Practical Considerations for Deployers of V2X Roadside Equipment in Light of the Recent FCC Ruling

Version 1.8.1

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Introduction

For almost 20 years, the USDOT, automakers, equipment vendors, transportation safety advocates, and Infrastructure Owners and Operators (IOOs) have been evaluating, planning for, and deploying vehicle-to-everything (V2X) equipment to enable a broad connected vehicle environment that improves safety and mobility in transportation. The FCC set aside 75 MHz of wireless spectrum in the 5.9 GHz band specifically for this purpose and Dedicated Short Range Communication (DSRC) systems (hardware and standards) were developed to operate in this band.

In 2015, the USDOT contracted for the deployment of three pilot projects requiring matching funds from the local agencies to take connected vehicle technology from the development stage to practical, sustainable deployment using the DSRC technology. These pilots demonstrated interoperability and integrated the security management system, both of which are essential to the deployment of this technology.

With the initiation of the Signal Phase and Timing (SPaT) Challenge in 2016, deployments grew rapidly. IOOs and other transportation stakeholders recognized the long-term potential of V2X communication for safety and improved mobility and desired to move the technology forward. An automaker deployed the technology on one of their vehicle models, and others made public statements that they were considering deployment. Additionally, in 2016 NHTSA issued a NPRM proposing to mandate V2V communication with DSRC or "alternate interoperable technologies"[1]. While the NPRM was not advanced to a rule, these events provided additional incentive for IOOs to prepare for a connected vehicle ecosystem.

A second 5.9 GHz communication technology, Cellular Vehicle-to-Everything (C-V2X), was standardized at the radio level in 2017. C-V2X has two components: C-V2X Direct (also known as C-V2X (PC5) or LTE C-V2X) which is a short-range equivalent of DSRC and does not use the traditional cellular network, and C-V2X Network (also known as C-V2X(Uu)) which does use the cellular network. In this document, C-V2X Direct is the referenced component unless otherwise stated; this is the technology some agencies have started to deploy in lieu of DSRC. Although both DSRC and C-V2X use the same 5.9 GHz spectrum and message applications and have identical goals, the two technologies are not interoperable. A national debate ensued over whether one or both of these technologies should be adopted. The USDOT took a neutral stance on this issue. Simultaneously, the cable industry and some in the wireless industry lobbied the FCC to open up additional spectrum for Wi-Fi use, and the FCC and other stakeholders continued to consider proposals for sharing some of the 5.9GHz spectrum with unlicensed Wi-Fi. Testing of various sharing schemes ensued. Transportation safety advocates strongly opposed efforts that would cause harmful interference to V2X communications.

The FCC Commissioners voted in November 2020 to approve a Report and Order (R&O) to allow unlicensed operations use the lower 45 MHz of the 5.9 GHz band, require all DSRC operations to temporarily move into the upper 30 MHz by July 2, 2022, and to formalize the use of C-V2X Direct in the upper 30 MHz. Formal promulgation of this initial FCC Report and Order[2] (hereafter called the first R&O) on Use of the 5.850-5.925 GHz Band was triggered on May 3, 2021, when it was published in the Federal

[1] At the time of the NPRM, there were no significant alternatives to DSRC, but NHTSA was offering flexibility for the future.

[2] https://www.federalregister.gov/documents/2021/05/03/2021-08802/use-of-the-5850-5925-ghz-band

Register. The rules became binding on July 2, 2021, 60 days after publication. On May 3, 2021, the FCC also published a Further Notice of Proposed Rulemaking (FNPRM)[3] (which will result in a second R&O, and hereafter referred to as the second R&O) which, among other things, calls for the eventual sunsetting of DSRC in favor of C-V2X.

For the IOOs who have deployed DSRC systems, these recent FCC decisions have raised a number of questions about how these actions impact existing and proposed deployments. Two NCHRP 23-10 documents[4] (one released in March 2020 and another in March 2021) provide significant background on the FCC actions. The purpose of this *Practical Considerations* document is to address deployment-related questions and provide insight to the decision-making process IOOs are facing. This is a working document, and the contents and answers will continue to change as the FCC releases additional information and more is learned.

Twenty-nine questions in this document are divided into the following sections to support decision-making that are linked here:

[3] https://www.federalregister.gov/documents/2021/05/03/2021-08801/use-of-the-5850-5925-ghz-band
[4] https://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=4902

Questions and Practical Considerations

Summary of FCC Actions and Timing

1. *What are the FCC R&O, FNPRM, and related timelines and key dates?*

   A good summary of the FCC documents and the timelines is found in in an NCHRP paper published in March 2021[5]. Additionally, an earlier NCHRP paper published in March 2020[6] describes background context around V2X communications in the 5.9 GHz spectrum. The pertinent dates for the first and second R&O as currently proposed by the FCC are as follows:

   First R&O

   - May 3, 2021: Publication in Federal Register as a Rule
   - June 2, 2021: Petitions for Reconsideration due
   - July 2, 2021: First R&O becomes effective (indoor Wi-Fi can use 5.9 GHz immediately, outdoor under special exception)
   - August 2, 2021: Waiver process and technical rules for C-V2X use in the upper 30 MHz are due from FCC
   - July 5, 2022: Existing DSRC installations must have vacated lower 45 MHz including rules for outdoor unlicensed activity

