An Overview of USDOT Connected Vehicle Roadside Unit Research Activities

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16. Abstract

The USDOT Vehicle-to-Infrastructure (V2I) research program has developed this white paper to provide stakeholders with an overview of the history, background, and plans relating to V2I Roadside Unit Research, focusing on the development of Dedicated Short Range Communications (DSRC) Roadside Unit (RSU) Specifications. Connected vehicle technologies are rapidly moving from research to deployment; as a result, a broader group of stakeholders is emerging, and the V2I program aims to ensure that stakeholders have an awareness of research progress and results, and continue to be engaged with future research efforts. As connected vehicle technologies rely upon systems deployed and operated on both vehicles and infrastructure, coordination of research, development, and deployment activities is essential. This paper provides a brief synopsis of USDOT-sponsored RSU specification development to facilitate common understanding and participation by stakeholders.

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An Overview of USDOT Roadside Unit Research

Introduction

This paper provides an overview of USDOT-sponsored research and development activities for a key enabling component of connected vehicle (CV) vehicle-infrastructure (V2I) technology, Dedicated Short Range Communications (DSRC) roadside units (RSUs). USDOT has engaged in connected vehicle research during the last decade that has focused on enabling vehicle-to-vehicle (V2V) and V2I communications-based applications to achieve safety, mobility, and environmental benefits. The vision behind connected vehicle technologies includes a variety of applications that can address differing needs, supported by standards and interoperable components that satisfy Infrastructure Owners and Operators' (IOOs) requirements. By providing a synopsis of the background and current and planned RSU-related activities, this paper offers stakeholders information to understand, plan for, and engage in V2I research, development, and deployment efforts.

Scope of the document

This document will begin by explaining the concept behind a V2I RSU and the USDOT's RSU specification. A brief history of the prior developments is provided, describing the needs for a minimum common specification are given, followed by a look toward future plans. Since both connected vehicle technology and the V2I program involve interaction with other activities in a cooperative fashion, the relationships with other projects and programs will be briefly described in order to help further a common understanding and coordinate related efforts. As V2I development and deployment planning efforts are still ongoing, this paper is based on currently available information, but notes areas where expected progress will lead to clearer definition of RSU capabilities needed and evolutionary development based on lessons learned.

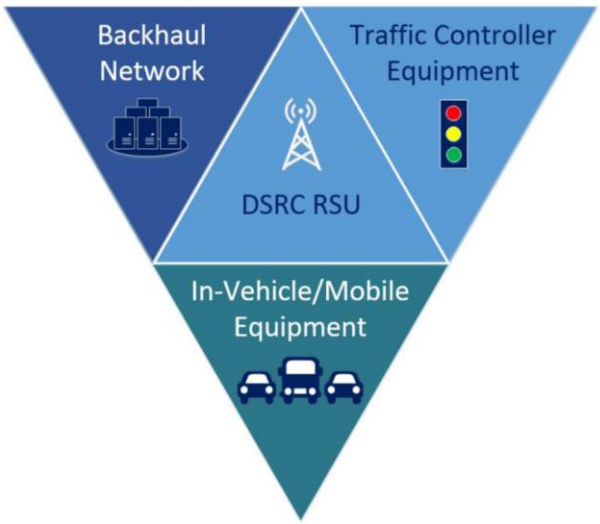
Overview of the RSU

What is an RSU? Variations in terminology and usage has sometimes resulted in a barrier in understanding and communications challenges among stakeholders, particularly since the RSU relates to diverse audience groups from traditional ITS infrastructure to wireless communications. The original definition of RSU was established by the Federal Communications Commission (FCC) as part of the allocation of the 5.9 GHz band for ITS. From 47 CFR Part 90 [1] definitions (§90.7):

"Roadside unit (RSU). A Roadside Unit is a DSRC transceiver that is mounted along a road or pedestrian passageway. An RSU may also be mounted on a vehicle or is hand carried, but it may only operate when the vehicle or handcarried unit is stationary. Furthermore, an RSU operating under this part is restricted to the location where it is licensed to operate. However, portable or hand-held RSUs are permitted to operate where they do not interfere with a site-licensed operation. A RSU broadcasts data to OBUs or exchanges data with OBUs in its communications zone. An RSU also provides channel assignments and operating instructions to OBUs in its communications zone, when required."

