SURFACE VEHICLE STANDARD

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LTE Vehicle-to-Everything (LTE-V2X)
Deployment Profiles and Radio Parameters
for Single Radio Channel Multi-Service Coexistence

RATIONALE

The LTE-V2X system provides a mechanism for information exchange between a host vehicle and other LTE-V2X-enabled devices which may be worn by or otherwise attached to a traveler, a roadside device, or a management center, to address safety, mobility, and communication system needs. Common LTE-V2X design elements are needed to support future application standards development.

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For more information on this standard, visit
https://www.sae.org/standards/content/J3161_202204/

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1. SCOPE

This SAE Standard describes a reference system architecture based on LTE-V2X technology defined in ETSI Release 14. It also describes cross-cutting features unique to LTE-V2X PC5 sidelink (mode 4) that can be used by current and future application standards. The audience for this document includes the developers of applications and application specifications, as well as those interested in LTE-V2X system architecture, testing, and certification.

1.1 Purpose

This SAE Standard provides a reference system architecture based on LTE-V2X technology; addresses the on-board system needs for ensuring the exchange of V2V, V2I, and I2V communications; and provides the desired interoperability and data integrity to support the performance of the envisioned safety applications.

2. REFERENCES

2.1 Applicable Documents

The following publications form a part of this specification to the extent specified herein. Unless otherwise indicated, the latest issue of SAE publications shall apply.

2.1.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

SAE J2735 V2X Communications Message Set Dictionary

SAE J2945/1 On-Board System Requirements for V2V Safety Communications

SAE J3161/1 On-Board System Requirements for LTE-V2X V2V Safety Communications

2.1.2 ETSI/3GPP Publications

The references to ETSI documents in this section refer to ETSI transposition of specific 3GPP technical specification available from 3GPP Mobile Competence Centre, c/o ETSI, 650, route des Lucioles, 06921, Sophia Antipolis Cedex, France www.etsi.org. The equivalent 3GPP documents are listed in brackets below.

The following list of of documents are from the ETSI Release 14 set of standards and are referred to in the body of this document by their 3GPP document number (e.g., ETSI TS 136 321, which is equivalent to 3GPP TS 36.321):

ETSI TS 136 213 Evolved Universal Terrestrial Radio Access (E-UTRA); Physical layer procedures, V14.2.0 (Release 14) [3GPP TS 36.213]

ETSI TS 136 300 Evolved Universal Terrestrial Radio Access (E-UTRA) and Evolved Universal Terrestrial Radio Access Network (E-UTRAN); Overall Description; Stage 2, V14.2.0 (Release 14) [3GPP TS 36.300]

ETSI TS 136 321 Evolved Universal Terrestrial Radio Access (E-UTRA); Medium Access Control (MAC) protocol specification, V14.2.1 (Release 14) [3GPP TS 36.321]

ETSI TS 136 322 Evolved Universal Terrestrial Radio Access (E-UTRA); Radio Link Control (RLC) protocol specification, V14.1.0 (Release 14) [3GPP TS 36.322]

These documents may reference other related ETSI documents.[1]

1 For example, ETSI TS 123 285 and ETSI TS 123 303.

2.1.3 IEEE Publications

Available from IEEE Operations Center, 445 and 501 Hoes Lane, Piscataway, NJ 08854-4141, Tel: 732-981-0060, www.ieee.org.

The following list of documents are from the IEEE 1609 set of standards and are referred to in the body by their IEEE document number (e.g., 1609.2):

IEEE Std 1609.2-2016 IEEE Standard for Wireless Access in Vehicular Environments - Security Services for Applications and Management Messages (as amended by IEEE Std 1609.2a-2017 and IEEE Std 1609.2b-2019)

IEEE Std 1609.3-2020 IEEE Standard for Wireless Access in Vehicular Environments (WAVE) - Networking Services

IEEE Std 1609.12-2019 IEEE Standard for Wireless Access in Vehicular Environments (WAVE) - Identifier Allocations

2.1.4 NTCIP Publications

Available from National Transportation Communications for Intelligent Transportation Systems (ITS) Protocol (NTCIP), www.ntcip.org.

NTCIP 8002 Annex B1 v01 Content Outline for NTCIP 1200-Series Documents

2.2 Related Publications

Refer to SAE J2945/1, 2.2.

3. TERMS AND DEFINITIONS

For the purposes of this standard, the definitions, abbreviations, and acronyms found in SAE J2735 also apply. The following additional definitions, abbreviations, and acronyms supersede those found in SAE J2735 in the case of conflict.

3.1 ACTOR

An entity that has an active role or interest in a use case, e.g., driver.

3.2 CERTIFICATE AUTHORITY (CA)

A back-office infrastructure entity that interacts with the host vehicle (HV) and the RA to enter into a dialog with the HV and provide certification services. A primary goal of the CA is to manage the collection of certificates for LTE-V2X devices.

3.3 CERTIFICATE MANAGEMENT

The definition, ordering, generation, provisioning (disribution), re-provisioning, and revocation of digital certificates (i.e., certificate managemnet uses a PKI but its requirements boil down to applications and use cases in V2X).

3.4 CHANNEL

An LTE-V2X radio channel used in exchanging control information and information relevant for ITS applications.

3.5 CONNECTED VEHICLE

A vehicle equipped with devices enabling interoperable wireless communication. The devices can communicate with other equipped vehicles, infrastructure, and personal communications devices.

3.6 CONTEXT DIAGRAM

A block diagram, showing a system as a whole, and its inputs and outputs from/to external factors. This diagram is the highest-level view of a system. It shows the borders, actors, and interaction between systems and the major information flow in and out of the system. It can also be referred to as a system context diagram (SCD).

3.7 DATA PLANE

Contains the entities that exchange protocol data units which accomodate application data units with their peers at the various layers in the protocol stack.

3.8 DEVICE

An ITS component (other than equipped vehicle and vulnerable road use) which is able to communicate through wireless or wireline interface.

3.9 DIALOG

A sequence of two or more messages which are exchanged in a known format (typically of a request followed by one or more replies) between the parties.

3.10 DRIVER

The human operating a vehicle (equipped or non-equipped) used in any role. Drivers may be actors in a use case.

3.11 GLOBAL NAVIGATION SATELLITE SYSTEM (GNSS)

A satellite system that is used to determine the geographic location of a user's receiver antenna. Two examples include the United States' Global Positioning System (GPS) and the Russian Federation's Global Orbiting Navigation Satellite System (Globalnaya Navigazionnaya Sputnikovaya Sistema or GLONASS).

3.12 HEAVY VEHICLE

Vehicles with a FHWA vehicle classification of 5 to 13.

3.13 HOST VEHICLE (HV)

The primary equipped vehicle of concern that is running a specific application about which a given use case may be constructed. The host vehicle (HV) can be a transmitting vehicle, a receiving vehicle, or both—this distinction is made clear in the use case description. There is typically only one host vehicle in any use case.

3.14 V2X INFRASTRUCTURE

Any LTE-V2X device which supports V2V/V2I/V2X communications flows (message exchanges), including—but not limited to—LTE-V2X RSU devices.

3.15 INTELLIGENT TRANSPORTATION SYSTEM (ITS)

A system that applies information technology to transportation challenges. ITS improves transportation safety and mobility and enhances productivity through the integration of advanced communications technologies into the transportation infrastructure and in vehicles. ITS encompasses a broad range of wireless and wireline communications-based information and electronics technologies. For more information, refer to http://www.its.dot.gov/index.htm.

3.16 LIGHT VEHICLE

A class 2 or class 3 vehicle as defined by FHWA (https://www.fhwa.dot.gov/policyinformation/tmguide/tmg_2013/vehicle-types.cfm) excluding ambulances, law enforcement vehicles, fire department vehicles, and construction vehicles.

3.17 LINK (RF)

A communications link being used in support of application data transfer needs.

3.18 MANAGEMENT INFORMATION BASE

A set of objects describing the attributes, properties, and controllable features of devices on a network, which can be remotely monitored, configured, and controlled. The information is provided in a format called Abstract Syntax Notation.1 (ASN.1), which is an international standard for defining objects.

3.19 MESSAGE

A set of data elements and data frames that can be sent between devices to convey some semantic meaning in the context of pre-defined applications.

3.20 MESSAGE SET

A collection of messages based on the functional area to which they pertain.

3.21 NETWORKING SERVICES

The collection of management plane and data plane functions at the network layer supporting WAVE communications.

3.22 ON-BOARD UNIT (OBU)

A vehicle-mounted LTE-V2X device used to transmit and receive a variety of message traffic to and from other LTE-V2X devices (other OBUs and RSUs). Among the message types and applications supported by this process are vehicle safety messages used to exchange information on each vehicle's dynamic movements for coordination and safety.

3.23 PACKET DELAY BUDGET (PDB)

The maximum delay that a packet can tolerate before transmission once it is received by the modem from an application stack and is generally based on the priority of the packet generated.

3.24 PROVIDER SERVICE CONTEXT (PSC)

A field associated with a PSID containing supplementary information related to the service. PSC is defined in IEEE Std 1609.3.

3.25 REFERENCE LANE

A lane drivable by motorized vehicle traffic which also contains a detailed path definition of the lane's geometry (a center line path and width) as well as basic attributes (such as the allowed maneuvers) about the lane. The provided path data may optionally be reused with another nearby lane (a "computed lane") in the same intersection.

3.26 ROADSIDE UNIT (RSU)

A device used to transmit to, and receive from, equipped vehicles (OBUs) and vulnerable road users (VRUs). The RSU transmits from a fixed position on the roadside (which may be either a permanent installation or "temporary" equipment brought on-site for a period of time associated with an incident, road construction, or other events). Some RSUs have the ability to transmit signals with greater power than OBUs and some may have connectivity to other nodes or the internet. An RSU contains a UE.

3.27 SAFETY VEHICLE

A vehicle used for emergency or incident management.

3.28 STANDARDS DEVELOPING ORGANIZATION

An organization whose primary activities are developing, coordinating, promulgating, revising, amending, reissuing, interpreting, or otherwise producing technical standards that are intended to address the needs of some relatively wide base of affected adopters.

3.29 SYNTAX

The structure of expressions in a language, and the rules governing the structure of a language.

3.30 SYSTEM

The INCOSE Systems Engineering Handbook describes a system as “A combination of interacting elements organized to achieve one or more stated purposes.” It further states that a system is “an integrated set of elements, subsystems, or assemblies that accomplish a defined objective. These elements include products (hardware, software, firmware), processes, people, information, techniques, facilities, services, and other support elements.” (IEEE Std 1609.12)

3.31 SYSTEM OF SYSTEMS

Applies to a system-of-interest whose system elements are themselves systems; typically, these entail large scale inter-disciplinary problems with multiple, heterogeneous, distributed systems. Another appropriate definition can be found in Wikipedia: “System of systems is a collection of task-oriented or dedicated systems that pool their resources and capabilities together to create a new, more complex system which offers more functionality and performance than simply the sum of the constituent systems.” (IEEE Std 1609.12)

3.32 TRANSIT VEHICLE

A vehicle engaged in transit operations, e.g., a bus.

3.33 VALIDATION

Assurance that the communication system fulfills its business or mission objectives and stakeholder requirements (user needs in ITS), achieving its intended use in its intended operational environment.