   FNPRM (for a second R&O)

   - May 3, 2021: Release date
   - June 2, 2021: FNPRM comments due
   - July 2, 2021: FNPRM reply comments due
   - Estimated to be Early/Mid 2022: Conclusion of FNPRM process, second R&O approved
   - Estimated to be Mid/Late 2022: Second R&O becomes official
   - Estimated to be Mid/Late 2024: Only C-V2X can utilize upper 30 MHz of 5.9 GHz spectrum

2. *What are my options when the R&Os restrict or eliminate DSRC licenses?*

   There are a variety of options available to IOOs that have deployed DSRC, but the evaluation of those options depends on the nature and scope of the existing deployments, the short- and long-term goals of the agency and funding constraints. Additionally, there are a number of outside factors to consider, things over which the agency has no control and issues which are still unresolved. Each agency will need to choose the option that best fits their situation.

   As options are explored, foundational questions that an agency should consider include:

   1) Is my deployment experimental with a finite useful life, or does it fill an on-going operational role?
   2) What is the useful life of my current hardware, and when will it need to be replaced regardless of regulatory changes?
   3) What are my near- and long-term plans for additional deployments and expanded use cases?
   4) Is my agency an early adopter of technology, or do we generally take a more cautious approach?

[5] http://onlinepubs.trb.org/Onlinepubs/nchrp/docs/NCHRP23-10WhitePaper.pdf
[6] http://onlinepubs.trb.org/onlinepubs/nchrp/docs/NCHRP23-10-V2XCommunicationsMarch2020Update.pdf

A first option for the future is to stay with DSRC for as long as is allowed with an eventual transition to C-V2X or other technologies. As noted elsewhere in this document, current DSRC deployments which operate in multiple channels will need to be modified to use only the upper 30 MHz of spectrum within a year of the effective date of the first R&O, which is July 5, 2022. Recent licensing by FCC allowed DSRC to only operate in channel 180. The language in the first R&O and the FNPRM suggests that the FCC may allow DSRC to operate in channels 180, 182, and 184, but there is not broad agreement about this.[7] Prior to that transition to the upper 30 MHz, operation in the lower 45 MHz of the spectrum could increasingly be impacted by new Wi-Fi traffic. Once adjusted to the upper 30 MHz of spectrum, those devices could continue to operate until two years after the second R&O, as currently proposed by the FCC. By then, some of the uncertainties that exist today about hardware and software market maturity and C-V2X licensing processes should be resolved. If the agency plans to add new DSRC devices during these transition periods, operations must be confined to channels in the upper 30 MHz of the spectrum. The FCC issued Public Notice DA 21-963[8] on August 6, 2021, that restricts all new applications for permission to operate to this portion of the spectrum and requires any pending applications to be modified to those channels. At the end of the two-year grace period, all DSRC operations will need to cease. If IOOs desire to continue their deployments beyond that time, other technologies will need to be considered, as described below. IOOs should give advance consideration to the process and amount of time that it will take to incorporate these new technologies so they can be in place before the deadline. Some estimate that timeframe to be over two years.

A second option is to transition from DSRC to C-V2X. Agencies with deployments in multiple locations may choose to do this gradually. Agencies with smaller, more uniform deployments might do this all at once. The most direct substitute for DSRC capability is C-V2X Direct. C-V2X devices are available and being used by some agencies. As noted above, C-V2X uses the 5.9 GHz spectrum and not the cellular network. IOOs will likely need new procurement and evaluation processes for this new hardware. C-V2X operates in a single, 20 MHz channel, so application software will require some modifications. Since not all V2V, V2I and I2V applications can fit into a single C-V2X channel (see the response to question 7), the agency will need to consider how to prioritize and consider other communication options for some use cases.

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[7] The December 2019 NPRM proposed to permit C-V2X operations in the upper 20 MHz of the band (5.905-5.925 GHz) and DSRC or C-V2X in the remaining 10 MHz (5.895-5.905 GHz, or channel 180), but the first R&O issued on May 3, 2021, does not designate specific allocations or channels within the upper 30 MHz for either technology. The FNPRM (paragraph 11) seeks comments on how the 30 MHz should be channelized. Because of the lack of specificity on channel use in the first R&O, some experts propose that DSRC will be allowed to operate anywhere in the upper 30 MHz during the transition period, not just in channel 180. In fact, the Order of Proposed Modification (paragraph 89 of the first R&O) says, "...the Commission modifies the licenses of all DSRC incumbents to add authorization to operate in the 5.895-5.925 GHz band to any RSU registrations currently lacking authority to do so." This is effective on July 2, 2021. We note that during the interim period between December 2019 and the present, the FCC has only approved new DSRC registrations in channel 180; any party that sought authorization in other channels was rejected. It appears that despite that recent practice, the FCC will allow DSRC in the full range of the 30 MHz spectrum. Deployers who are planning to begin transitioning to C-V2X during this period, however, should consider the likely interference between DSRC and C-V2X operating on the same channels and plan to keep the two technologies on different channels within the band.