RSE vs. RSU

The term Roadside Equipment (RSE) has also been used to describe a broader set of field equipment, incorporating the narrowly-defined "RSU" (see Figure 1) and other functional components such as applications. Early USDOT efforts used the "RSE" terminology, and some of this usage continues (e.g., Connected Vehicle Reference Implementation Architecture (CVRIA) https://www.iteris.com/cvria/html/physobjects/physobj11.html). Roadside equipment may also be used to refer more generically to ITS field equipment including signal controllers, etc.; in an effort to encourage the common usage of a single term in the development of a specification, the USDOT has used "Roadside Unit (RSU)" in the recent specification-related documents to help clarify the scope. It should be noted that "RSE" also continues to be used outside the USDOT specification activity, when discussing the broader roadside infrastructure, but sometimes even when referring to the DSRC subsystem or components. As a result, in discussions with other interested parties, efforts should be made to clearly describe concepts and components being referenced and *seek clarification whenever potential for miscommunication is possible*.

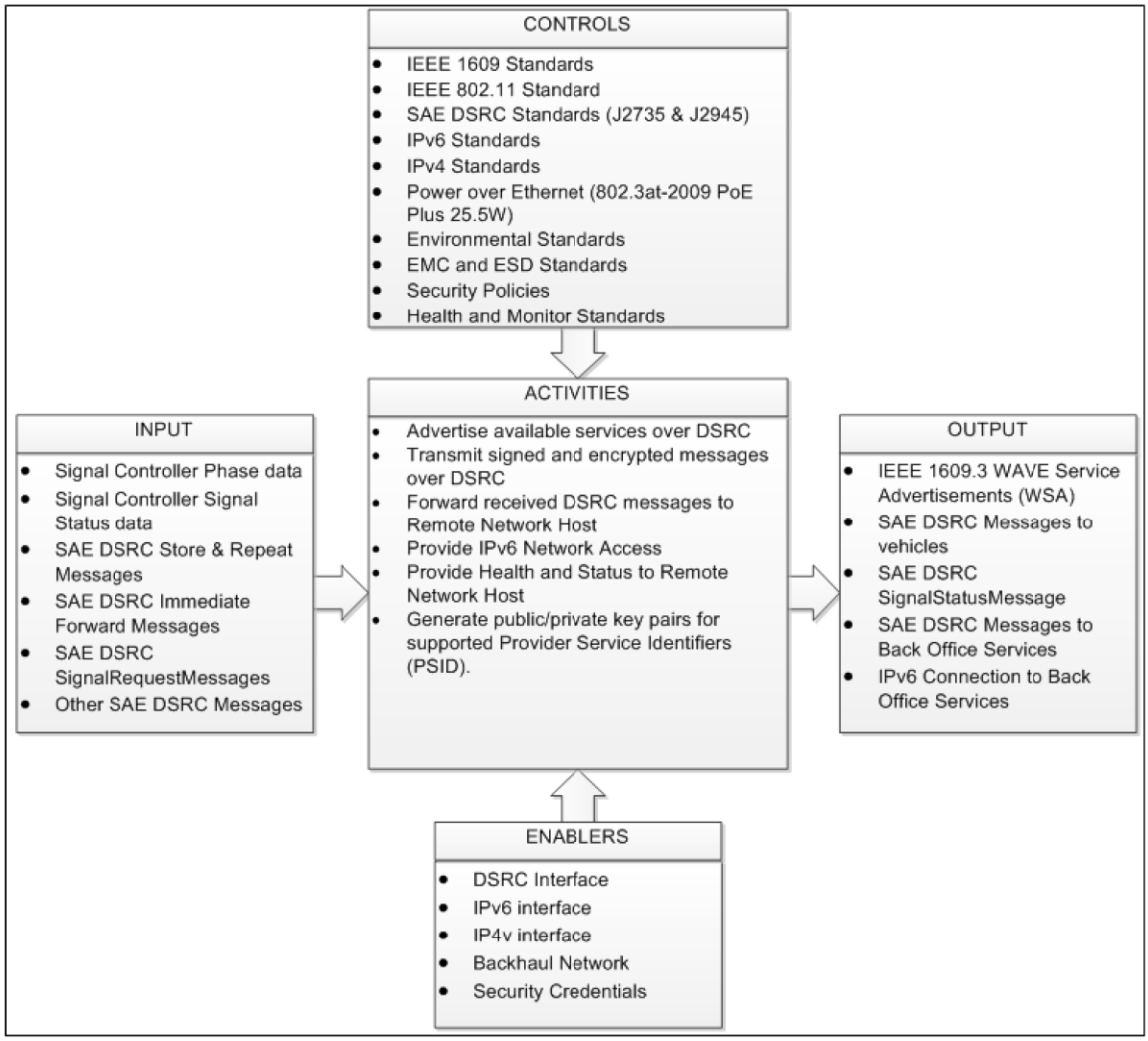


Source: Leidos

Figure 1: High-Level Conceptual Diagram of the RSU [2]

Functional vs. Physical Oriented Specification

In addition, it is important to note that the use of RSU within the USDOT's V2I research program is focused on a functional perspective, and does not specify an exact physical manifestation. Inclusion of certain device-specific non-functional factors (see Figure 2), such as environmental requirements, are unavoidable. However, the rationale to maintain a functional focus is to promote CV interoperability and avoid precluding the potential integration of RSU functionality within other ITS field equipment, where increased efficiency, effectiveness or market sustainability are possible. As a result, vendors may choose to offer RSU's with varying capabilities, beyond a minimum specification, to meet market needs and demand. Within the connected vehicle environment, capabilities are not expected to be static as a variety of application development efforts can leverage the basic DSRC and enabling V2I



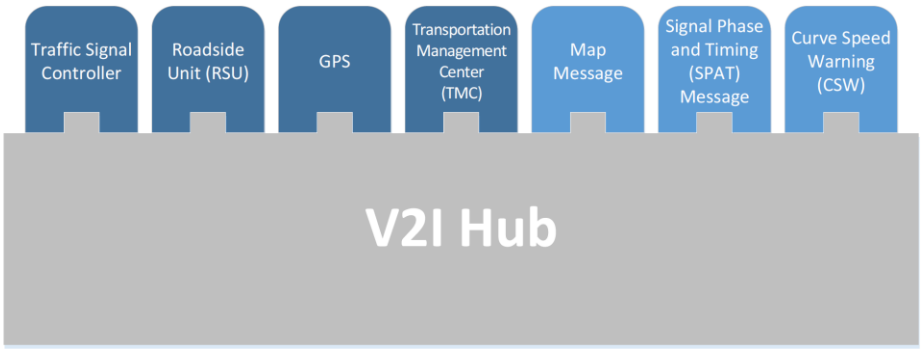
Source: Leidos

Figure 2: Context diagram of an RSU [2]

technologies. Future evolution of RSU capability may also include service oriented alternatives that implement components in physically separated or integrated configurations depending on the operational and other needs and constraints within the local environment. For example, equipment form factors to serve an isolated rural roadway segment may differ significantly from urban grid intersections tied to a Traffic Management Center.