3.34 VERIFICATION

a. The process of evaluating a system or component to determine whether the products of a given development phase satisfy the conditions imposed at the start of that phase.

b. The process of providing objective evidence that the system, software, or hardware and its associated products conform to requirements (e.g., for correctness, completeness, consistency, and accuracy) for all life cycle activities during each life cycle process (acquisition, supply, development, operation, and maintenance); satisfy standards, practices, and conventions during life cycle processes; and successfully complete each life cycle activity and satisfy all the criteria for initiating succeeding life cycle activities.

4. ABBREVIATIONS AND ACRONYMS

The additional abbreviations and acronyms cited below are terms related to this standard (and of the other companion volumes and guides) unless specifically cited otherwise.

3GPP	Third Generation Partnership Project
BSM	Basic Safety Message
CAMP	Crash Avoidance Metrics Partnership
CBR	Channel Busy Ratio
CR	Channel Occupancy Ratio
DE	Data Element
DMRS	Demodulation Reference Signal
ECU	Electronic Control Unit
eNB	Evolved Node B
EVA	Emergency Vehicle Alert
ETSI	European Telecommunication Standard Institute
E-UTRA	Evolved Universal Mobile Telecommunications System (UMTS) Terrestrial Radio Access
FCC	Federal Communications Commission
FHWA	Federal Highway Administration
FIPS	Federal Information Processing Standards
GHz	Gigahertz
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
HARQ	Hybrid Automatic Repeat Request
Hv	Heavy Vehicle
HV	Host Vehicle
Hz	Hertz
I2V	Infrastructure-to-Vehicle
ICT	Information and Communications Technology
ID	Identifier
IEEE	Institute of Electrical and Electronics Engineers
IP	Internet Protocol

IPv6	Internet Protocol Version 6
ITT	Inter-Transmit Time
km/h	Kilometers per Hour
LOS	Line of Sight
LSB	Least Significant Bit
LTE	Long Term Evolution
MAC	Medium Access Control
MAP	SAE J2735 Map Data Message
MCS	Modulation and Coding Scheme
MHz	Megahertz
MPDU	MAC Protocol Data Units
MSB	Most Significant Bit
MSG	Message
NHTSA	National Highway Traffic Safety Administration
NIST	National Institute for Standards and Technology
NTCIP	National Transportation Communications for ITS Protocols
OBE	Onboard Equipment
OBU	Onboard Unit
OEM	Original Equipment Manufacturer
OFDM	Orthogonal Frequency Division Multiplexing
OTA	Over the Air
PC5	ProSe Communications 5
PDB	Packet Delay Budget
PDM	Probe Data Message
PDCP	Packet Data Convergence Protocol
PDCP SN	Packet Data Convergence Protocol Sequence Number
PER	Packet Error Ratio
PGK	ProSe Group Key
PH	Path History
PHY	Physical Layer

PICS	Protocol Implementation Conformance Statement
PP	Path Prediction
PPPP	ProSe per Packet Priority
PPS	Pulse per Second
ProSe	Proximity Services
PRB	Physical Resource Block
PSSCH	Physical Sidelink Shared Channel
PSCCH	Physical Sidelink Control Channel
PSID	Provider Service ID
PTK	ProSe Traffic Key
PVD	Probe Vehicle Data
QPSK	Quadrature Phase Shift Keying
RAN	Radio Access Network
RB	Resource Block
RF	Radio Frequency
RLC	Radio Link Control
RLC UM	Radio Link Control Unacknowledged Mode
RSA	Roadside Alert
RSE	Roadside Equipment
RSM	Road Safety Message
RSU	Roadside Unit
RSRP	Reference Signal Receive Power
RP	Radiated Power
RTCM	Radio Technical Commission for Maritime Services
RV	Remote Vehicle
RWM	Road Weather Message
SCMS	Security Credential Management System
SAP	Service Access Point
SC-FDMA	Single-Carrier Frequency-Division Multiple Access
SCI	Sidelink Control Information

SoS	System of Systems
SDO	Standards Developing Organizations or Standards Development Organization
SPaT	Signal Phase and Timing Message
SPS	Semi-Persistent Scheduling
SRM	Signal Request Message
SRS	Safety Restraint System or Supplemental Restraint System
SSM	Signal Status Message
SSP	Service Specific Permissions
STA	Station
STCH	Sidelink Traffic Channel
Std	Standard
3D	Three-Dimensional
TB	Transmit Block
Tx	Transmit
TCP	Transmission Control Protocol
TIM	Traveler Information Message
TMDD	Traffic Management Data Dictionary
UARFCN	UTRA Absolute Radio Frequency Channel Number
USIM	Universal Subscriber Identity Module
UDP	User Datagram Protocol
UP	User Priority
USDOT	United States Department of Transportation
UTC	Universal Coordinated Time
V2V	Vehicle-to-Vehicle
V&V	Verification and Validation
V2D	Vehicle-to-Device
V2Hv	Vehicle-to-Heavy Vehicle
V2I	Vehicle-to-Infrastructure
V2P	Vehicle-to-Pedestrian
V2Sv	Vehicle-to-Safety Vehicle

V2Tv	Vehicle-to-Transit Vehicle
V2V	Vehicle-to-Vehicle
V2X	Vehicle-to-Everything Equipped Object
VRU	Vulnerable Road User
WAVE	Wireless Access in Vehicular Environments
WSM	WAVE Short Message
WSA	WAVE Service Advertisement
WSMP	WAVE Short Message Protocol

5. INTRODUCTION TO THE LTE-V2X SYSTEM AND STANDARDS

Vehicle-to-everything (V2X) communications are comprised of various connected devices including vehicles (V), infrastructure (I), and other devices (D). Subsets of V2X communications referenced in this document include vehicle-to-vehicle (V2V), vehicle-to-infrastructure (V2I), and infrastructure-to-vehicle (I2V). This section provides an overall LTE-V2X system architecture and describes the existing components of LTE-V2X communication.

5.1 Intelligent Transportation System (ITS)

ITS is a system that applies information technology to transportation challenges. ITS improves transportation safety and mobility and enhances productivity through the integration of advanced communications technologies into the transportation infrastructure and in vehicles. ITS encompasses a broad range of wireless and wireline communications-based information and electronics technologies. Various forms of wireless communication technologies (including LTE-V2X, dedicated short range communication, and bluetooth) have been proposed for ITS inter-device connectivity. This standard focuses on the LTE-V2X architecture and presents overall system architecture, common design elements, the functionality of different elements, and communication parameters for different traffic types.

5.2 Connected Transportation System Context Diagram

The connected transportation system of systems (SoS), as shown in Figure 1, consists of a collection of systems. Each system is comprised of various connected devices including vehicles (V), infrastructure (I), network (N), and other devices (D). Interactions between the devices within the system include vehicle-to-vehicle (V2V), vehicle-to-infrastructure (V2I), vehicle-to-network (V2N), vehicle-to-device (V2D), device-to-network (D2N), and device-to-infrastructure (D2I). Additionally, systems that may be included in the SoS are developed to address more specific varieties of devices, as an example, with vehicles there are light vehicles (Lv), heavy vehicles (Hv), transit vehicles (Tv), safety vehicles (Sv), and motorcycle (M). Other devices such as vulnerable road users (VRU) are examples that are not vehicles.

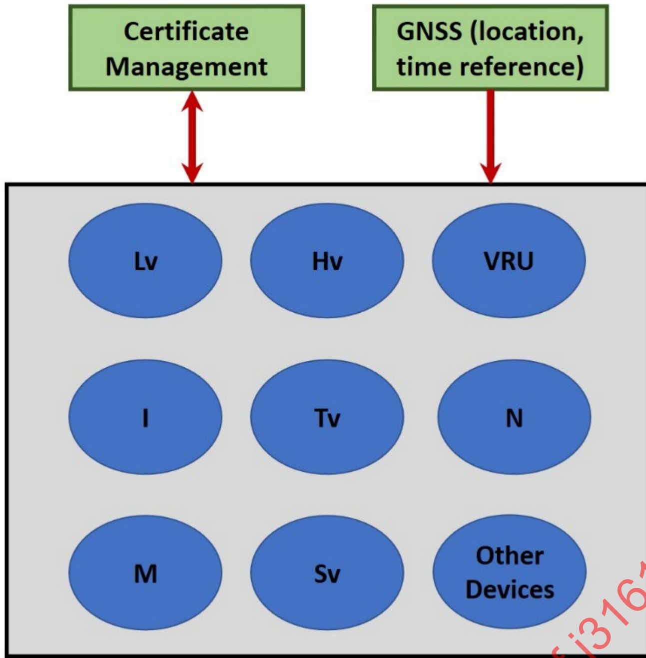

Figure 1 - Connected transportation (system of systems)

Systems:

a. Vehicle system (V ↔ V)[2]

b. Infrastructure system (V ↔ I)

c. Network system (V ↔ N)

d. Light vehicle (Lv) system (V ↔ Lv, Lv ↔ I)

e. Heavy vehicle (Hv) system (V ↔ Hv, Hv ↔ I)

f. Transit vehicle (Tv) system (V ↔ Tv, Tv ↔ I)

g. Motorcycle (M) system (V ↔ M, M ↔ I)

g. Safety vehicle (Sv) system (V ↔ Sv, Sv ↔ I)

h. Vulnerable road user system (V ↔ VRU, N ↔ VRU, VRU ↔ I)

i. Others

It is important to note that only a few of the vehicle types have been addressed. There are many additional types of vehicles. For reference, Figure 2 illustrates the FHWA vehicle classifications. These classifications are used to help differentiate the vehicle types specified in the connected systems. This classification is used in subsequent context diagrams.

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2 Bidirectional arrow in mean bidirectional communication link.