[8] https://docs.fcc.gov/public/attachments/DA-21-963A1.pdf

A third option is to transition some or all of the use cases to a network system (i.e. C-V2X Network and/or traditional telematics), using 4G or 5G cellular networks. This approach could be appropriate for applications that do not require low latency but would be inadequate for most low-latency safety applications today. Latency could also be negatively impacted in locations with limited cellular coverage or during events that have heavy cellular traffic. Mobile network operators are working to reduce latencies with the Multi-Access Edge Computing (or MEC, which is sometimes called Mobile Edge Computing). Moreover, there are concepts and discussion on using 5G network slicing to essentially reserve a high-speed path to the core network and dramatically reduce latencies. However, unlike short range direct broadcast communications (DSRC and C-V2X), network systems will incur over-the-air charges. An additional consideration is that coverage may not be complete, as rural areas may be underserved. A transition to the use of commercial networks brings IOOs into the realm of paid-for vehicle-to-cloud services, and with that the necessity to establish or expand upon enterprise relationships with vehicle OEMs and/or third-party service providers.

3. *When do my DSRC broadcasts need to stop and the transition to C-V2X need to occur?*

The effective date of the first R&O was on July 2, 2021, 60 days after publication in the *Federal Register* on May 3, 2021. This first R&O stipulates (Section 12) that DSRC must vacate the lower 45 MHz of the band within one year of the effective date and limit operations to the upper 30 MHz of spectrum. That date is July 5, 2022. A FNPRM was published along with the first R&O. After considering comments and responses on the FNPRM, the FCC will issue a second R&O that will likely formalize the requirement that existing DSRC operations cease two years after the date of the adoption of the second R&O and any subsequent V2X communications use C-V2X technology. Timing for a second R&O is unknown, but if that R&O is published in early- to mid-2022, the deadline to complete the transition away from DSRC is anticipated to be in mid- to late-2024. That date is an estimate and could change. More information can be found in white papers produced through NCHRP 23-10 in March 2020 and March 2021.

4. *What entities specify the process and timeline for transitioning to C-V2X?*

The FCC has taken initial steps to define which technologies can be used in the 5.9 GHz spectrum and the deadlines for transitioning between technologies. The First R&O signals their intent to only support C-V2X in the future, and at the conclusion of the FNPRM process a second R&O will be published; that R&O is expected to provide further definitions and detail to support that intent. The FCC Wireless Telecommunications Bureau and FCC Public Safety and Homeland Security Bureau (Bureaus) have the responsibility to define technical rules and a streamlined waiver process on how to operate C-V2X RSUs and OBUs in the 5.9 GHz spectrum. Current deployers of C-V2X have obtained a temporary use authorization (also called an experimental license)[9] to permit operations. The Bureaus issued Public Notice DA 21-962[10] on August 6, 2021, defining a revised waiver process and guidance for permitting C-V2X operations. This process is now in force (see the response to question 11). After the FCC renders a decision on the rule changes proposed in the FNPRM, final technical operating rules will be issued.

[9] https://www.qualcomm.com/media/documents/files/c-v2x-experimental-license-user-guide.pdf
[10] https://docs.fcc.gov/public/attachments/DA-21-962A1.pdf

Beyond this initial licensing adjustment, it is also possible that the market could drive its own future timeline for the transition. Some vendors may choose to stop supporting DSRC, while others might invest more heavily in dual mode units; some vendors might find themselves unable to meet the demand for C-V2X, while new vendors might enter the scene. If large automakers make an announcement in any particular direction related to V2X there could be a surge in demand. The bottom line is that the FCC is directing the regulatory expectations, but the market could just as easily adjust on its own.

Changes and Modifications to Existing DSRC Deployments

5. *What do I need to do to migrate from DSRC to C-V2X?*

   The NCHRP 23-10 March 2021 white paper addresses this question in great detail, including what will need to change with an existing DSRC deployment. While some items like the interface to the traffic signal controller, backhaul communications, connectors, antenna placement, and MAP message can remain the same, the RSU radio technology will not be reusable. Since C-V2X operates in the 5.9 GHz band, the antennas and connectors are, in principle, the same. You should consult with your RSU/OBU vendors, however, as they may suggest other ways to change over.

6. *Will my current applications require modification?*

   Yes, unless the current applications are already able to use both DSRC and C-V2X. The actual messages being exchanged (SPaT, MAP, BSM, etc.) and the underlying application logic will not need to be changed. However: 1) If DSRC is retained for the near term, the software will need to be modified to move communications from multiple channels in the full 75MHz of spectrum to the upper 30 MHz of spectrum. 2) The process of exchanging messages changes with the technology, so moving the application from DSRC to C-V2X will require further modifications. The revised applications will also need to be tested before deployment to ensure they meet application requirements.