Relationship with V2I Hub - Integrated V2I Prototype (IVP) and V2I Hub Reference Implementation

Other projects within USDOT's V2I research program are working toward development of a prototype and reference implementation of the broader V2I field infrastructure (through a "V2I Hub", see Figure 3) to enable V2I safety, mobility, and environmental applications. The initial Prototype of the V2I Hub, originally named the *Integrated V2I Prototype* [3] serves as a computing platform that interfaces with a variety of ITS field equipment, such as traffic signal controllers, dynamic message signs, road/weather sensors, and a DSRC RSU (see Figure 4). The IVP project, which will be complete by March 2017, has also helped to identify deployment-related lessons in interfacing with commercial (COTS) ITS field equipment and performing a complete field installation, in partnership with a local contractor and county/state DOT staff. These implementations are aimed at establishing an understanding of the enabling technologies and integration needed for V2I applications, and producing a stable, non-proprietary platform that can be used as a reference for researchers, developers, vendors, and integrators. The successor project (*V2I Hub Reference Implementation*), scheduled to be complete by September 2018, aims to provide a reference implementation of the V2I Hub that is stable and modular, and which can be integrated into vendor products, or used as a research or basic reference platform for V2I capabilities.



Source: Battelle

Figure 3: V2I Hub Concept [3]