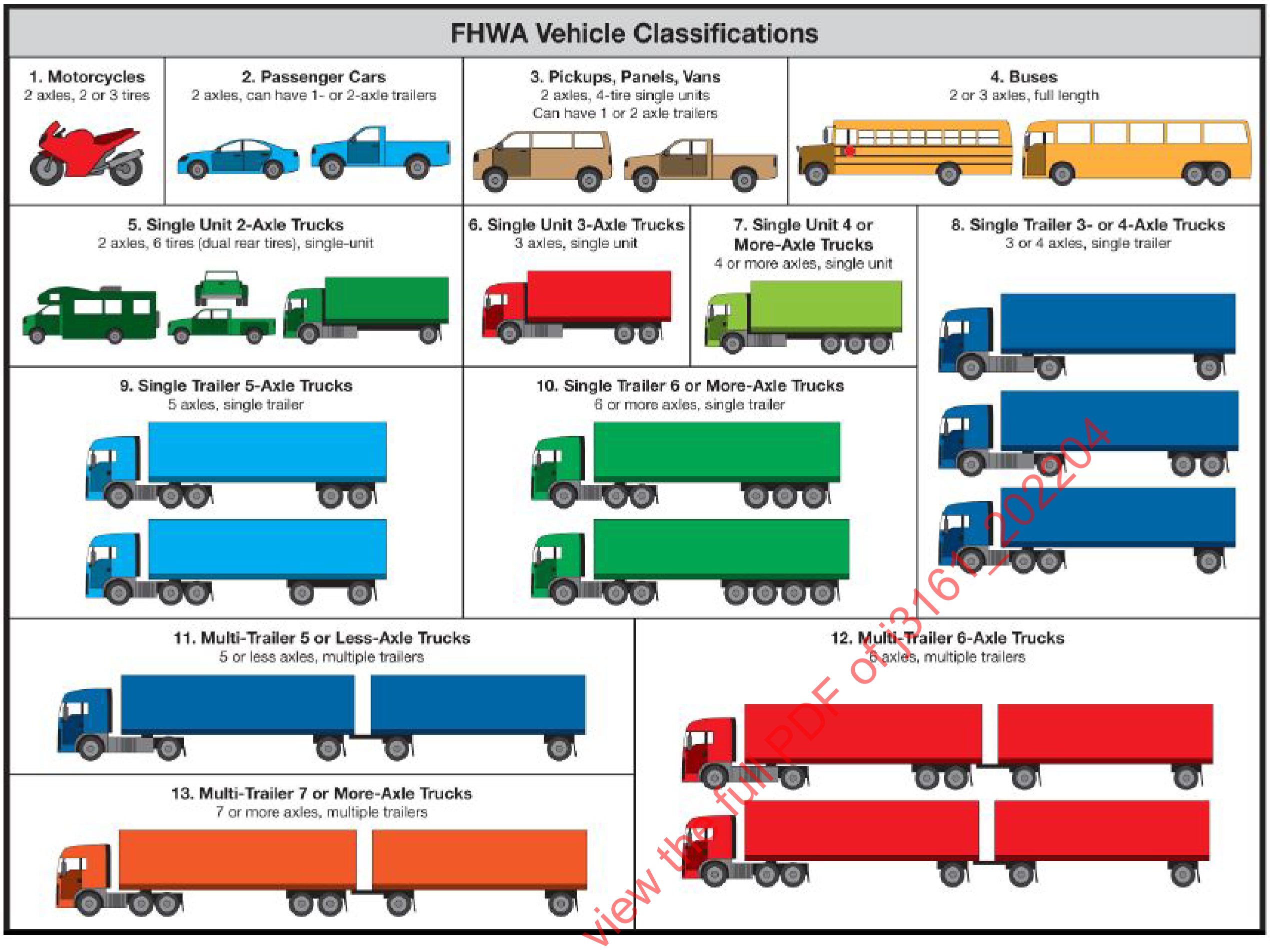

Figure 2 - Vehicle classification using FHWA 13 - category scheme

Figures 3 and 4 further illustrate the context diagram for two systems: V2V and V2I systems. To develop the specific system context diagrams (SCDs), a block diagram is created showing the system as a whole and its inputs and outputs from/to external factors. These context diagrams are the highest-level view of a system and are included in the concept of operation. The diagrams show the borders, actors, and systems interacting with the specified system and the major information flow in and out of the system. These interfaces and interdependencies will drive the system design. The SCD typically describes the flow of information in the system with labeled communication arrows drawn between the system components. If there are different types of information, one arrow may be used per information type. This distinguishes between the input and output of information. The objective of the system context diagram is to focus attention on external factors and events that should be considered in developing a complete set of systems requirements and constraints. The following context diagrams are intended to be for instructive and illustrative purposes and are not to be considered complete, normative, or exhaustive.

5.2.1 V2V System Motorized Vehicle Context Diagram

The V2V system, as shown in Figure 3, consists of on-board units (OBUs) installed in the vehicles. The OBU broadcasts and receives vehicle safety and status information. Applications reside on the OBU for notifying the vehicle occupants of specific situations. The OBU communicates with the other vehicles and interfaces with GNSS and a certificate management system, in addition to other devices.

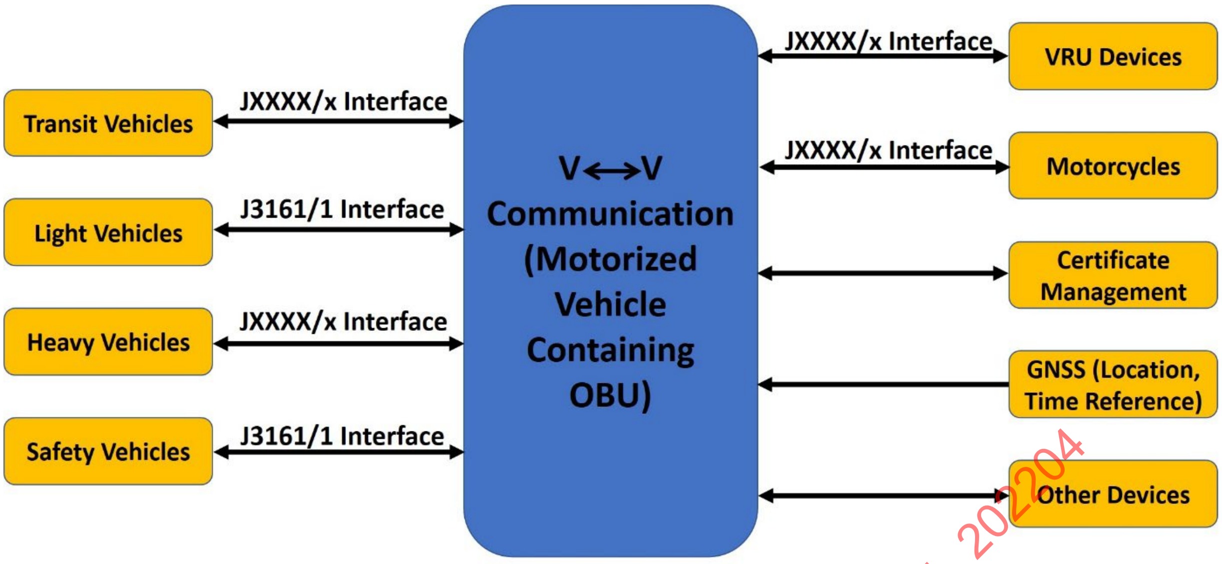

Figure 3 - Vehicle-to-vehicle (V2V) context diagram for LTE-V2X

- GNSS: The OBU interfaces with one or more GNSS sources for location and time data.

- Certificate management: In order to authenticate the source of a message, the OBU may interface with a certificate management system (CMS). The OBU messages that include a valid certificate indicate to the receiver that the sending device has been granted permission from a mutually trusted authority.

- Light vehicle: A vehicle with a FHWA vehicle classification of 2 and 3, as described in Figure 2, can include factory-installed devices, after-market devices, or retrofit devices that interface with systems installed on other vehicles to improve safety and movement within the road system. Taxis, while possibly being light vehicles, may be considered as shared passenger transport service vehicles and therefore transit vehicles.

- Transit vehicle: A shared passenger-transport service that is available for use by the general public which is equipped with a device that can interface with other equipped devices to improve safety and movement within the transportation system. Buses, FHWA vehicle classification 4, are considered to be transit vehicles instead of heavy vehicles due to being a shared passenger-transport service.

- Heavy vehicle: Heavy vehicles, those with the FHWA vehicle classification of 5 through 13, can have V2V systems installed to assist in their movements and safety. These larger vehicles have unique needs due to their size and weight.

- Safety vehicle: Emergency and incident management vehicles such as police vehicles, ambulances, and motorist assist vehicles can have devices installed to communicate within the V2V systems to assist in their response and safety during operations. Safety vehicles are made up of other physical vehicle types (light, heavy, transit, motorcycle, etc.), but operate in the role of safety vehicles when using a certificate granting them the additional rights and privileges.

- VRU device: A road user who is not using a motorized vehicle is particularly vulnerable to serious injury or death when involved in a motor-vehicle-related collision. These users include pedestrians, cyclists, and road workers. The V2V systems in motorized vehicles can communicate with these users via the VRU devices.

- Motorcycle: Motorcycles are vehicles with a FHWA vehicle classification of 1. They have more safety concerns than other vehicle types. They can have OBUs installed to allow them to communicate with other vehicles to improve their safety and to improve awareness of nearby vehicles in relation to themselves.

5.2.2 V2I Vehicle to Infrastructure Context Diagram

The V2I system, as shown in Figure 4, interfaces with vehicles, ITS infrastructure devices, agencies, GNSS, a certificate management system, along with other external systems. The interfaces can utilize various standards including, but not limited to, those standards developed by SAE, NTCIP, IEEE, ITE, and NEMA.

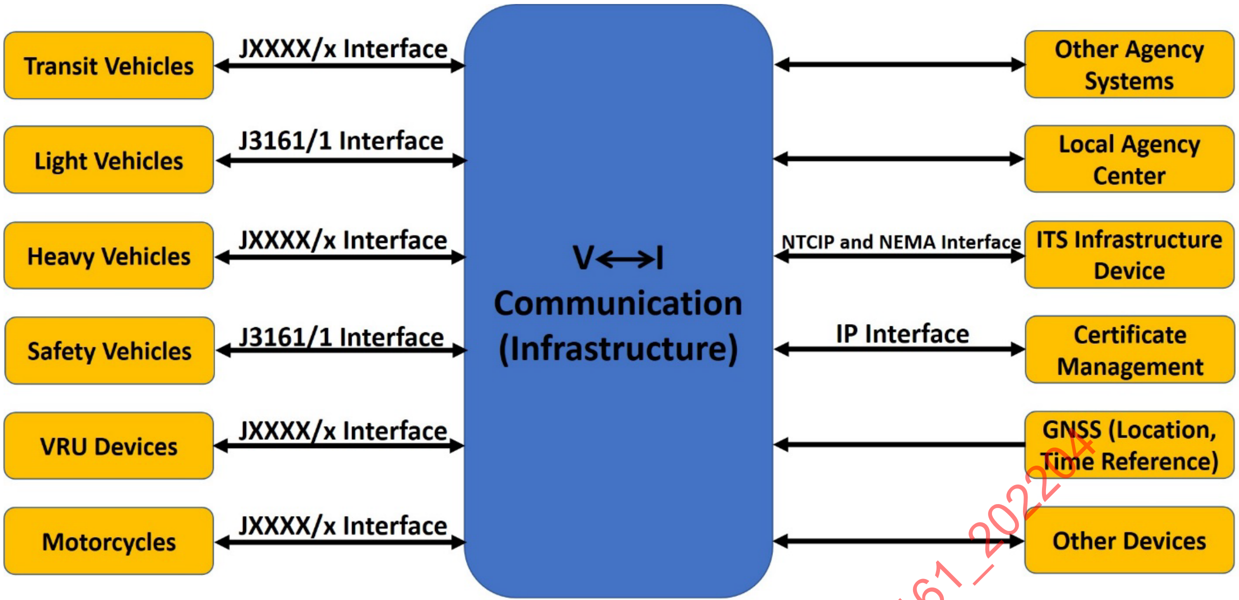

Figure 4 - Vehicle-to-infrastructure (V2I) context diagram[3]

Definitions common between the context diagrams have not been repeated. See 5.2.1.

- Agency centers: The V2I infrastructure can communicate with agency centers to notify the agencies of the current state of the device and its environment, including vehicle mobility within its area.

- Field devices: The field devices can consist of, but are not limited to, road-side units, signal controllers, and other transportation regulating or monitoring devices.

