The Future of V2X: 30 MHz Application Map

Introduction and Summary

Vehicle-to-Everything (V2X) technology, including Vehicle-to-Vehicle (V2V), Vehicle-to-Infrastructure (V2I), and Vehicle-to-Pedestrian (V2P) technology, allows vehicles to communicate with other vehicles, infrastructure, and vulnerable road users to enhance safety, prevent traffic crashes and reduce fatalities, reduce congestion, and reduce the environmental impact of the transportation system. The full 75 MHz of the 5.9 GHz spectrum band has long been reserved for intelligent transportation services such as V2X technologies. However, the Federal Communications Commission (FCC) has recently advanced a rulemaking that would reallocate 45 MHz of this spectrum for use by unlicensed devices, leaving V2X technologies with only 30 MHz of spectrum.

The Intelligent Transportation Society of America (ITS America) represents stakeholders across the transportation industry, including state, county, and city departments of transportation, metropolitan planning organizations, automotive manufacturers and suppliers, technology companies, engineering firms, and research universities. ITS America strongly believes that the full 75 MHz of the 5.9 GHz band should be preserved for V2X technologies and that the FCC's proposal will not provide sufficient spectrum for existing and anticipated V2X technologies nor effectively protect the remaining 30 MHz of spectrum from out-of-band emissions (OOBE) that will likely interfere with V2X technologies.

Due to the FCC's proposal, ITS America established a Future of V2X Working Group that includes representatives from infrastructure owner operators (IOOs), automotive manufacturers, and technology companies, to evaluate the potential effect of the proposal on the types of messages and V2X applications that could be deployed. The Working Group drafted a preliminary application map that attempts to show the message types and applications that will likely be deployed in the proposed limited 30 MHz spectrum environment and the message types and applications that would likely be lost in such a scenario. Notably, advanced V2X applications, including those that rely on collective perception messages (CPM),[1] maneuver coordination messages (MCM), and personal safety messages (PSM) will likely be lost.

ITS America continues to advocate that the full 75 MHz of the 5.9 GHz band be preserved for transportation communications. However, we believe it is prudent to evaluate what is possible in a limited 30 MHz spectrum environment to ensure that the transportation industry can continue to develop and deploy these life-saving technologies. This document includes a preliminary application map as a starting point for discussions within the transportation industry regarding operating V2X technologies in such an environment. The application map is based on several assumptions and to the extent possible reflects current and anticipated standards and methods of deployment. The application map should not be considered final nor conclusive, as much work remains to test the assumptions and further evaluate the impact that a 30 MHz environment will have on V2X application deployment. Furthermore, many of the assumptions are based on existing deployments and technologies, and a number of applications have the potential to be deployed using alternative message types.

[1] While we refer to Collective Perception Messages within this document, the SAE J3224 standard in development refers to the same concept as a Sensor Data Sharing Message (SDSM).

ITS America is eager to involve a broader set of transportation stakeholders in this conversation as the industry seeks to establish a path forward to realize the many safety, environmental, and economic benefits of V2X technologies.

FCC Actions and V2X

In February 2020, the FCC published a Notice of Proposed Rulemaking to reallocate 45 MHz of spectrum (5.850-5.895 GHz) in the 5.9 GHz Band for use by U-NII-4 devices, taking away the majority of the spectrum that had previously been designated for use by Vehicle-to-Everything (V2X) transportation technologies.[2] The proposal would leave only 30 MHz of spectrum (5.895-5.925 GHz) for V2X technologies and would require that all V2X technologies use Cellular Vehicle-to-Everything (C-V2X) technology in the future. Despite significant opposition from transportation stakeholders to the reallocation of spectrum for unlicensed devices, the FCC voted in November 2020 to issue a Final Report and Order that reallocates the lower 45 MHz.[3]

V2X technologies, including V2V, V2I, and V2P technologies, were initially planned to operate in 75 MHz of spectrum. While no single V2X application requires 75 MHz of spectrum, significant spectrum is required to simultaneously deploy V2X applications that require low-latency communication to prevent interference and to ensure that safety messages, sent as many as ten times per second, are effectively communicated between vehicles, infrastructure, and vulnerable road users.

If the FCC's actions to reallocate 45 MHz of spectrum for unlicensed devices are finalized, only 30 MHz of spectrum will remain for V2X applications. This requires a new analysis of the spectrum available to V2X technologies to identify which message types and applications are likely to be deployed in the limited 30 MHz spectrum environment.