7. *If software was built around DSRC, it was written to handle multiple channels. Will this need to change?*

   Yes. As a minimum, application software will need to be modified to reflect the new broadcast channels to be used in the upper 30 MHz of spectrum. If the agency chooses to put all of the DSRC operations into one 10 MHz channel, further changes will be necessary. C-V2X operates in one 20 MHz channel; SAE J3161 WIP provides rules on how to do V2I, I2V and V2V message exchange in one 20 MHz C-V2X channel.

   A further consideration for IOOs with multiple current or planned applications is whether all those applications will remain possible in an environment with less dedicated spectrum. There is currently no clear understanding about how many message sets of different types might be transmitted in this constrained scenario, and that has a direct impact on which applications can operate within a limited 30 MHz bandwidth, especially at scale. The SAE C-V2X Technical Committee is developing a standard, J3161, to provide rules on which applications have priority within single C-V2X channels[11].

[11] https://www.sae.org/standards/content/j3161/1/

An ITS America working group has produced a first-draft assessment of which V2X message types can likely be accommodated in 30 MHz of spectrum at full build-out, and which message types are unlikely to fit within that constraint.[12] This ITS America effort remains in-progress as industry volunteers continue to debate critical issues such as prioritization and explore methods to substantiate the preliminary conclusions and the emerging SAE standard through modeling and simulation. These findings shed some early light on the capacity of the reduced spectrum but are not final and do not represent consensus. IOOs should be aware of, and should engage in, these discussions while considering future application development. Additionally, OmniAir is working on certifications for some applications, an effort that will help introduce some uniformity in future applications.

8. *If I want to leave my DSRC operational, is that okay?*

Please see the answers to questions 2, 3, and 6. In short, yes, there will be a one-year window to migrate all DSRC activities to the upper 30 MHz of spectrum, and then another period of time (likely two years after a second R&O issued at the end of the FNPRM) when DSRC will need to cease operations altogether. During that first year, DSRC can continue to operate as it is now, but agencies should keep in mind since the first R&O allows indoor unlicensed operations to begin immediately, DSRC could be subject to interference from unlicensed Wi-Fi in the lower 45 MHz of the 5.9 GHz band, particularly as more Wi-Fi devices are installed that use that portion of the spectrum. Agencies should consider their use cases, locations, and monitor the growth of unlicensed Wi-Fi as they plan and execute their transitions. Once DSRC operations are in the upper 30 MHz, operators will need to be aware of any use of that spectrum by C-V2X devices and coordinate with those operators to avoid potential interference.

9. *Do I need to transition all my RSUs at once?*

No. Per the FNPRM, Section 5, the FCC is proposing that deployers will have two years from the effective date of the second R&O to completely transition from DSRC (deadline projected to be mid- to late-2024). Entities using C-V2X must coordinate their operations to ensure no harmful interference to DSRC-based RSUs. If your agency operates both, then the coordination should be straightforward and via the recently issued waiver process mentioned in the response to question 4.

When planning for a transition, the agency must consider the geographic location and grouping of the RSUs and the applications currently being used. If, for instance, a group of RSUs in a contiguous geographic area are all communicating with a finite set of fleet vehicles, a partial transition of RSUs (or OBUs) in that area will render part of the system unusable because DSRC and C-V2X are not interoperable. Consideration should be given to replacing systems in contiguous geographic locations all at once.

It may be possible to replace RSUs with dual-mode (DSRC and C-V2X) RSUs without replacing the existing DSRC OBUs immediately. Agencies will need to carefully consider the existing and new hardware to be used in this type of scheme and perform laboratory and field testing to ensure compatibility of hardware and applications. For example, adjacent channel 180 (DSRC) and channel

[12] https://itsa.org/wp-content/uploads/2021/01/ITS-America-30-MHz-Application-Map-1-27-21.pdf

183 (C-V2X) operation may result in blocking and interference. To avoid that would require antennas to be isolated (e.g., by distance and angle) or ensure that they do not broadcast a lot at the same time.

Licensing

10. What happens to my existing DSRC licenses during this transition?

The first R&O indicates[13] that all existing licenses will be modified to allow operations only in the upper 30 MHz of the spectrum. This will happen automatically. In addition, the R&O requires[14] that all incumbent users "certify by that deadline [July 5, 2022] that they have ceased operating in the 5.850 – 5.895 GHz portion of the band." Public Notice DA 21-963 indicates that details on how to notify the FCC about this transition out of the lower band "will be provided at a later date"[15].

11. Is the licensing process for C-V2X the same as for DSRC?

No. (Please see the reply to questions 4 and 10.) Licensing for DSRC RSUs involves obtaining a license for a defined geographical area and individual permits for each location within that geographical area at which an RSU will be placed. Following installation, the licensee must confirm that an RSU has been placed in service at the specified location. Current C-V2X deployments have been permitted through a temporary use authorization (also called an experimental license), which authorizes RSU installation within a geographical area but does not require site-specific permits. Application for an experimental license is described in the March 2020 NCHRP 23-10 paper and discussed in the response to question 4. As also noted in the response to question 4, the Bureaus issued Public Notice DA 21-962 on August 6, 2021, defining a revised waiver process and guidance for permitting C-V2X operations in the upper 30 MHz of the spectrum, replacing the experimental license process. This revised waiver process is now in force and includes certifications by the applicant that: 1) there are no other ITS licensees authorized to operate (DSRC or similar devices) in this same geographic area or that the applicant has coordinated with each current licensee to ensure that C-V2X devices will not interfere with existing DSRC operations, 2) the applicant's C-V2X operations will comply with existing DSRC rules on power and out-of-band emissions limits, 3) the applicant's operations will be modified to meet final technical rules that the FCC will adopt, and 4) that the applicant's operations will be limited to transportation and vehicle safety-related communications. Manufacturers of C-V2X RSUs and OBUs will also need to certify their equipment meets certain FCC rules before offering them for sale.