5.3 LTE-V2X System Architecture

LTE-V2X is defined by the ETSI Release 14 specifications, including PC5-based direct communications. As shown in Figure 5, an LTE-V2X network architecture consists of different communication links including V2V, V2I, V2P, and V2N. It is implied that these communication links are generally bidirectional.

In LTE-V2X architecture, there are two communication interfaces (i.e., PC5 and Uu):

1. PC5 is a sidelink low-latency direct communication interface and has two standardized modes of operations (mode 3 and mode 4). This document focuses on PC5 mode 4, where the users can select the radio resources for their direct communication without the help of the cellular network.[4]

2. The Uu interface is used for network-based communication where vehicles and VRUs can communicate with V2X application servers and connect to the network via the Uu interface.

This standard focuses only on PC5 sidelink interface; Uu interface is out of the scope of this document.

[3] Motorcycle and VRU are the components that interact in the V2I communication system. They can provide useful information to the vehicle or infrastructure. For example, VRU can provide information to the infrastructure that can be used to send a warning message from infrastructure to vehicle.

[4] Hereafter in this document, whenever the terms “LTE-V2X,” “sidelink,” or “PC5” are used separately or in any combination, they refer to ETSI Release 14 PC5 Sidelink (Mode 4) communication.

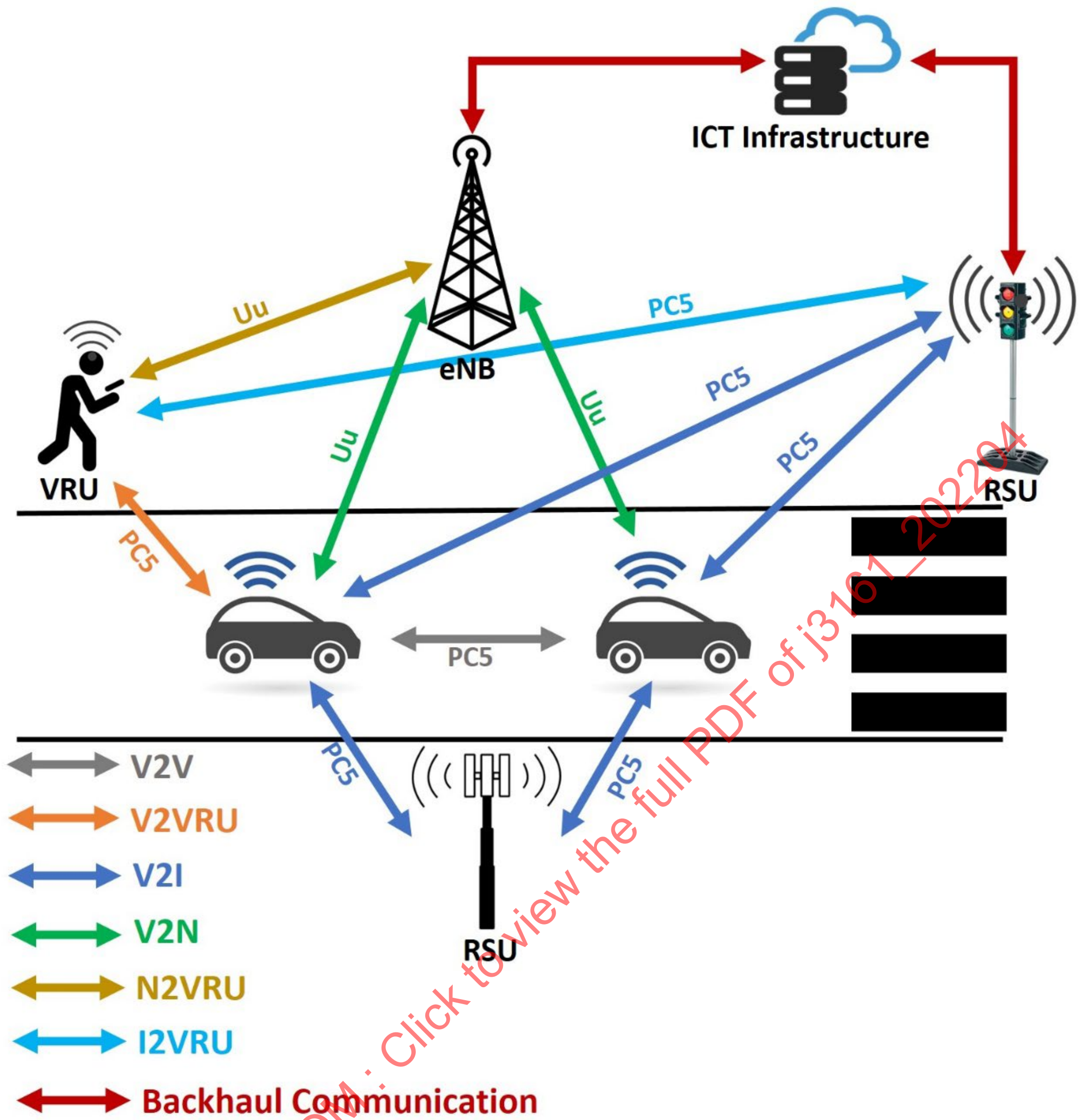

Figure 5 - LTE-V2X system architecture

5.4 SAE Standards Series Supporting ITS Communication Using LTE-V2X

The SAE Standards series, that supports the LTE-V2X deployment, is made up of two types of documents. First are the common documents including SAE J2735 and this document, SAE J3161, which will be referenced by V2X application documents (SAE J3161/1 and SAE JXXXX/x). The second type will be SAE J3161/1 and the specific SAE JXXXX/x documents which will include applications and provide their associated needs, requirements, and design, within the connected transportation ecosystem.[5] For illustrative purposes, Figure 6 shows the typical relationship between a system and its associated SAE JXXXX/x standards. SAE J2735 and SAE J3161 are not shown in this figure.

[5] In SAE J3161/1, apart from the minimum requirements and design, the communication system parameters for BSM transmission is also included. However, SAE J3161 provides communication system parameters for the rest of V2V, V2I, and I2V messages. This means that compliance with SAE J3161/1 does not imply compliance with SAE J3161.

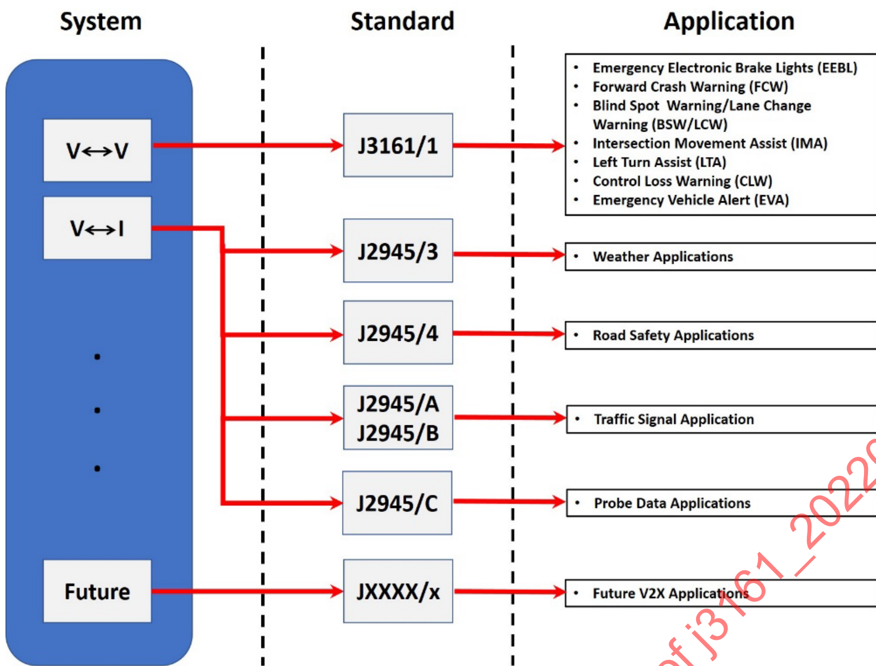

Figure 6 - Relationship of system and SAE Standards[6]

6. COMMON DESIGN ELEMENTS FOR LTE-V2X COMMUNICATION

This section describes common design elements of LTE-V2X used by different message types, especially elements related to communications and security.

6.1 Over the Air Communications

While systems that can transmit and receive V2V and V2I messages may use communication technologies other than LTE-V2X—such as dedicated short range communication (DSRC), WiFi, or bluetooth—the focus of this standard is on LTE-V2X (specified in ETSI Release 14).

6.1.1 LTE-V2X Communication

An LTE-V2X system uses the protocols specified in ETSI Release 14 and the IEEE Std 1609 Wireless Access in Vehicular Environments (WAVE) series of standards. Applications that use the SAE J2735 data dictionary (messages) may use LTE-V2X as illustrated in Figure 7. In North America, LTE-V2X uses the LTE band 47 using UARFCN 55140 with a 20 MHz channel width which corresponds to 5905 to 5925 MHz.

6 The SAE J3161/1 and SAE J2945/x applications listed in the figure have not completed ballot process at the time of this document's publication.

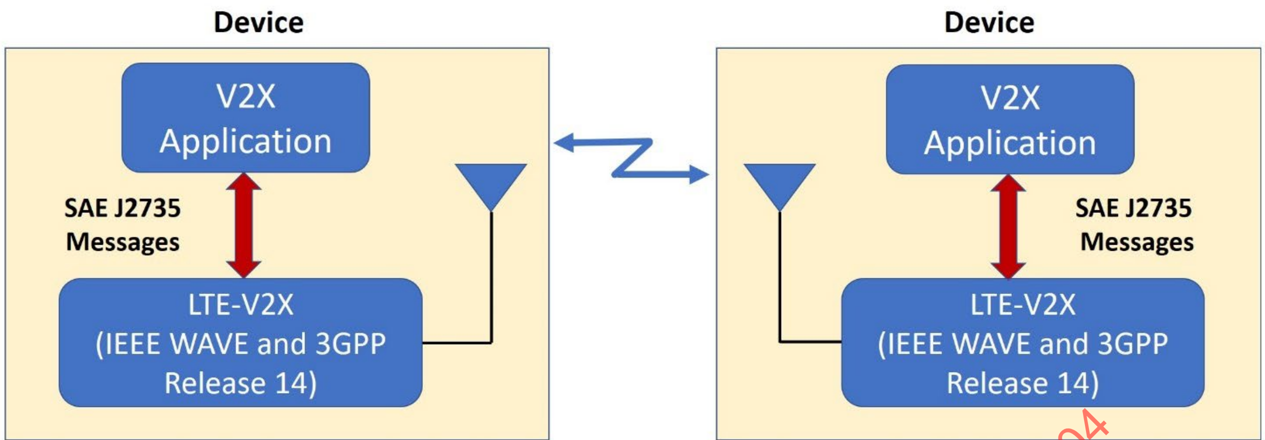

Figure 7 - Use of LTE-V2X for SAE J2735 message set

6.1.2 WAVE Standards Overview

The WAVE standards were developed to support low latency data exchange. The reference LTE-V2X protocol stack and corresponding ETSI and WAVE standards are shown in Figure 8. The automotive industry, through SAE International, ETSI, and IEEE, has done considerable work in defining the applications, the message/facilities layer, security services, and the transport/networking layers. LTE-V2X leverages all of the existing standards in these layers and just replaces the PHY and the MAC (commonly called the access layers) from ETSI to provide the end to end solution. As illustrated by Figure 8, LTE-V2X uses the upper layer WAVE standards for security services (IEEE Std 1609.2) and transport/networking (IEEE Std 1609.3). As shown in Figure 7, SAE J2945/x applications and/or a corresponding application layer reside above the LTE-V2X protocol stack shown in Figure 8.