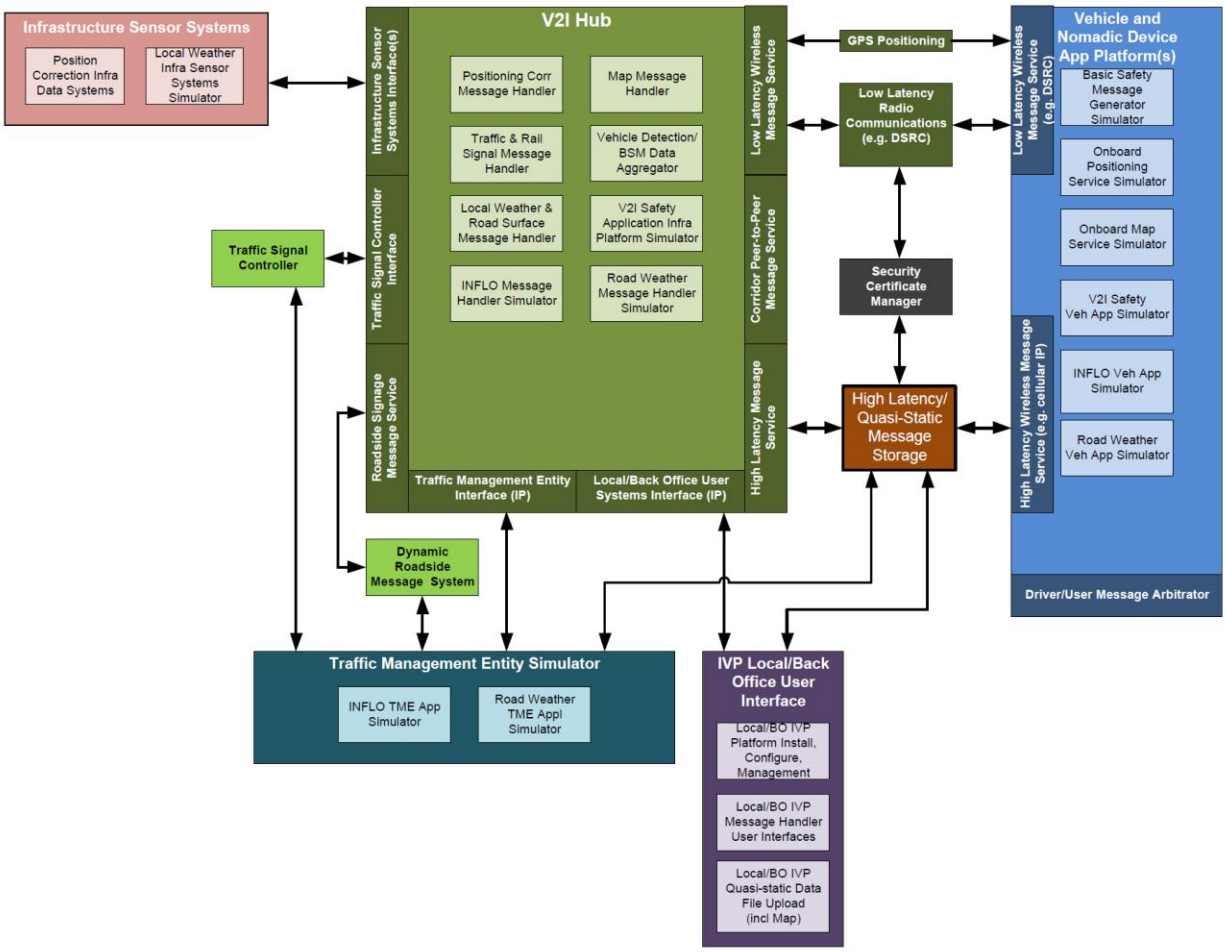


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Figure 4: V2I Hub Detailed System View with Candidate Message Handlers [3]

History of RSU

By supporting the development of a minimum RSU specification, USDOT is building upon prior efforts to define and specify capabilities required for V2I prototyping and testing. In preparation for the Safety Pilot Model Deployment (SPMD) in Ann Arbor, MI, the USDOT engaged in an iterative effort to specify the design requirements for a "roadside equipment grade electronic module capable of acting as the first-point-of-contact device for a 5.9GHz infrastructure". The resulting v. 3.0 (March 2012) "5.9GHz DSRC Roadside Equipment" Device Specification was used as the basis for testing, initial qualification and early certification research. The v. 3.0 specification was also used in procuring infrastructure devices for SPMD to enable testing of a limited set of V2I applications (Curve Speed Warning, Pedestrian in Signalized Crosswalk Warning, test conductor operations support). [4] The SPMD test

conductor recognized that the maturity of the devices was still limited and continued with multiple rounds of testing to permit vendors to address issues that were encountered.

After the conclusion of SPMD, USDOT sought to revise the v. 3.0 specification to incorporate the lessons learned from the interoperability testing, SPMD-related testing, deployment and operational experience [4], and stakeholder input. In April 2014, the resulting v. 4.0 RSU specification was released publicly. The v. 4.0 specification reflected the information available at the time of its publication, referencing the then-current versions of connected vehicle standards, (e.g., updating from IEEE P1609.2 draft to IEEE 1609.2-2013), and included functionality such as enhanced monitoring and management capabilities, based on experiences from SPMD.

