach is no longer consistent with the current NPRM. At the time of this original testing, C-V2X had not yet been introduced as an alternative to DSRC, and such was not considered as part of the Phase I tests either.

The FCC evaluated the behavior of DSRC devices in the presence of undesired co-channel interference from prototype U-NII-4 devices, devices configured to exhibit the behavior of the next generation of Wi-Fi devices, under both of the proposed coexistence strategies. Based on the test cases performed, the report’s findings conclude that either of the proposed coexistence efforts could be employed to share the spectrum with DSRC. These results were primarily based on the controlled-environment ability of the prototype U-NII-4 device to detect and react to DSRC transmission at power levels consistent with the lowest levels of received power detectable by a DSRC receiver. Put another way, the premise was, if DSRC can receive the signal, so too can the U-NII-4 device, at which point the U-NII-4 device would react. It should be noted that these test cases were performed using stationary devices that were direct-wired together and do not necessarily reflect the real-world conditions of over-the-air wireless transmission with vehicles moving at different speeds or directions. Data collected from these measures were also intended to inform a qualitative assessment of adjacent channel rejection of DSRC.

### *Impairing Traffic Safety from Changes in the Safety Band: Introduction of Interference from Unlicensed Users*

This August 2019 Draft Report from USDOT, published in March of 2020, puts the impact of the prior and ongoing interference testing, and the proposed re-channelization, into context by identifying the expected impact to the current, demonstrated spectrum use and resulting safety applications as

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<sup>28</sup> <https://docs.fcc.gov/public/attachments/DA-18-1111A2.pdf>

provided by DSRC.<sup>29</sup> This includes the exchange of BSMs between vehicles, as well as the use of SPaT and other safety-critical messages. This report further explores the functional impact of re-channelization to the use of the service and control channels, as prescribed by the standards governing DSRC.

When the approach to implementing DSRC was designed, particular attention was paid to how the 75 MHz spectrum was used to ensure that all of stated goals of this spectrum were used. In the process, specific uses were assigned to specific channels, and along with that power limits and spectral masks were developed for each channel, to ensure that they themselves would not interfere with one another.

With the current FCC NPRM intending to compress all of the DSRC communications into a single 10 MHz channel, the RF design that had been performed previously and rigorously tested to ensure reliable and robust communications, without interference, is no longer applicable, and will require new design considerations and testing.

#### *USDOT DSRC-U-NII-3 Sharing & Spectrum Interference Testing – Draft Report*

In March 2020, USDOT released the January 2020 Draft Report on USDOT DSRC-U-NII-3 Sharing & Spectrum Interference Testing.<sup>30</sup> Unlike FCC Report TR 17-006 which used prototype U-NII-4 devices, devices that don't yet exist commercially, this report considers the impacts of existing Wi-Fi devices, known as U-NII-3, if they are allowed to share or operate adjacent to DSRC in unlicensed spectrum. This report was intended to serve as a baseline for the existing wireless environment, serving as a pre-cursor to the Phase II U-NII-4 testing prescribed in NPRM 16-68, and evaluating co-channel radio performance. In the process of conducting this testing, adjacent channel interference was also observed and recorded.

Most significant of the findings was that a U-NII-3 Wi-Fi access point, located as far as 100 meters away or more, and even if operated inside a building, or on an adjacent channel, caused significant interference with DSRC:

This represents a consequential impact to safety given that DSRC was designed to provide situational awareness in a safety zone defined by a 300-meter radius around a vehicle. Co-channel sharing with Wi-Fi or any unlicensed radio service with similar power and duty cycle as Wi-Fi will not be possible without a robust and reliable sharing mechanism that defers to the high priority safety messages. Similarly, a reallocation of channels would need to provide guard bands to protect both radio services from adjacent channel interference from the other.

The report goes on to provide several additional findings related to both co-channels sharing, and adjacent channel interference caused by Wi-Fi that, if present, would severely impact the safety capabilities of DSRC.