When the FCC renders a decision on the rule changes proposed in the FNPRM and issues the second R&O, final technical operating rules are expected to be issued. These final rules will supersede the current wavier process.

12. Am I able to get a C-V2X license now?

Yes. As described in the answer to question 11, a streamlined waiver process is currently available.

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[13] https://www.federalregister.gov/d/2021-08802/p-23
[14] https://www.federalregister.gov/d/2021-08802/p-22
[15] https://docs.fcc.gov/public/attachments/DA-21-963A1.pdf

Understanding C-V2X and 5G

13. *Since the final licensing and operational requirements for C-V2X have not yet been specified, shouldn't I wait until those issues are all resolved before I purchase any C-V2X, so that I don't risk buying hardware / firmware that is soon to be outdated or somewhat obsolete?*

    As referenced in the NCHRP 23-10 March 2021 paper, there are many benefits to continued deployment of V2X communications. With regard to C-V2X devices, the industry will benefit from its experience with DSRC. Agencies deploying C-V2X today will benefit from the no-regret elements that are not specific to the communications technology -- such as next generation signal controllers, enhanced communications and network architecture, data collection, and security, as well as the potential benefits that can still be garnered through pilot testing and early deployments. Agencies that delay their transition can still focus on those foundational elements of their system.

14. *If I install C-V2X today, which is based on 4G LTE, will I have to replace or upgrade it when 5G becomes available?*

    No. Elements of C-V2X (LTE C-V2X) are designed to remain in operation for a fairly lengthy period since they are intended to deliver the basic or "Day 1" V2X services that the transportation community has been developing over the past two decades. That is, C-V2X equipment deployed today, based on 4G LTE, is not designed to be replaced by 5G V2X (see the response to question 15). 5G V2X is designed to add additional services to supplement and enhance existing C-V2X systems, while those initial C-V2X services and uses are designed to continue. As an example, AM radio continues to function on existing devices with the addition of FM or XM radio, even though new equipment may be required to leverage the new services in addition to the AM radio services. In short, investments in C-V2X systems today are designed to continue to function in the foreseeable future, even as technologies and services continue to be enhanced and evolve.

15. *What really is 5G and how does it fit into my options?*

    We hear a lot about 5G, the next generation of cellular communication, in the media. 5G is network cellular service, using closely spaced, "small cell" cell towers. It is important to note that 5G is <u>not</u> the same as Cellular V2X (C-V2X). C-V2X, the direct communication technology that has been standardized by IEEE 1609 Working Group[16], is being standardized in SAE J3161, and is referenced in NEMA TS 10 standards[17] is based on 4G LTE technology defined internationally in Release 14 of the 3rd Generation Partnership Project (3GPP)[18]. C-V2X communicates directly, like DSRC, not through a cell tower. The C-V2X waveform is based on 4G LTE. The 4G and 5G wide area network specifications (that enable your cell phone or your car to a cellular network) are different than the direct C-V2X communications operation in the 5.9 GHz band.

[16] https://standards.ieee.org/standard/1609_0-2019.html
[17] https://www.nema.org/standards/view/connected-vehicle-infrastructure-roadside-equipment
[18] https://www.3gpp.org/about-3gpp/about-3gpp

There is a version of direct C-V2X under development, sometimes referred to as 5G New Radio sidelink or 5G V2X, which will use 5G technology, but will still be direct communication. As described in the response to question 14, today's 4G LTE C-V2X and 5G V2X are designed to provide different services. In essence, 4G LTE C-V2X was designed to deliver V2V, V2I and I2V services currently envisioned by the ITS community in the 5.9 GHz spectrum, whereas 5G V2X was designed to deliver advanced services, e.g., distance based groupcast for connected and automated vehicles and roadside to reliably coordinate. As currently envisioned, 5G V2X would require different spectrum than 4G LTE C-V2X, outside of the 5.9 GHz spectrum; that additional spectrum has not yet been identified.

In contrast, the 5G network is the paid-for commercial cellular service. One way to think of this is that 5G networks upload and download to and from the cloud through commercial cellular subscription. 5G V2X can be referred to as a "sidelink" or the point-to-point communications for local safety and other cooperative vehicle applications. Because 4G LTE C-V2X and 5G V2X are designed to be used in ITS spectrum and not on commercial spectrum, they are not operated by a mobile network operator and are not subscription based.