A limited number of RSU devices aimed at the v. 4.0 specification have been tested both at the FHWA Saxton Transportation Operations Lab and other testbed locations. Concurrently, as research in V2V safety systems and international harmonization efforts have progressed, the underlying connected vehicle standards have been revised by the primary standards development organizations, SAE, and IEEE. These 2016 revised standards, primarily the IEEE 1609 series, and SAE J2735, are not backward-compatible with earlier versions. As a result, in the summer of 2016, USDOT engaged in a rapid, limited scope update to the v. 4.0 specification to reflect these new standards as well as other changes based on lessons learned since the previous release. A significant aspect of this v. 4.1 RSU Specification Update [2] was the need to balance the early pilot deployers' needs for device availability from the vendor community against a set of needs that have not been entirely defined in a stable form. This limited-scope update was therefore constrained to include requirements for those changes that could be reasonably expected to be upgradable in firmware, while those relating to hardware changes were not strictly required but recommended for future update cycles. In this manner, devices targeting the v. 4.1 specification could be available in a significantly shorter timeframe to support the Connected Vehicle Pilots program and other early deployers, as well as certification-related efforts.

RSU Specification Concept

The RSU specification development has utilized an approach to establish a common set of functionality to enable V2I while minimizing constraints on the vendor community, such as allowing integration of the functionality into existing product lines. To enable V2I applications, more is required than a DSRC radio. For example, broadcasting a SPaT and MAP message to enable a Red Light Violation Warning (RLVW) application, obtaining data from the traffic signal controller and incorporating back-office mapping systems are essential. As many of these related systems exist today, the approach used in the specification development attempts to allow the vendor community to provide the required functionality in a market driven fashion, to meet site-specific requirements. At the same time, defining interfaces is critical. Without clearly defined and specified interfaces, interoperability will face many risks and challenges.