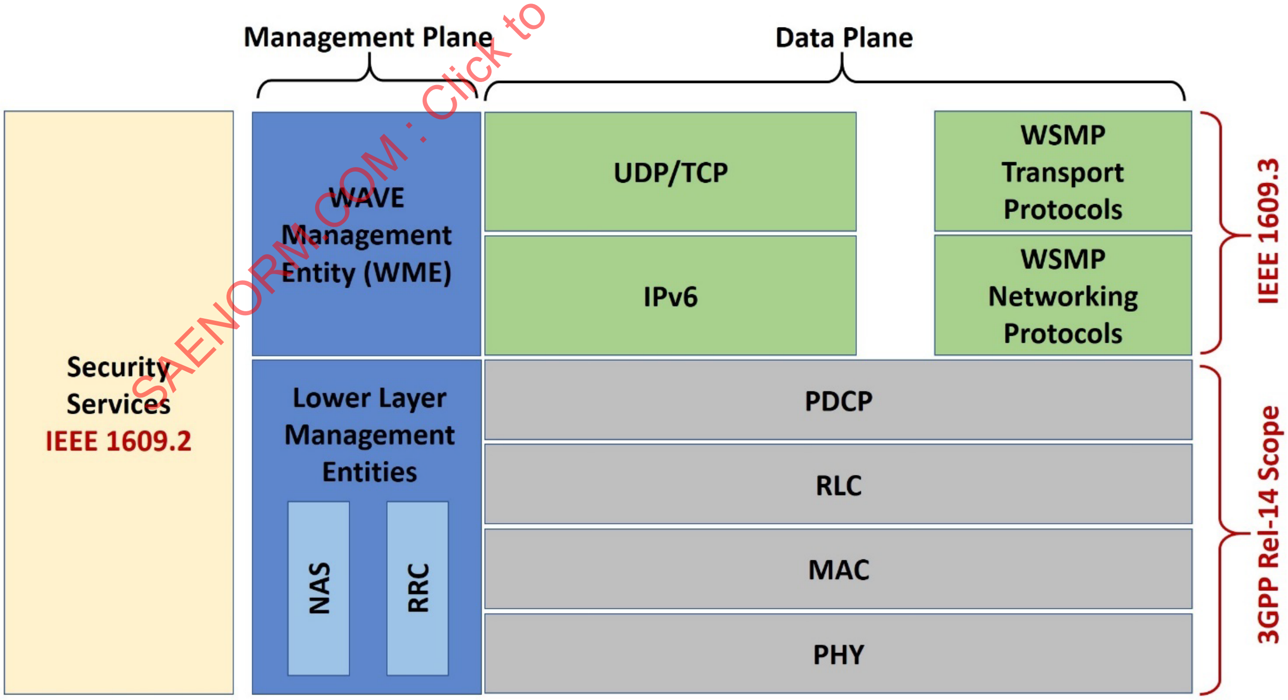

Figure 8 - LTE-V2X protocol stack

a. IEEE Std 1609.2, WAVE - Security Services for Applications and Management Messages. This standard specifies two primary security features: the cryptographic signing and validation of messages, which enables verification that the information being received is from a trusted sender, and the encryption/decryption of messages, which prevents an unintended recipient from obtaining the application data.

b. IEEE Std 1609.3, WAVE - Networking Services. This standard enables the exchange of data at the network and transport layers using either the WAVE short message protocol (WSMP) or IPv6. Services may be advertised by a Provider using a WAVE service advertisement, or data may be exchanged directly without advertisement on a pre-determined channel.

c. IEEE Std 1609.12, WAVE - Identifier Allocations. This standard describes identifiers used in WAVE standards (e.g., PSID, Ethertype). PSID values allocated to date for specific application areas (e.g., V2V safety and awareness) are included.

d. ETSI Release 14 - Wireless LAN MAC and PHY Specifications. This standard specifies the medium access control (MAC) and physical (PHY) layers.

6.1.3 Provider Service Identifier (PSID)

The Provider Service Identifier is specified in WAVE standards, with allocated values published in https://standards.ieee.org/products-services/regauth/psid/public.html. A PSID value identifies an application specification (e.g., one or more SAE SAE J3161/1 standards). The PSIDs used to support applications or services corresponding to the messages in the SAE J2735 data dictionary are the primary focus in this standard. PSIDs used for the WSA and testing purposes are also included because those PSIDs are also relevant to SAE J2945/x standards.

A PSID is an integer number with a value from 0 to 270549119 (0x10-20-40-7F, where “0x” indicates hexadecimal, or hex, notation). Each allocated PSID value is assigned to an organization that is responsible for specifying the application behavior (protocol) for the application associated with that PSID. The PSID is allocated from the same number space as the ITS Application Identifier (ITS-AID) used in other ITS standards. A common registration service for the PSID and ITS-AID is foreseen.

PSIDs have multiple uses as specified in IEEE Std 1609.3 and IEEE Std 1609.2. First, WSMP delivers received transport layer service data units (aka application (protocol) data units) to higher layer entities based on the PSID value contained in the destination address (port number) field of the transport layer header. Second, PSIDs are included in digital certificates to identify the application whose signed secured protocol data units the certificate is used to authenticate. Third, an application layer may use the PSID value in the process of decoding messages and distributing the corresponding contents to one or more applications.

6.2 Applications and Services

LTE-V2X uses 5905 to 5925 MHz band with a 20 MHz channel width, designated LTE band 47 using UARFCN 55140 by ETSI and Channel 183 by IEEE, for different traffic types including V2V, V2I, and I2V. The LTE-V2X uses cases include, but are not limited to, data exchange using SAE J2735 message. Several LTE-V2X use cases are introduced in this section. The selected use cases are representative, and not intended to be exhaustive. Table 1 lists different applications that LTE-V2X supports on UARFCN 55140 with a 20 MHz channel width. The “source and destination device” column indicates the dominant type of traffic on this channel for each application, e.g., I2V means most of the traffic will flow from RSUs to OBUs. A given application or protocol may require a small amount of source-to-destination traffic that does not conform to this column. For example, on an application dominated by I2V traffic, a vehicle OBU may occasionally transmit to RSU (e.g., request initiation of the service, or to send an acknowledgment packet). The source and destination are defined as follows:

- V: Vehicle (OBU)

- I: Infrastructure (RSU)

In Table 1, the “techncial report” column identifies the SAE and IEEE standard that includes the application.

Table 1 - Supported messages/applications in LTE-V2X

Message	Source and Destination Device	Technical Report[7]
BSM	V2V	SAE J3161/1
RSA	V2V	SAE J2945/2
EVA	V2V	SAE J3161/1
BSM (SAW content)	V2V	SAE J2945/2
SPAT	I2V	SAE J2945/B
MAP	I2V	SAE J2945/A
RTCM	I2V	SAE J2735
RWM	I2V	SAE 2945/3
WSA	I2V	IEEE 1609.3
RSM	I2V	SAE J2945/4
SSM	I2V	SAE J2735
SRM	V2I	SAE J2735

Infrastructure-based applications may use WSMP or IP to exchange data. Infrastructure can be licensed to operate from a single fixed location or may move between fixed locations where it operates. Use cases for both advertised services and broadcast services are described in this section.

6.2.1 Advertised Services

The WAVE service advertisement (WSA) is used to advertise one or more services (each identified within the WSA by a PSID). If an OBU wants to participate in the service identified by a PSID, it may use the parameters contained in the WSA (e.g., transmit power and data rate; for IP-based services, the IPv6 service parameters) to access the service. One device may transmit multiple WSAs to offer services of different criticality (e.g., an RSU may transmit one WSA every 100 ms and a different WSA once per second). WAVE standards offer two communication protocol options: (1) internet protocol (IP), and (2) WAVE short message protocol (WSMP). This section introduces IP- and WSMP-based applications and block diagrams of different advertised services.

6.2.1.1 IP-Based Advertised Services

General packet data, such as that used for SCMS certificates, may use a standard internet protocol (IPv6) protocol stack. Each device using IP must have at least one IP address. IP provides the ability to route information through a network to a destination IP address, making it suitable for communicating between an OBU and an infrastructure device not located at the roadside, e.g., a certificate authority. The transmission control protocol (TCP), running over IP, provides session-based reliability features such as data error recovery.

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[7] At the time of publication of this document, some of the documents listed in the “technical report” column of this table are works-in-progress.

6.2.1.2 WSMP-Based Advertised Services

LTE-V2X message may be sent over the WAVE short message protocol (WSMP), which is optimized for delivering point to point unicast and broadcast messages with low latency and low overhead. WSMP is a “best-effort” service, providing no error checking, acknowledgments, or multi-hop routing.

For applications requiring enhanced control of the over-the-air properties of their transmitted messages, WSMP allows control of transmitted power and data rate on a message-by-message basis. This could be used, for example, in support of congestion control: a lower transmitted power or a lower data rate reduces interference with other devices at the expense of reduced propagation range. Besides, WSMP allows the dissemination of channel load information that may be used in congestion control. The format and processing of this information are expected to be specified in SAE Standards.

6.2.1.3 Local Advertised Service

Local services are services that are originated by the RSU. After receiving a WSA on UARFCN 55140 with a 20 MHz channel width, the OBU can start exchanging application data. This data/message exchange may be IP or WSMP and is shown in Figure 9. An example of this service type could be electronic toll collection or weigh-station bypass.

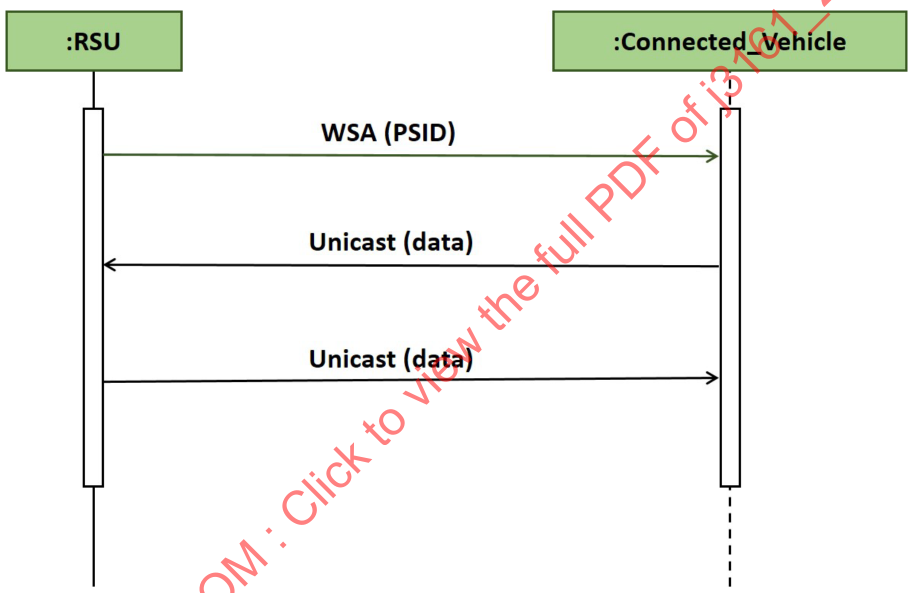

Figure 9 - Local advertised service

6.2.1.4 Separate Provider and Advertiser

In some cases, the advertisement of service and the providing of a service correspond to different RSUs. The advertiser RSU broadcasts the WSA, and the provider RSU exchanges data with the connected vehicle/OBU as shown in Figure 10. For this special case, the provider is identified in the WSA by the provider’s MAC address, and local advertised services can be supported with this model.