Interference and Out-of-Band Emissions

16. *As I transition from DSRC, is it possible to have both DSRC and C-V2X operating simultaneously in some areas during the transition?*

This will not likely be a problem in early deployments with limited traffic. As indicated above, DSRC and C-V2X use the same 5.9 GHz spectrum but will not communicate with each other because they use different communications protocols. Consider the fact that these RSUs broadcast asynchronously and that they transmit for short, bursty periods of time (that is, they are not transmitting > 98% of the time). If they are operating simultaneously only a very small percentage of packets will collide. Some agencies are currently using dual-mode RSUs which contain both DSRC and C-V2X radios. As noted in the response to question 9, as the amount of wireless traffic increases, DSRC and C-V2X broadcasts in adjacent channels may result in some blocking and interference. Careful antenna placement and other measures may mitigate these issues.

17. *How will the FCC ruling impact out-of-band emissions?*

The first R&O states (Section 31), "To enable a smoother and more rapid development and deployment of C-V2X-based ITS operations in the near term. . . the Commission will also condition C-V2X operations on complying with specific technical rules (e.g., power and out-of-band emission limits consistent with current DSRC-based rules) . . .". While this is not a guarantee, the expectation is that this means current FCC Class C limits for out-of-band emissions will likely be the same or be somewhat relaxed. The underlying radio access technology for C-V2X also stipulates emission masks which are conformal to FCC Class C; hence, the design of C-V2X equipment will not likely change. The first R&O stipulates (Section 3) rules for unlicensed operations in the lower 45 MHz, allowing only indoor Wi-Fi devices. These devices and the handsets associated with them could cause harmful interference. The FNPRM (Section 30) proposes to allow unlicensed outdoor Wi-Fi to operate in the lower 45 MHz. This could add significantly more risk of interference. (See the response to question 18). IOOs and other interested parties used the 30-day FNPRM comment period and subsequent 30-day reply period to urge that unlicensed Wi-Fi uses have strict power

restrictions and remain limited to indoor uses. At least one Petition for Reconsideration was filed to challenge the out-of-band emissions limits defined in the first R&O. (See the response to question 29).

18. *If the out-of-band emission issue (from the 45 MHz which has been moved to Wi-Fi) isn't solved, will C-V2X end up being unworkable because of interference?*

    As noted in the response to question 17, the first R&O (Section 3) allows indoor Wi-Fi in the lower 45 MHz, and the FNPRM (Section 30) proposes to eventually allow outdoor Wi-Fi access points. The Crash Avoidance Metrics Partners LLC (CAMP) has published a study that concluded that in-vehicle operation of U-NII-4 devices (e.g., unlicensed Wi-Fi in adjacent bands) would cause harmful interference to C-V2X[19]. However, the results did not differentiate between the effects from indoor versus outdoor Wi-Fi. The first R&O (Section 16) prohibits outdoor Wi-Fi access points in this band but allows point-to-point communication. Moreover, the FNPRM (Section 44) asks about the operation of outdoor Wi-Fi in the U-NII-4 band. The ITS community widely believes that allowing outdoor Wi-Fi access points would cause harmful interference to C-V2X if those access points are close to the roadside and V2X messages are broadcast nearby. IOOs and other interested parties responded to the FCC during the FNPRM comment period to help reinforce this concern and oppose the use of outdoor Wi-Fi in the lower 45 MHz.

Equipment Compatibility and Interoperability

19. *During DSRC deployments, there were issues of incompatibility between the equipment provided by different vendors. Some of that has been resolved. Has there been any field testing identifying or demonstrating that these challenges have been resolved for C-V2X?*

    OmniAir has a C-V2X certification program[20] and is conducting a series of plugfests to encourage interoperability and gain confidence in the systems. See the response to question 26 for more details. Two additional efforts are underway by the Institute of Transportation Engineers (ITE), funded by the USDOT: The RSU Standardization project[21] and the Connected Intersections[22] project. The RSU project is producing a technology-neutral hardware standard for Roadside Units. The Connected Intersections project is producing a recommended practice that defines the key capabilities and interfaces a connected intersection must support to ensure interoperability for state and local IOOs. All of these efforts will help prevent the incompatibility challenges that early DSRC deployers encountered.

    While C-V2X is promising and some agencies have begun to deploy C-V2X, there has not been a large-scale deployment proof-of-concept test of the technology in the United States. Application standards and operating rules for C-V2X devices are still unfolding. As agencies prepare to migrate their DSRC installations to C-V2X, they should plan to proceed through typical steps of evaluating hardware and software, adherence to standards, interoperability testing and requirements development before making significant decisions about procurement. This may involve procuring a

[19] https://pronto-core-cdn.prontomarketing.com/2/wp-content/uploads/sites/2896/2020/09/CAMP-CV2X-WiFi-Interference-Testing-Results-v6.11.3.pdf
[20] https://omniair.org/news/omniair-consortium-accepting-c-v2x-applications-for-labs-and-tools-programs/
[21] https://www.ite.org/technical-resources/standards/rsu-standardization/
[22] https://www.ite.org/technical-resources/standards/connected-intersections/

number of appropriate devices and testing them in a laboratory and field setting to make sure they meet agency requirements. Agencies that delay their transition to C-V2X will benefit from early-adopter agencies that undertake these evaluation steps.