Future of V2X in 30 MHz of Spectrum

In 2020, ITS America convened a Future of V2X Working Group to analyze the impact of the FCC's proposal with a specific goal of identifying which V2X message types and applications would be likely to be deployed in the proposed limited 30 MHz spectrum environment. The objective was two-fold: to demonstrate the message types and safety applications that would be lost due to the FCC's spectrum reallocation and to identify a path forward for safely deploying V2X technologies.

The Working Group was comprised of stakeholders from across the transportation industry, including infrastructure owner operators (IOOs), automotive manufacturers, and technology companies directly involved in the development and deployment of V2X technologies across the country. Through this set of stakeholders, ITS America incorporated into a draft application map the perspectives of IOOs responsible for deploying roadside infrastructure technologies, automotive manufacturers responsible for deploying vehicle-based V2X technologies, and technology companies that develop and aid in the deployment of both roadside and vehicle-based V2X technologies. Notably, the Working Group included organizations both focused on DSRC technology and on C-V2X technology, and the application map reflects considerable agreement among a variety of transportation stakeholders regarding which message types and applications are likely to be deployed in 30 MHz

[2] In the Matter of Use of the 5.850-5.925 GHz Band, ET Docket No. 19-138, Notice of Proposed Rulemaking, FCC 19-129 (rel. Dec. 17, 2019).

[3] In the Matter of Use of the 5.850-5.925 GHz Band, ET Docket No. 19-138, First Report and Order, Further Notice of Proposed Rulemaking, and Order of Proposed Modification, FCC 20-164 (rel. Nov. 20, 2020); available here: https://ecfsapi.fcc.gov/file/11202021603352/FCC-20-164A1.pdf.

of spectrum. The perspectives and priorities of each of these stakeholders are necessary to effectively create an application map to guide the development and deployment of V2X in a 30 MHz spectrum environment.

The Working Group met regularly over the course of several months to discuss the impact that a limited 30 MHz environment would have on V2X deployment and evaluated numerous V2X applications based on several inputs: spectrum requirements, stakeholder priority, and likely safety benefit. Spectrum requirements were calculated based on assumptions about the number of vehicles within communication range, packet size, repetition rate, activity factors, spectral efficiency, and channel utilization. Stakeholder priority was assessed both through informal discussion among Working Group members and a limited survey of IOO priorities for applications. The likely safety benefit of an application was assessed through informal discussion and the National Highway Traffic Safety Administration's (NHTSA) Vehicle Safety Communications Project final report evaluating the potential safety benefits of V2X applications.[4] These evaluations led the Working Group to create a priority list of V2X message types and applications.

The Working Group identified numerous V2X message types and applications that are likely to be deployed in a limited 30 MHz environment, including applications dependent on the following types of messages: basic safety (BSM), intersection mapping (MAP), signal phase and timing (SPaT), traveler information (TIM), road safety (RSM), signal request (SRM), signal status (SSM), GNSS correction messages (RTCM), and probe vehicle data (PVD). These types of messages support a broad set of V2V and V2I applications, including: forward collision warning, pre-crash sensing, emergency vehicle warning and signal preemption, and infrastructure-to-vehicle warning messages. A number of these applications operate based on the same message types, allowing numerous applications to be operated without requiring additional spectrum. However, different applications using the same message types can have vastly different spectrum needs due to differing message sizes and frequency of message transmission, so there are scenarios in which some applications using the same message types could and could not be deployed. Additionally, available spectrum will be dependent in part on the number of vehicles within communication range and the types of applications operating in a given area. Because of this, it will likely be necessary to establish a scheme that prioritizes safety-critical applications while dropping non-safety-critical applications in such situations. While the application map below attempts to provide some initial prioritization, it is not intended to establish such a scheme and additional work is needed.

The Working Group also identified numerous V2X message types and applications that are unlikely to be deployed in a limited 30 MHz environment due to spectrum requirements, including applications dependent on collective perception messages (CPM), maneuver coordination messages (MCM), and personal safety messages (PSM). These types of messages support a broad set of advanced V2V, V2I, and V2P applications, including: intersection collision warnings, intersection movement assist, cooperative adaptive cruise control, and numerous pedestrian safety applications. Notably, these message types support important advanced V2X applications that are necessary to fully realize the potential transportation safety benefits of V2X technologies. These message types are vital to allow vehicles to communicate information gained from vehicle-based sensors, such as radar and lidar, to other vehicles; to provide cooperative operation among automated vehicles; and to support numerous applications intended to protect vulnerable road users such as pedestrians and bicyclists.

[4] Vehicle Safety Communications – Applications (VSC-A) Final Report, National Highway Traffic Safety Administration (April 2006); available at: https://www.nhtsa.gov/DOT/NHTSA/NRD/Multimedia/PDFs/Crash%20Avoidance/2006/Vehicle%20Safety%20Communications%20Project%20-%20Final%20Report.pdf.