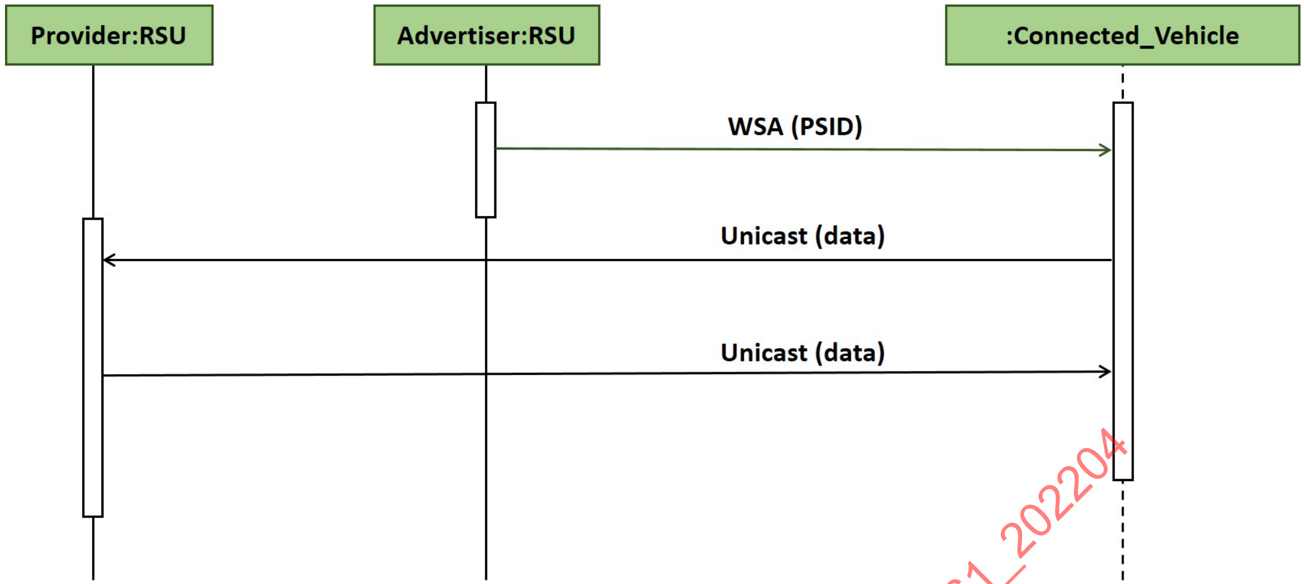

Figure 10 - Separate provider and advertiser

6.2.2 Broadcast Services

6.2.2.1 I2V Broadcast Services

An RSU may also provide information via simple broadcast messages as shown in Figure 11. In this case, the RSU broadcasts messages on UARFCN 55140 with a 20 MHz channel width. Examples of this service type may include applications that use SPAT messages.

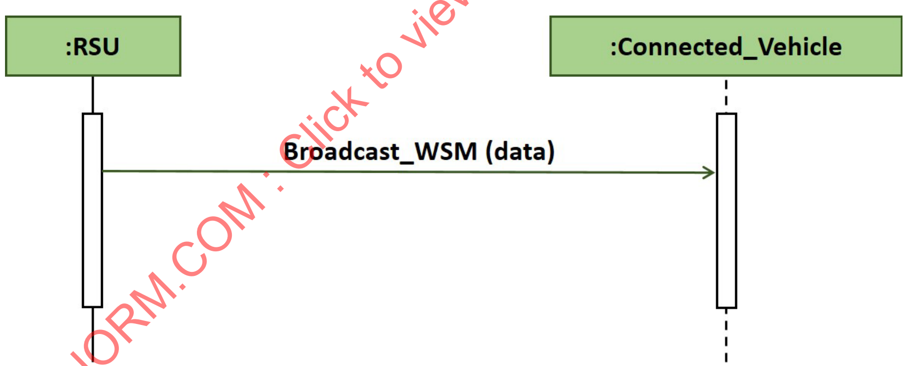

Figure 11 - I2V broadcast service

6.2.2.2 V2V Broadcast Services

The V2V broadcast use case is analogous to the unadvertised RSU-based use case specified in 6.2.2.1. This standard provides only the simple use case of broadcast messages between OBUs and between OBUs and devices. WSMs are typically used for broadcast data exchange between connected vehicles (or between connected vehicles and devices, such as devices used to support VRUs), as shown in Figure 12. Important examples of this use case are specified in SAE J3161/1.

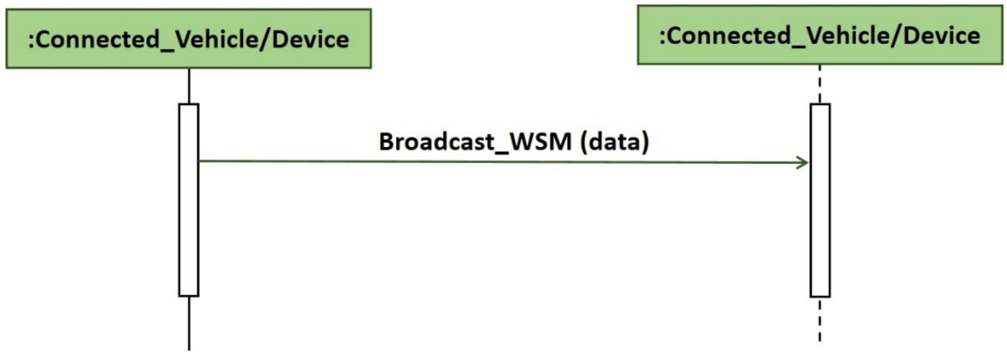

Figure 12 - V2V broadcast service

7. LTE-V2X FUNCTIONALITY

This section describes the physical layer, channel access procedure, and unicast addressing. It also describes how repetitive collisions can be avoided in LTE-V2X.

7.1 LTE-V2X

As it is stated in 5.3, this document focuses on LTE-V2X PC5 mode 4, where it is referred to as just LTE-V2X. LTE-V2X uses single-carrier frequency-division multiple access (SC-FDMA) and supports both 10 MHz and 20 MHz channels. Each channel is divided into resource blocks (RBs), sub-channels, and subframes. Each subframe has a duration of 1 ms and each RB consists of 12 subcarriers of 15 kHz (180 kHz wide in frequency). Subcarriers have 14 symbols in each subframe, where four of these symbols are dedicated to the transmission of demodulation reference signals (DMRSs) to address the doppler effect at high speed. In LTE-V2X, a sub-channel is composed of a group of adjacent RBs in the same subframe. In this document, each sub-channel consists of ten RBs.

The LTE-V2X transmits data in the form of transmit blocks (TBs) over the physical sidelink shared channel (PSSCH) and exchanges the link control information in form of sidelink control information (SCI) blocks over the physical sidelink control channel (PSCCH). An SCI consists of MCS, RBs, and resource reservation intervals information. There are two possible schemes for sub-channelization in LTE-V2X: (1) adjacent PSSCH+PSCCH scheme, and (2) nonadjacent PSSCH+PSCCH scheme. However, the adjacent PSSCH+PSCCH scheme is used for the purpose of implementation and is the focus of this document.

In the adjacent PSSCH+PSCCH scheme (as shown in Figure 13), TBs and SCI are transmitted over the adjacent RBs. The SCI occupies the first two RBs of the sub-channel, and the TB occupies the RBs following the SCI in the sub-channel. For the cases where the size of the TBs is greater than a maximum allowed number of RBs in a single sub-channel, the transmitter allocates more than one sub-channel for packet transmission. The modulation scheme for TBs can be either QPSK or 16-QAM, whereas SCI modulation scheme is always QPSK.

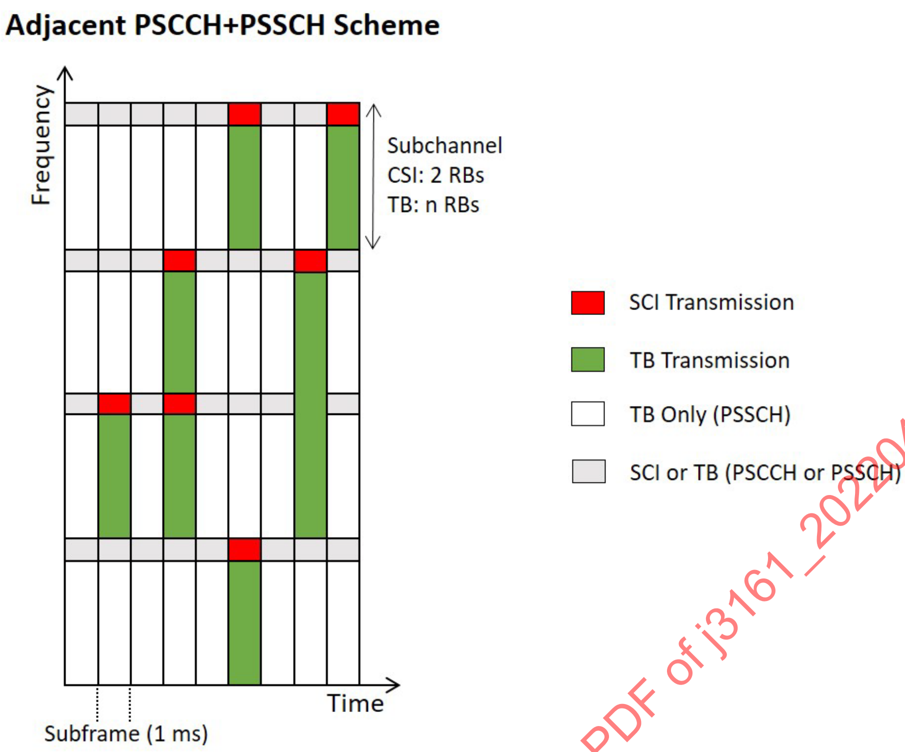

Figure 13 - LTE-V2X sub-channelization

7.2 Half-Duplex

LTE-V2X is based on half-duplex and the transmitter cannot send and receive data at the same time. This means when a transmitter is in transmission mode, it cannot sense the channel and receive packets from the other transmitters. On the other hand, if two or more vehicles select and reserve the same resources for their transmission, the repetitive collision may happen as the transmitters reselect the same resources with probability 0.8 (SAE J3161/1). In 7.3.3, it is explained how LTE-V2X addresses the repetitive collision.

7.3 Channel Access in PC5 Sidelink

There are two methods of channel access in LTE-V2X: (1) semi-persistent scheduling (SPS), and (2) one-shot transmission. These channel access methods are described in 7.3.1 and 7.3.2.