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<sup>29</sup> Arnold, James A., et. al, Impairing Traffic Safety from Changes in the Safety Band: Introduction of Interference from Unlicensed Users, Pre-Final Version, August 2019, [https://www.transportation.gov/sites/dot.gov/files/2020-03/Rechannelization%20Inteference-01AUGUST2019\\_FINAL\\_0.pdf](https://www.transportation.gov/sites/dot.gov/files/2020-03/Rechannelization%20Inteference-01AUGUST2019_FINAL_0.pdf)

<sup>30</sup> Arnold, James A., et. al, USDOT Spectrum Sharing Test Report: Effects of Unlicensed-National Information Infrastructure-3 (U-NII-3) Devices on Dedicated Short-Range Communications (DSRC), Draft, January 2020, <https://www.transportation.gov/sites/dot.gov/files/2020-03/Draft%20report%20on%20USDOT%20DSRC-UNII-3%20Sharing%20%26%20Spectrum%20Interference%20Testing%20.pdf>

*USDOT Analysis of FCC Phase I Sharing Report Out-of-Band Emissions for U-NII Adjacent and Next Adjacent Channel*

In March 2020, USDOT released a Pre-Final Version of their findings related to a deeper exploration of the test results captured by the FCC during the FCC's Phase I testing.<sup>31</sup> With C-V2X now part of the equation, and with the latest NPRM allocating an individual channel each for DSRC and C-V2X, this further exploration by USDOT considers the impact to both, assuming a 10 MHz channel (Ch. 180) for DSRC, and a 20 MHz channel (Ch. 183) for C-V2X.

The USDOT team generally used the same test apparatus and approach as was performed in the FCC Phase I testing, but instead of focusing on how U-NII devices might behave, they looked at the impact of the OOB from U-NII devices in adjacent channels on both DSRC and C-V2X. The tests explored the impact from adjacent U-NII devices operating in spectrum both immediately below and immediately above the 30 MHz proposed for ITS safety.

The USDOT tests revealed that a significant amount of energy (interference) remained from these adjacent channels. This interference is what is known as OOB, and the impact of OOB, particularly in transmission patterns consistent with real-world use cases, would not allow for the intended operation of either DSRC or C-V2X.

This report concluded that the FCC-led testing from Phase I provided insufficient evidence to ensure interference from co-existing and adjacent U-NII devices would not impact the ITS safety band and that a full technical assessment still needs to be completed.

*CAMP DSRC and Wi-Fi Baseline Cross-channel Interference Test and Measurement Report*

This report documents the findings of cross-channel interference testing as conducted by the Crash Avoidance Metrics Partnership LLC (CAMP), a group comprised of numerous automakers working together to test and evaluate V2x technologies and applications. These tests were conducted as part of the V2V Communications Research Project, in cooperation with the National Highway Traffic Safety Administration.<sup>32</sup>

The process included collection of baselines DSRC performance data, introducing Wi-Fi on adjacent, overlapping channels, and comparing the results. Test results showed the potential for cross-channel interference that would impact DSRC up to 500 meters or more, but specifically in the 200–300m range. It further demonstrated that the closer the waveform conformed to the spectral mask requirements for Wi-Fi devices, the greater the cross-channel interference impact was.

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<sup>31</sup> Analysis of FCC Phase I Sharing Report Out of Band Emissions for UNII Adjacent and Next Adjacent Channel Power, Pre-Final Version, March 2020, [https://www.transportation.gov/sites/dot.gov/files/2020-03/Analysis%20of%20FCC%20Phase%20I%20Sharing%20Report\\_V02\\_04%2011MARCH2020.pdf](https://www.transportation.gov/sites/dot.gov/files/2020-03/Analysis%20of%20FCC%20Phase%20I%20Sharing%20Report_V02_04%2011MARCH2020.pdf)

<sup>32</sup> VanSickle, S., et. al., Vehicle-to-Vehicle Communications Research Project (V2V-CR) DSRC and Wi-Fi Baseline Cross-channel Interference Test and Measurement Report, Pre-Final Version, December 2019, [https://www.nhtsa.gov/sites/nhtsa.dot.gov/files/documents/v2v-cr\\_dsrc\\_wifi\\_baseline\\_cross-channel\\_interference\\_test\\_report\\_pre\\_final\\_dec\\_2019-121219-v1-tag.pdf](https://www.nhtsa.gov/sites/nhtsa.dot.gov/files/documents/v2v-cr_dsrc_wifi_baseline_cross-channel_interference_test_report_pre_final_dec_2019-121219-v1-tag.pdf)