20. *Will future standards be incompatible with C-V2X technologies that I deploy today?*

    Most of the standards used in DSRC deployments will still apply and standards bodies are working to update those that are not directly compatible. There may be some stumbling blocks along the way that cause standards to be updated, but this is not unique to C-V2X. There were similar needs to update standards as DSRC evolved. As an example, the SAE J2735 standard[23] describing the MAP message is viewed by IOOs as stable, but SAE is currently working to develop an expanded geometry-related message to meet the needs of additional applications as a supplement to this standard. Just as deployers of DSRC needed to be flexible as the technology matured, so will deployers of C-V2X over the next several years.

Security

21. *Are C-V2X devices capable of operating within a Security Credential Management System (SCMS)?*

    Yes, C-V2X devices are capable of operating with security certificates within a SCMS framework in the same way that DSRC devices operate. Further, SCMS systems are now readily available for V2X deployments; a number of IOOs have begun to implement SCMS. Agencies should consider security certificates as part of their transition even if the SCMS is currently not in use in their current deployments. RSUs need to have the security key installed in the device before being deployed in the field. As such, if the agency is buying new devices or implementing any new deployments as part of this transition, consider long-term plans and selecting an SCMS provider to incorporate SCMS into all deployments. Moreover, the underlying security services standard, IEEE 1609.2, is technology neutral and applies to authenticate V2X messages under this SCMS framework.

Broadcast Range

22. *Will C-V2X have the same range as DSRC? Is there any opportunity for wider spacing between RSUs with C-V2X?*

    Range depends on many factors, e.g., fading environment, set power, and location. While both DSRC and C-V2X meet the expected nominal range of 300 meters, several studies have concluded that the C-V2X range is generally higher.[24,25] If RSUs are placed at intersections, the spacing is defined by the location of those intersections so an RSU with a longer range may not provide an advantage. For non-intersection placements, additional range could be helpful, but cost-efficient placement is often dictated by existing poles and other infrastructure.

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[23] https://www.sae.org/standards/content/j2735_200911/

[24] https://5gaa.org/wp-content/uploads/2018/11/5GAA_P-190033_V2X-Functional-and-Performance-Test-Report_final-1.pdf

[25] Field Tests on DSRC and C-V2X Range of Reception, posted at https://transportationtechnology.utah.gov/what-were-learning/

Automaker Reaction

23. *How are the automakers responding to the FCC action and how does that impact my deployment decisions?*

    Prior to the 2020 FCC action, Ford announced through an online post[26] that they would be installing C-V2X OBUs on all of their new vehicles starting in late 2022 (Model Year 2023), pending regulatory certainty. In recent months, Ford has confirmed their intent to move ahead with this plan on certain models. Similar, recent commitments have not been made by other automakers, but sources have suggested that there is still strong interest among the automaker community to deploy V2X systems once regulatory issues are settled. The CAT Coalition document *Clarifications for Consistent Implementations*[27], which was used as the basis for the current USDOT / ITE Connected Intersections Guidance Document project, was created largely out of the need to be prepared for V2X-equipped production vehicles, like those Ford will develop. The Crash Avoidance Metrics Partners LLC (CAMP), an organization led by a number of automakers, is actively pursuing the verification of broadcast message format and content on RSU-equipped corridors in an effort to support future deployment of V2X in production vehicles. Given this environment some agencies are considering their near-term conversion to C-V2X as a preparation for these production vehicles and are timing their deployments accordingly. Others are waiting to see whether, and how quickly, other automakers will announce their OBU intentions, including those automakers who have traditionally been focused on DSRC equipment.

Examples for Deploying C-V2X

24. *Are there any examples of procurement language that have been used to procure C-V2X RSUs and/or C-V2X OBUs (e.g. for use on agency fleet vehicles) that we could use to begin to procure C-V2X equipment?*

    Yes. An example from Utah DOT is on their website[28]. Others will be shared in future versions of this resource as they become available.

25. *Where can I find a summary of commercially available C-V2X suppliers/ecosystem (RSUs, OBUs)?*

    The 5G Automotive Association (5GAA) has compiled a global list of commercially available devices[29]. The OBU suppliers and links are given on page 5 and RSU suppliers and associated links are given on pages 6 and 7. Those that supply the US market are so indicated. The Utah DOT has published a document that includes a section on the market availability of C-V2X devices and summarizes the vendors[30]. The market is changing rapidly, and vendors are responding to the FCC ruling, so these lists are subject to change.