As the V2I deployment and supplier community gain experience, the definition of interfaces will build upon real-world implementations, and standards development efforts will need to encapsulate the V2I industry consensus. Similarly, the RSU specification will need to evolve over time to reflect both technical developments as well as a sustainable deployment community. Current USDOT efforts are working to establish certification processes and procedures and supporting testing (e.g., verify device conformance to standards) and tools (e.g., establish a Test System Interface to support efficient

testing). These efforts aim to support IOOs' procurements by allowing for consistent conformance verification for equipment as well as encouraging interoperability by testing and vetting devices prior to CV credential issuance. Since nationwide interoperability across key V2I interfaces is a core element of the V2I vision, a consensus-driven standards-based approach will be essential.

Timeline

The draft RSU v. 4.1 specification was released in August, 2016 for a six-week period for clarification comments and final review. In addition, interim drafts were shared with the implementer community to enable early integration of revisions into product implementations. The RSU v. 4.1 specification document was finalized on October 31, 2016 [2] and will support RSU early deployers, including the CV Pilots Phase 2-3 efforts.

Based on the lessons learned from early deployments, and as related work in the Security Credential Management System (SCMS) matures to an operational, permanent system, it is envisioned that a future "v. 5.0" revision of the RSU specification will be undertaken. The development of a future v. 5.0 specification would aim to establish a mature, RSU standard using the ITS standards development process [5]. This effort is envisioned to be maintained by the relevant stakeholder communities and standards development organizations, as is the case with other standards such as the National Transportation Communications for ITS Protocol (NTCIP) and the Advanced Transportation Controller (ATC) series [6]. It is important to note that as the v 5.0 specification depends on results from future experience, it will not be limited in scope to firmware-upgradable changes as with the v. 4.1 specification. For example, progress in the state of the practice in areas such as V2I security are likely to result in hardware requirements, such as inclusion of a hardware security module (HSM) to protect credentials issued by the SCMS, increase signature verification performance, generate cryptographic keys, etc. However, these hardware requirements are not known precisely at this time and therefore the v. 4.1 specification mentions the HSM as a desirable feature but does not define a specific requirement. Future information on the RSU research and development efforts within USDOT will be posted as it becomes available.

Related Projects

The nature of connected vehicle technology is a cooperative system where many different participants interact in a common environment. As a result, there are interactions and interdependencies between related components, both from technical and institutional perspectives. The following sections offer highlights of key aspects of these relationships to other projects.

V2V

In August 2014, USDOT's National Highway Traffic Safety Administration (NHTSA) released an Advance Notice of Proposed Rulemaking (ANPRM) [7] to require V2V safety technologies in new light vehicles (passenger cars and light trucks with a gross vehicle weight rating of 10,000 pounds or less). In December 2016, NHTSA released the proposed rule in a Notice of Proposed Rulemaking (NPRM) [8] (see https://www.nhtsa.gov/press-releases/us-dot-advances-deployment-connected-vehicle-technology-prevent-hundreds-thousands), requiring V2V technology in new light vehicles

in the 2021-2023 timeframe. The core of the V2V safety requirement is the broadcast and reception of SAE J2735 Basic Safety Messages via 5.9 GHz DSRC, which will enable a variety of V2V safety applications such as Intersection Movement Assist (IMA) and Lane Change Warning / Blind Spot Warning (LCW/BSW). In support of these V2V safety applications, SAE published in early 2016 a set of minimum performance requirements relating to the core enabling V2V BSM (but not specific application requirements) in SAE J2945/1 (On-Board System Requirements for V2V Safety Communications). The light vehicles satisfying this proposed rule will comprise the vast majority of connected vehicles, and therefore the interactions with RSU's will be a significant component of the connected vehicle environment. In NHTSA's V2V readiness report [9], the potential interaction with RSU's are discussed with respect to two key areas: providing a supporting interface with a supporting SCMS, and V2I safety applications. The need for connected vehicles to communicate with the SCMS may be satisfied in more than one way, but RSU's can play an important role, for example, in providing the ability to obtain Certificate Revocation Lists (CRLs), obtain new certificates, and report potential malicious attacks on the system. With respect to V2I safety applications, the V2V capability on board vehicles will enable the addition of complementary V2I safety applications through firmware/software with little additional vehicle hardware.