7.3.1 Semi-Persistent Scheduling (SPS)

In LTE-V2X mode 4, the transmitter can access the channel in the absence of the cellular tower. In this communication mode, a transmitter uses sensing-based semi-persistence scheduling (SPS) algorithm to reserve the channel and transmit the data. In this scheme, the transmitter senses the channel for 1 second (referred to as sensing window) and reserves the selected sub-channels (as described below) for a number of consecutive transmissions. The number of consecutive transmissions is set by resource reselection counter (ResourceReselectionCtr), which is a random number between SPSCtrMin and SPSCtrMax. After each transmission in the SPS flow, ResourceReselectionCtr is decremented by one, and when it equals zero, new radio resources should be selected and reserved with a probability of 1 - P, where P can be set between 0 and 0.8. In this document, P is set to 0.8.

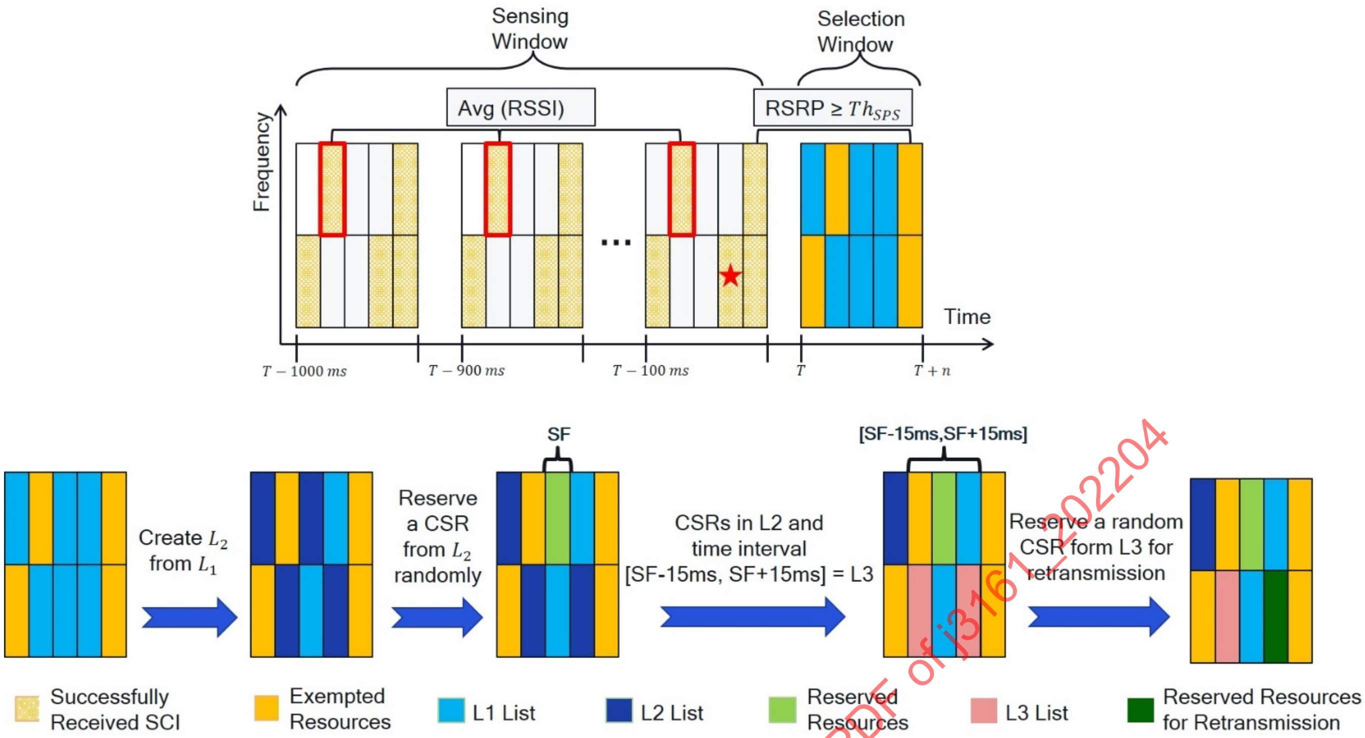

Figure 14 - Illustration of semi-persistent scheduling (SPS) algorithm

In case the data cannot be fitted in the reserved sub-channel(s), the transmitter must compete over the medium again. To decrease the probability of packet collision, SPS includes packet transmission interval in SCI, which enables the other vehicles to estimate the time of the availability of the radio resources. Figure 14 demonstrates the utilized SPS algorithm of resource selection in LTE-V2X MAC layer architecture. To select a sub-channel, the transmitter makes a list, L1, of candidate subframe resources (CSRs) in the selection window [T; T + n], where T corresponds to the time that the transmitter requires the radio resource to perform transmission and n is the maximum tolerable latency. The list L1 includes all the CSRs in the selection window except the ones that will be utilized.

A CSR is recognized as utilized under two conditions:

1. In the sensing window, the host transmitter has received an SCI from a remote transmitter indicating that the remote transmitter will utilize this CSR in any of its reselection counter transmissions.

2. The average measured reference signal received power (RSRP) over the RBs utilized to transmit the packet associated with the SCI is higher than a given threshold. The threshold depends on the priority of the packet. If the vehicle receives multiple SCI from an interfering transmitter on a given CSR, it will use the latest received SCI to estimate the average RSRP.

The transceiver will exclude a CSR from L1 if it met both above conditions. For example, in Figure 14, the CSR distinguished with red star is not excluded from the L1 list as it meets the first condition but not the second one. Moreover, due to the half-duplex transmission mode, the transceiver cannot either receive any packet or sense the channel during the transmission time; hence, it must exclude all the CSRs of subframe F in the selection window if transceiver was transmitting during any previous subframe F-100*j (j ϵ N, 1 ≤ j ≤ 10).

After excluding the utilized CSRs, the L1 must include at least 20% of CSRs in the selection window. Otherwise, the transmitter will do the procedure with a 3 dB increment in Th_{SPS} until 20% target is met.

After forming the L1 list, the transmitter creates another list of CSRs, L2, which is a subset of L1 and includes exactly 20% of the selection window CSRs with the lowest average received signal strength indicator (RSSI) over last ten intervals. Finally, the transmitter randomly reserves one of the CSRs in L2 for its next ResourceReselectionCtr transmissions. This behavior helps avoid collisions between devices at the resource selection stage and gives more protection to devices using an SPS flow for transmission.

The LTE-V2X can enable retransmission to increase the reliability and communication range by transmitting a package twice. To search for the required CSR for retransmission purposes, the SPS constitutes a third list, L3 of CSRs from L2, which falls within SF ±15 ms interval, where SF refers to the scheduled sub-frame for the packet transmission. The transmitter reserves a random CSR from L3 for redundant transmission and maintains it for the following ResourceReselectionCtr retransmissions.

7.3.1.1 Two Flows Limit

In LTE-V2X PC5 mode 4, each transmitter can support two SPS flows at the same time (ETSI TS 136 300). Two SPS flows should be used for two higher bandwidth-consuming traffic flows, and extra traffic flows will be transmitted through the one-shot transmission. The mapping of traffic flows to SPS flows versus the use of the on-shot transmission is an implementation design decision.

7.3.1.2 Available Periodicities

The periodicity of SPS resource reservation can be 20 ms, 50 ms, 100 ms, 200 ms, 300 ms, 400 ms, 500 ms, 600 ms, 700 ms, 800 ms, 900 ms, and 1000 ms.

7.3.2 One-shot

One-shot transmission is mainly used for critical event-based packet transmissions (e.g., critical BSM). However, it can be used for periodic packets as well. The resource selection procedure is exactly the same as SPS, but the transmitter does not reserve the selected resources for future transmission. This means that the reselection counter packet is zero in one-shot transmission. As explained in 7.2, one-shot transmission can be used to address the repetitive packet collision in LTE-V2X as well.

7.3.3 SPS + One-Shot

As it is explained in 7.2, half-duplex and reselection of reserved resources in SPS flow may cause repetitive packet collision when the transmitter uses SPS flow for periodic packet transmission. To address this issue, LTE-V2X shall use one-shot transmission along with SPS flow to avoid repetitive packet collision.[8]

For this purpose, the transmitter shall use another counter for one-shot transmission (OneShotCtr) along with ResourceReselectionCtr. The former is chosen uniformly between OneShotCtrMin and OneShotCtrMax and the latter is chosen uniformly between SPSCtrMin and SPSCtrMax, respectively. After each packet transmission using SPS flow (or retransmission being HARQ enabled), both ResourceReselectionCtr and OneShotCtr are decremented by one.

When the OneShotCtr becomes zero and ResourceReselectionCtr is not equal to zero, the transmitter shall skip the SPS flow and the transmission is made using the one-shot transmission. After one-shot transmission, OneShotCtr shall be set to a new random number. The ResourceReselectionCtr also shall not be decremented if a one-shot transmission is made.

When ResourceReselectionCtr becomes zero and OneShotCtr is not equal to zero, the transmitter shall determine whether the current resources are going to be kept using the probResourceKeep-r14. If the device keeps the current recourses, then only ResourceReselectionCtr shall be reset to another random number between SPSCtrMin and SPSCtrMax. If, however, the resources are not going to be kept and the transmitter decides to select other resources, both ResourceReselectionCtr and OneShotCtr shall be set to new random values after selecting the new resources.

[8] Note that SPS + one-shot shall be applied to all SPS flows generated by LTE-V2X radio (e.g., OBU and RSU).

If both ResourceReselectionCtr and OneShotCtr become zero simultaneously, the transmitter shall (1) transmit the next packet using one-shot transmission, (2) then determine whether the current SPS resources are going to be kept using the probResourceKeep-r14, (3) based on the decision selects new resources or keeps the current resources, and (4) reset both counters. The resource selection for the one-shot transmission interleaved with SPS transmissions as defined above is based on the same PPPP and PDB as the associated SPS. The resources used for one-shot and SPS transmission respectively are always non-overlapping and determined through a separate selection procedure.

7.4 ProSe per Packet Priority (PPPP) for V2X Communication

In LTE-V2X, each packet generated by the application layer is associated with a certain priority value, called ProSe per packet priority (PPPP). PPPP is an integer number and can range from 1 to 8 where packets with lower PPPP values have higher priority. As it is explained in Section 8, PPPP can be used to determine the packet delay budget (PDB), CR limit, and RSRP threshold for accessing the channel.

7.5 Destination Layer-2 ID (Normative)

This section defines LTE-V2X broadcast and unicast addressing.

7.5.1 Broadcast Addressing

The mapping from IEEE Std 1609.3 application PSID to destination Layer-2 ID is provided to help filter unwanted broadcasts. The mapping shall be as follows: unless the application specification specifies otherwise,[9] for the PSIDs less than 65536 (0xFFFF or lower), the destination Layer-2 ID for broadcast messages will be set to PSID with the most significant byte set to 0x00.

Examples:

- If is PSID 0x01 (electronic fee collection) then the default destination Layer-2 ID will be set to 0x000001.
- If PSID is 0x21FA, then the destination Layer-2 ID for the broadcast messages will be set to 0x0021FA.
- If PSID is 0x87, then the destination Layer-2 ID for the broadcast message will be set to 0x000087.