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[26] https://medium.com/cityoftomorrow/how-talking-and-listening-vehicles-could-make-roads-safer-cities-better-f215c68f376f

[27] https://transportationops.org/sites/transops/files/Updated%20Signalized%20Intersection%20CCI%20-%20June%202020%20ver%201.9.5%20-%20June%202020.pdf

[28] V2X Hardware RFP, posted at: https://transportationtechnology.utah.gov/what-were-learning/

[29] https://5gaa.org/wp-content/uploads/2020/11/5GAA_List-of-C-V2X-Devices.pdf

[30] Field Tests on DSRC and C-V2X Range of Reception, posted at https://transportationtechnology.utah.gov/what-were-learning/

26. *Where can I find details about C-V2X certification process and associated/verified use cases?*

    OmniAir Consortium is a third-party testing and certification entity. OmniAir Certification is available for both DSRC and C-V2X OBUs and RSUs, as well as dual use RSUs. This certification provides assurance that devices conform to industry standards. OmniAir Certification offers testing against over 300 test cases for C-V2X radios. In total, OmniAir has over 150 tests that an RSU or OBU would have to undergo to attain certification. Currently, OmniAir tests for proper conformance and interoperability for SAE messages such as BSM, SPaT, MAP, and TIM; testing of application layer responses to these messages for use cases is under review and could be incorporated in future certification programs. More information about OmniAir Certification is available on their website[31].

27. *Where can I get access to experiences from actual C-V2X deployments?*

    A number of IOOs have deployed some C-V2X devices, including Caltrans District 11, Colorado DOT, Georgia DOT, Florida DOT, Hawaii DOT, Michigan DOT, Ohio DOT, Utah DOT, and Virginia DOT. IOOs interested in these deployments can contact those agencies for more information.

Funding

28. *Is funding available to recover the costs of the transition?*

    IOOs with active DSRC deployments will incur costs to modify the channel allocations in their software applications, and to plan, procure, purchase, test, coordinate, and install new RSUs and OBUs to replace their existing units. There are no provisions in the first R&O to compensate DSRC licensees for vacating the spectrum. There is some precedent for the FCC enabling compensation of incumbent users when they are displaced from a given portion of the spectrum. The FCC states in the FNPRM for the second R&O that "while we did not propose . . . to provide compensation for such relocation, we nonetheless seek further comment"[32] on the types of costs that might be appropriate for compensation and how that compensation would be determined. The FNPRM points out that many DSRC deployments are "demonstration projects"[33], inferring that these are not permanent and might not be eligible for relocation compensation. They also ask for information on funding grants that have been used and the types of funding that can be used by agencies to cover transition costs. IOOs and other interested parties commented directly to the FCC during the 30-day comment period about the real costs of the transition and urged them to provide reasonable compensation. The second R&O is expected to address this request.

Challenges to the FCC Actions

29. *What efforts have been undertaken to challenge the FCC decisions and preserve the full 75 MHz of spectrum or keep DSRC as a technology option?*

    The transportation community - USDOT, State DOTs, local agencies, automakers, suppliers, and associations - have consistently and strongly opposed the FCC's action. Many comments have been filed in response to the previous NPRM, and those are cited and responded to in the first R&O. To date, the FCC has rejected the arguments made by those seeking to retain the full 75 MHz of spectrum and have not been persuaded by arguments in support of DSRC. While the FCC is made up

[31] https://omniair.org
[32] https://www.federalregister.gov/d/2021-08801/p-48
[33] https://www.federalregister.gov/d/2021-08801/p-47

of five Commissioners appointed by Presidents belonging to both parties, they have generally been unanimous in their approach to reducing the spectrum for transportation safety.

About 37 comments were filed in response to the current FNPRM (for the second R&O)[34]; over 30 of those comments supported the arguments of the transportation community, including the need for the full 75 MHz of spectrum, concern over interference issues, reimbursement of incumbent users, and adequate time frames for transitions. Only one or two comments focused on the selection of C-V2X over DSRC.

Any interested stakeholder may file a Petition for Reconsideration of the first R&O within 30 days of the publishing date and three organizations did – The Alliance for Automotive Innovation (AAI), the 5G Automotive Association (5GAA), and the Amateur Radio Emergency Data Network (ARDEN)[35]. 5GAA and ARDEN also asked for a "stay of the rules" related to specific elements of the first R&O to allow time for issues to be resolved. The 5GAA petition specifically addressed concerns over emission limits. The FCC is required to respond to these but there is no specific timeline requirement. In addition to these Petitions, ITS America and AASHTO filed a legal appeal in June 2021 in the D.C. Circuit Court seeking a judicial review to reverse the FCC decision to allow unlicensed use of the lower 45 MHz of the spectrum[36]. The appeal is focused only on the reallocation of the spectrum, and does not address other issues, including the selection of C-V2X as the preferred V2X technology. The appeal also does not ask for the process put in motion by the first R&O to be stopped while the case is heard and does not address the FNPRM (for the second R&O). It is expected that it may take about a year for this appeal to be resolved.

Other potential courses of action that could impact the decision to reduce the spectrum are: 1) additional legal action by other parties, 2) direct action by the White House, and 3) specific Congressional action. To date, none of these actions have been taken.

[34] https://www.fcc.gov/ecfs/search/filings?limit=25&offset=0&q=(%22Use%20of%20the%205.850%5C-5.925%20GHz%20Band%22)&sort=date_disseminated,DESC

[35] These petitions and the subsequent filings related to them can be found in the comment docket for the FNRPM (see previous footnote).

[36] https://itsa.org/news/its-america-aashto-take-legal-action-to-retain-5-9-ghz-band-for-v2x-technologies/