Next-Stage Certification Program

USDOT has engaged in a cooperative agreement with three entities to develop and test certification testing capabilities to support connected vehicle devices. The Certification Operating Council (COC) represented by Danlaw, OCS, and 7Layers, developed test specifications and test suites for connected vehicle interfaces defined by standards, focused initially in V2V safety due to its higher level of maturity and NHTSA's V2V Notice of Proposed Rulemaking [8]. However, plans are being developed for establishing an initial set of V2I-related test specifications [10] to accommodate needs of early deployers (CV Pilots sites). The expectation is that the V2I test suites may involve some iteration based on experience and testing, as well as the ongoing development of a Test System Interface for certification testing [11]. However, the early efforts will aim at providing a basic set of tests oriented toward key V2I enabling elements such as broadcast of SPaT, MAP, etc.

Security Credential Management

Another key related effort is the development of a SCMS to support connected vehicle technology, including both V2V and V2I. USDOT has supported efforts to establish a design that supports key priorities such as privacy, and enables the trusted exchange of connected vehicle messages so that applications can be deployed. Much of SCMS design activity has been completed, and work has progressed to the implementation of a Proof-of-Concept (POC) [12] version of the SCMS that can support refinement of the design, as well as enable the provision of security credentials and related services to early deployers (supporting CV Pilots) and others testing connected vehicle technologies. To date, the SCMS-POC project has released three iterations of End-Entity (EE) requirements that cover how RSU's interface with the SCMS-POC system. The latest version 1.2 will be a living document and will be updated based on the SCMS-POC End User Group Meetings. An overview of the SCMS-POC EE interface was also presented at the USDOT Connected Vehicle Plugfest in November 2016 [13].

Ongoing Connected Vehicle Architecture Activity

Work to integrate the Connected Vehicle Reference Implementation Architecture (CVRIA) [14] and the National ITS Architecture into a common framework [15] is currently underway. At the same time, various solutions to implement components of the architecture, such as an Operational Data Environment (ODE) [16, 17] are being studied and tested. For example, the USDOT Southeast Michigan Testbed Architecture is in the process of adding capabilities for locally managed and owned real-time CV data distribution (ODE) which will allow for flexibility and experimentation on different data distribution models [18]. These and other efforts will provide insights into how the RSU may connect to other connected vehicle data systems.

Keeping Involved

One of the key lessons learned from the efforts to develop and revise the RSU specification is the importance of coordination with related efforts, such as standards development, and timelines. Much progress has been made in this area, and the goal of this document is to support continued information sharing and involvement in the stakeholder community. Below are some useful references and resources to stay aware and engaged with future RSU-related developments.

References

1. US Government Publishing Office (2017) Electronic Code of Federal Regulations, 47 CFR Part 90. Available from http://www.ecfr.gov/cgi-bin/text-idx?tpl=/ecfrbrowse/Title47/47cfr90_main_02.tpl
2. FHWA (2016) DSRC Roadside Unit (RSU) Specifications Document v4.1, October 31, 2016, Available from http://www.its.dot.gov/research_archives/testbed/PDF/USDOT_RSUSpecification4%200_FInal.pdf
3. USDOT Open Source Application Development Portal (2017) V2I Hub v2.3. Available from https://www.itsforge.net/index.php/forum/v2i-hub
4. Gay, K., & Kniss, V. (2015) Safety Pilot Model Deployment: Lessons Learned and Recommendations for Future Connected Vehicle Activities, Report FHWA-JPO-16-363, Available from https://ntl.bts.gov/lib/59000/59300/59361/FHWA-JPO-16-363.pdf
5. USDOT (2017) ITS Standards Development Process. Available from https://www.standards.its.dot.gov/LearnAboutStandards/StandardsDevelopment
6. American Association of State Highway and Transportation Officials (AASHTO), the Institute of Transportation Engineers (ITE) and the National Electrical Manufacturers Association (NEMA). Advanced Transportation Controller (ATC) suite of standards. Available from https://www.ite.org/standards/atc/index.asp