The message types and applications included in the application map below are based on conversations with industry stakeholders regarding existing V2X applications with developed standards and anticipated applications with standards that are currently in development.[5] It is important to note that some applications could move lists based on message type used and on in-vehicle computing abilities. Additionally, some applications will likely change as V2X standards are changed or further developed. Furthermore, the chart will likely need to be adjusted based on the results from actual deployments in the field.

30 MHz Application Map Chart

V2X Application	IOO Priority	Safety Priority	Message Used
Message Types and Applications Likely in a 30 MHz Scenario			
Forward Collision Warning	5.00	5	BSM
Pre-Crash Sensing	4.67	5	BSM
Cooperative Collision Warning	4.33	5	BSM
Cooperative Forward Collision Warning	4.33	5	BSM
Approaching Emergency Vehicle Warning	4.33	5	SRM, SSM, RSA
Emergency Vehicle Signal Preemption	4.33	5	SRM, SSM, RSA
Emergency Electronic Brake Lights	4.33	4	BSM
Work Zone Traveler Information	4.33	4	TIM
Emergency Vehicle Preemption	4.00	4	SRM, SSM, RSA
Blind Spot/Lane Change Warning	4.00	4	BSM
Curve Speed Warning	3.67	4	TIM
Motorist Advisories and Warnings	3.67	4	TIM
Ramp Speed Warning	3.67	4	TIM
Signal Priority (transit, freight)	3.67	3	SRM, SSM, RSA
Freight-Specific Dynamic Travel Planning and Performance	3.67	2	TIM
In-Vehicle Signage Warning	3.33	4	TIM
SOS Services	3.33	4	TIM
Intelligent Traffic Signal System	3.33	3	SPAT, MAP, SSM
CV-Enabled Turning Movement and Intersection Analysis	3.33	2	BSM
In-Vehicle Amber Alert Warning	3.33	2	TIM
Incident Scene Work Zone Alerts for Drivers and Workers	3.33	2	TIM
Road Condition Warning	3.00	3	TIM
Post-Crash Warning	3.00	3	BSM
Eco-Cooperative Adaptive Cruise Control	3.00	2	BSM
Eco-Approach and Departure at Signalized Intersections	3.00	2	BSM, SPAT, MAP
Probe-Enabled Traffic Monitoring	3.00	2	PVD
Eco-Traffic Signal Timing	3.00	2	SPAT, MAP
Spot Weather Impact Warning	3.00	2	TIM
Do Not Pass Warning	2.67	3	BSM
Truck Height Detection	2.67	3	BSM, TIM

[5] Many of the application standards used in our analysis are available at here: https://local.iteris.com/cvria/html/applications/applications.html and https://local.iteris.com/arc-it/html/servicepackages/servicepackages-areaspsort.html.

V2X Application	IOO Priority	Safety Priority	Message Used
Weather Response Traffic Information	2.67	3	TIM
Emergency Communication, Perception Sharing, and Evacuation	2.67	3	TIM
Eco-Speed Harmonization	2.67	2	BSM
Connected Eco-Driving	2.67	2	TIM
Dynamic Eco-Routing (light vehicle, transit, freight)	2.67	2	TIM
Eco-ICM Decision Support System	2.67	2	TIM
Cooperative Glare Reduction	2.33	2	BSM
Eco-Lanes Management	2.33	2	TIM
Eco-Ramp Metering	2.33	1	TIM
CV-Enabled Origin-Destination Studies	2.33	1	BSM
Adaptive Headlamp Aiming	2.00	2	BSM
Vehicle Classification, Perception Sharing-based Traffic Studies	2.00	1	BSM
Smart Truck Parking	2.00	1	TIM
Eco-Smart Parking	1.67	1	TIM
Eco-Traveler Information	1.67	1	TIM
Message Types and Applications Unlikely in a 30 MHz Scenario			
Intersection Collision Warning	5.00	5	ICA, CPM
Highway/Railroad Collision Warning	4.67	5	ICA, CPM
Work Zone Warning	4.67	4	RSA, TIM, PSM
Wrong Way Driver Warning	4.33	5	RSA, TIM
Emergency Electronic Brake Lights	4.33	5	ICA, CPM
Mobile Accessible Pedestrian Signal System	4.33	5	ICA, CPM
Pedestrian in Signalized Crosswalk Warning (transit)	4.33	5	PSM, ICA, CPM
Pedestrian Crossing Information	4.33	5	PSM, TIM
Road Condition Warning	4.33	4	RSA
Queue Warning	4.33	3	RSA
Traffic Signal Violation Warning	4.33	3	RSA, ICA, CPM
Blind Merge Warning	4.00	5	ICA, CPM
Left Turn Assist	4.00	4	ICA, CPM
Stop Sign Violation Warning	4.00	3	RSA, ICA, CPM
Cooperative Adaptive Cruise Control	4.00	2	ICA, CPM
Cooperative Vehicle-Highway Automation System (Platoon)	4.00	2	ICA, CPM
Intersection Movement Assist	3.67	4	ICA, CPM
Advanced Traveler Information System	3.67	4	PVD
Reduced Speed/Work Zone Warning	3.67	3	TIM, RSA
Left Turn Assistant	3.67	3	ICA, CPM
Blind Spot Warning	3.67	3	ICA, CPM
Vehicle Turning Right in Front of Bus (transit)	3.00	3	ICA, TIM, SRM, SSM
Highway Merge Assistant	3.00	3	ICA, CPM
Lane Change Warning	3.00	3	ICA, CPM
Dynamic Speed Harmonization	3.00	2	ICA, CPM
Incident Scene Pre-Arrival Staging Guidance for Emergency Responders	3.00	2	ICA, CPM, TIM