7. NHTSA (2014) Federal Motor Vehicle Safety Standards: Vehicle-to-Vehicle (V2V) Communications: Advance Notice of Proposed Rulemaking (ANPRM). Available from https://www.nhtsa.gov/staticfiles/rulemaking/pdf/V2V/V2V-ANPRM_081514.pdf
8. NHTSA (2016) Federal Motor Vehicle Safety Standards; V2V Communications: Notice of Proposed Rulemaking. Available from http://www.safercar.gov/v2v/pdf/V2V%20NPRM_Web_Version.pdf
9. NHTSA (2014) Vehicle-to-Vehicle Communications: Readiness of V2V Technology for Application, Report DOT HS 812 014. Available from https://www.nhtsa.gov/staticfiles/rulemaking/pdf/V2V/Readiness-of-V2V-Technology-for-Application-812014.pdf
10. USDOT (2016) Certification Program – Update [ITS America 2016 Annual Meeting slide deck] Available from http://www.its.dot.gov/pilots/pdf/ITSA2016_certification_Gay.pdf
11. USDOT (2016) USDOT Certification Project [November 2016 PlugFest slides] Available from http://www.its.dot.gov/presentations/plugfest_2016/Certification_Overview.pdf
12. USDOT (2016) Secure Credential Management System (SCMS) Proof of Concept (PoC) Overview [November 2016 PlugFest slides]. Available from http://www.its.dot.gov/presentations/plugfest_2016/SCMS_Plugfest.pdf
13. USDOT (2016) Connected Vehicle PlugFest [Presentation Slide Decks] Available from http://www.its.dot.gov/resources/presentations.htm#plug2016
14. USDOT (2017) Connected Vehicle Reference Implementation Architecture (CVRIA) Development Activities. Available from https://www.standards.its.dot.gov/DevelopmentActivities/CVReference
15. USDOT (2016) ITS Architecture and Standards Programs [ITS America Annual Meeting slides] Available from http://www.its.dot.gov/pilots/pdf/ITSA2016_standards_CVdeployment_Sill.pdf
16. USDOT (2016) ITS Data Program Update [ITS America Annual Meeting slides] Available from http://www.its.dot.gov/pilots/pdf/ITSA2016_ITSdataProgram_Pisano.pdf
17. USDOT (2017) USDOT Joint Program Office Operational Data Environment (JPO-ODE) development site and documentation. Available from https://github.com/usdot-jpo-ode/jpo-ode & https://github.com/usdot-jpo-ode/jpo-ode/tree/develop/docs
18. USDOT ITS JPO (2016) Early Deployer Technical Assistance [November 15, 2016 PlugFest slides] Available from http://www.its.dot.gov/presentations/plugfest_2016/Plugfest_Gold_2016.pdf

Other Resources

- V2I Resources Page: http://www.its.dot.gov/v2i/
- V2I Deployment Coalition: http://www.transportationops.org/V2I/V2I-overview
- NHTSA V2V Page: https://icsw.nhtsa.gov/safercar/v2v/
- Connected Vehicle Pilot Deployment Program: http://www.its.dot.gov/pilots/
- SmartColumbus Project: https://www.columbus.gov/smartcolumbus/
- JPO-ODE development site: https://github.com/usdot-jpo-ode/jpo-ode
- ITS JPO Professional Capacity Building site: https://www.pcb.its.dot.gov/

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