V2X Application	IOO Priority	Safety Priority	Message Used
Probe-based Pavement Maintenance	3.00	1	TIM, RSA
Vehicle-to-Vehicle Road Feature Notification and Perception Sharing	2.67	4	RSA
Low Bridge Warning	2.67	3	TIM, RSA
Stop Sign Movement Assist	2.67	3	ICA, CPM
Visibility Enhancer	2.67	2	ICA, CPM
Connection Protection	2.67	2	1609
Eco-Traffic Signal Priority	2.67	2	SRM, SSM, RSA
Low Parking Structure Warning	2.00	3	RSA
Dynamic Transit Operations	2.00	1	SRM, SSM, RSA
Dynamic Ridesharing	1.67	1	RSA

Remaining Concern: Interference

It is important to note that this application map is based on a 30 MHz spectrum environment that is not encumbered by interference from out-of-band emissions from adjacent spectrum bands. For the remaining 30 MHz to be effectively utilized, interference from unlicensed devices operating in the lower 45 MHz of the 5.9 GHz band or in the 6 GHz band must be mitigated.

During the FCC rulemaking notice and comment process, transportation stakeholders across the industry raised concerns regarding unlicensed device power limits and the potential for harmful interference in the remaining 30 MHz. Preliminary technical assessments related to the FCC's proposal show that it would likely result in harmful interference that may render effective operations of V2X technologies in the 30 MHz difficult, if not impossible.[6] While the FCC has adopted power limits for indoor unlicensed devices operating in the lower 45 MHz, the power limits and associated interference issues for outdoor unlicensed devices are the subject of a Further Notice of Proposed Rulemaking.[7] It is incumbent that the FCC work with USDOT and the transportation industry to ensure that the remaining 30 MHz is free of interference and usable for V2X technologies.

Next Steps and Additional Questions

While the Future of V2X Working Group completed an initial evaluation of which V2X message types and applications are likely or unlikely to be deployed within a limited 30 MHz spectrum environment, additional steps must be undertaken to continue the development of this application map.

[6] USDOT Preliminary Technical Assessment (Dec. 6, 2019); available at: https://www.transportation.gov/sites/dot.gov/files/docs/research-and-technology/360181/oobe-energy-59-safety-band-final-120619.pdf. CAMP LLC Cellular V2X Device-to-Device Communication Consortium: C-V2X Performance Assessment Project Task 8: Assessment of WiFi Interference to C-V2X Communication Based on Proposed FCC 5.9 GHz NPRM (April 15, 2020); available at: https://pronto-core-cdn.prontomarketing.com/2/wp-content/uploads/sites/2896/2020/04/CAMP-CV2X_Project_Task_8_Final_04242020.pdf.

[7] Transportation stakeholders have voiced significant concern with both the adopted power limits for indoor unlicensed devices and the anticipated power limits for outdoor unlicensed devices.

Next Steps:

- Run simulations and evaluate the assumptions underlying the spectrum requirement calculations for the message types identified in the preliminary application map.
- Further refine the prioritization of applications based on IOO priority and expected safety benefit.
- Incorporate additional feedback from transportation stakeholders.

Additional Questions:

- How should Channel 180 (5.895-5.905 MHz) be best used to provide V2X functionality for applications that may be more tolerant to interference in a scenario where priority safety applications operate in Channel 183 (5.905-5.925 MHz)?
- How should other critical service needs, such as over-the-air support for certificate top-off, certificate revocation lists, misbehavior detection and reporting, and device management, be provided?