For PSIDs greater than 65535 (greater than 0xFFFF), the mapping between PSID and destination Layer-2 ID is left to be determined by the other standards and the most significant byte shall be set to anything other than 0x00. Note that an application with a given PSID may use multiple different destination Layer-2 IDs. If application PSID is less than 65536, then one of the destination Layer-2 IDs may be as defined by the mapping above.

7.5.2 Unicast Addressing

V2X applications may employ unicast in both sender and receive-side filtering in addition to, or in lieu of, application layer filtering. If unicast is required, an application specification must include requirements pertaining to expected unicast behavior. Note that Layer 2 filtering is optional; thus, its use and application behaviors must be specified in the V2X application specification.

Sending via Layer 2 unicast is performed per IEEE Std 1609.3 Annex M, in which the wave management entity (WME) indicates to the LTE-V2X radio the destination Layer 2 ID. LTE-V2X implementations are expected to include the internal primitives for the application to configure the WME with Layer 2 destination ID information. The primitive AS-DATA.req from the WME to the LTE-V2X radio shall include the value of the V field to indicate whether the transmission is unicast or broadcast.

Note that the application specification dictates for unicast whether the transmissions are sent using RLC acknowledged mode (AM) or RLC unacknowledged mode (UM) along with expected receiver responses.

[9] For example, in SAE J3161/1, destination Layer-2 ID for BSM does not follow the mapping and is set to 0xFFFFFF while the PSID is 0x20.

Reception of V2X unicast messages is performed per IEEE Std 1609.3 Annex M. In this case, the receiver implementation must instruct the LTE-V2X radio to pre-filter at the MAC layer and then only relay the message via the AS-DATA.ind primitive to WSMP if it is the intended recipient. The internal primitives supporting this capability are implementation-specific. Implementations are expected to include Layer 2 ID filtering information to the WME which in turn provides it to the LTE-V2X radio for filtering.

8. PC5 SIDELINK PROFILES AND COMMUNICATION PARAMETERS

This section describes how V2X traffic is divided into different traffic families and provides PC5 sidelink communication parameters for these traffic families.

8.1 Different Traffic Classes

V2X messages are divided into different traffic families based on the priority and direction of the messages. As shown in Table 2, V2X messages are divided into safety and mobility services. Safety service messages are those that are used in safety applications (e.g., BSM, SPaT, MAP) and mobility service messages address other ITS functions. Although V2X communication consists of communication of vehicles with other vehicles (V2V), infrastructure (V2I and I2V), and pedestrians (V2P[10]), this standard focuses on defining V2V, V2I, and I2V traffic. Hence, V2X messages are dividing into seven traffic families as described below. Application standards should comply with the minimum PPPP value for different traffic classes which is defined in Table 2. Application standards can define higher PPPP values than what is defined in Table 2.

Table 2 - Different traffic families and corresponding priority

Traffic Type	Safety Services				Mobility Services		
Traffic Families	Critical V2V	Essential V2V	Critical V2I - I2V	Essential V2I - I2V	Transactional	Low Priority	Background
Traffic Direction	V2V		V2I - I2V		V2I - I2V		
Minimum PPPP	2	5	3	5	6	7	8
Minimum PDB	20 ms	100 ms	100 ms	100 ms	100 ms	100 ms	100 ms
Example Messages	Critical BSM, EVA	BSM	RSM, MAP	SPaT	SSM/SRM	TIM	TCP, UDP

8.1.1 Critical V2V Traffic

This traffic has the highest priority among all V2X messages. High priority and event-based V2V messages (e.g., critical BSM) are included.

8.1.2 Essential V2V Traffic

This traffic includes V2V safety messages (e.g., BSMs) for which no critical event flag is set and has a lower priority than critical V2V messages.

8.1.3 Critical V2I - I2V Traffic

This traffic has the highest priority among all the V2I - I2V messages. High priority safety I2V messages (e.g., RSM and MAP) are included.

8.1.4 Essential V2I - I2V Traffic

This traffic includes V2I - I2V safety messages (e.g., SPaT) but has a lower priority than critical I2V - V2I messages.

[10] This standard does not recommend deployment of V2P traffic in LTE band 47 using UARFCN 55140 with a 20 MHz channel width.

8.1.5 Transactional Traffic

This traffic has the highest priority among the mobility service messages and includes bi-directional message exchanges between vehicle and infrastructure (e.g., SSM/SRM).

8.1.6 Low Priority Traffic

This traffic consists of low priority V2I and I2V messages for mobility services (e.g., TIM).

8.1.7 Background Traffic

This traffic has the lowest priority among all the V2X messages. TCP, UDP, PDM, and PVD data exchange messages are in this category.

8.1.8 Associating Traffic Families to Message Types (Informative)

This document recommends a mapping between the messages types and traffic families which is indicated in Table 3.

Table 3 - Associating traffic families to message types

Message	Source and Destination Device	Technical Report[11]	Traffic Family	Recommended PPPP
BSM	V2V	SAE J3161/1	Critical/Essential V2V	2, 5
EVA	V2V	SAE J3161/1	Critical V2V	2
SPAT	I2V	SAE J2945/B	Essential I2V	5
MAP	I2V	SAE J2945/A	Critical I2V	3
RTCM	I2V	SAE J2735	Essential I2V	5
RWM	I2V	SAE 2945/3	Low Priority	7
WSA	I2V	IEEE 1609.3	Essential I2V	5
RSM	I2V	SAE J2945/4	Critical I2V	3
SRM[12]	V2I	SAE J2735	Critical V2I/Transactional	3, 6
SSM[13]	I2V	SAE J2735	Critical I2V/Transactional	3, 6

11 At the time of publication of this document, some of the documents listed in the “technical report” column of this table are works-in-progress.

12 PPPP 3 is used for signal preemption requests (e.g., emergency vehicles) and that PPPP 6 is used for signal priority requests (e.g., transit, commercial vehicles).

13 PPPP 3 is used to signal status message to the signal preemption requests (e.g., emergency vehicles) and that PPPP 6 is used to send signal status message to signal priority requests (e.g., transit, commercial vehicles).

8.2 Preconfiguration Parameter Sets (Normative)

Preconfiguration parameters provide a wide variety of parameters that are used to configure the behavior of the LTE-V2X radio. These parameters are split into multiple areas and each set of parameters help configure a specific area including, but not limited to, channel bandwidth, maximum transmit power, limits on modulation and coding schemes, priority handling, limits on sub-channel sizes and the number of sub-channels, and lastly channel busy ratio and channel access limits (CR-limit). The preconfiguration parameters can be effectively broken down into six sets:

1. General parameter set.

2. Common RX and TX pool configuration set.

3. RSRP-based exclusion parameter set.

4. Speed-based configuration set.

5. Channel busy ratio (CBR) configuration set.

6. Priority-based configuration set.

Sections 8.2.1 to 8.2.6 describe these six sets of parameters.

8.2.1 General Parameter Set

This set of parameters is used to configure high-level parameters.

- Maximum number of supported frequencies for this particular configuration.

- Frequency of operation.

- Overall maximum transmit power.

- Configured channel bandwidth.

8.2.2 Common RX and TX Pool Configuration Set

This set of parameters is used to configure general transmission and reception pool configurations.

- Maximum number of RX and TX pool configurations.

- Subframe bitmap for configuration of subframes enabled for LTE-V2X communication.

- Sub-channel configuration: The size of each sub-channel, number of sub-channels, and start resource block of the sub-channel.

- Maximum transmit power for the configured transmit pool. This cannot exceed the maximum configured power in the general parameter set.

- Type of synchronization source.

8.2.3 RSRP-Based Exclusion Parameter Set

These parameters are used to set RSRP thresholds for resource exclusion. In LTE-V2X, a transmitting device transmits periodic messages using an SPS flow. A receiving device that successfully decodes the control portion of these payloads will know the resources that carry the data portions. It then performs an RSRP measurement on the data portions of the payloads and marks the future resources of the same SPS flows in an excluded list if the measured RSRP exceeds the configured RSRP parameters. When the receiving device needs to perform an LTE-V2X, transmission it will randomly choose a resource from a list of resources in which all the above resources are already excluded.

This helps avoid collisions between devices at the resource selection stage and gives more protection to devices using an SPS flow for transmission. As an additional level of protection, the RSRP thresholds are configured based on the priority of packets, giving the flexibility to protect higher-priority packets at the cost of lower priority packets in extremely congested scenarios if a need ever arises. V2X applications shall comply with the RSRP threshold for different PPPP in Table 5.

8.2.4 Speed-Based Configuration Set

This set of parameters is used to configure transmission parameters based on the speed threshold.

The final transmission parameters are chosen based on the intersection of speed-based and congestion-based parameter sets.

- Configuration of a speed threshold.
- Parameters within each of speed configurations entail:
    - Minimum and maximum MCS.
    - Minimum and maximum sub-channels.
    - Retransmission configuration.
- There are two sets of transmission parameters:
    - The first set of parameters needs to be used when speed is above the configured threshold (see Table 7).
    - The second set of parameters needs to be used when speed is below the configured threshold (see Table 8).
- Speed threshold is 120 km/h.

8.2.5 Channel Busy Ratio (CBR) Configuration Set

This set of parameters is used to configure CBR levels and transmission parameters based on CBR levels.

- RSSI threshold above which a sub-channel will be considered occupied for channel busy ratio calculation.
- Maximum number of CBR configurations based on CBR levels.
- Each channel busy ratio configuration further helps configure:
    - CR-limit: Maximum number of sub-channels that can be used in one second for a given CBR.
    - Minimum and maximum MCS that can be used.
    - Minimum and maximum number of sub-channels that can be used.
    - Retransmission setting.

8.2.6 Priority-Based Configuration Set

This set of parameters configures priority configurations.

- Maximum number of priority configurations.
- For each priority configuration, it further allows configuration of the below elements:
  - Default CBR configuration to be used when there is not CBR measurement available.
  - A mapping from measured CBR range to a CBR configuration to be used when CBR measurement is available.

8.3 Common V2X System Parameters

The communication parameters in LTE-V2X are set based on the direction of the traffic. As it is indicated in Table 2, in this standard the V2X messages have three directional flow types (e.g., V2V, V2I, and I2V). Although three different parameter sets are defined based on the direction of the traffic, some parameters are common between all traffic flows. These parameters are described in Table 4.

- General parameter set (index elements from 1 to 13 in Table 4).
- Common RX and TX pool configuration set (index elements from 14 to 21 in Table 4).
- RSRP-based exclusion parameter set (index elements from 22 to 25 in Table 4).

Table 4 - LTE-V2X PC5 common communication parameters

Index	Pre-Configuration Parameter (3GPP Information Element)	Value	Explanation of Information Elements
1	maxFreqV2X-r14	1	Maximum number of carrier frequencies for which V2X PC5 Sidelink communication can be configured.
2	profile0x0001-r12	FALSE	Legacy from D2D, not needed for LTE V2X.
3	profile0x0002-r12	FALSE	Legacy from D2D, not needed for LTE V2X.
4	profile0x0004-r12	FALSE	Legacy from D2D, not needed for LTE V2X.
5	profile0x0006-r12	FALSE	Legacy from D2D, not needed for LTE V2X.
6	profile0x0101-r12	FALSE	Legacy from D2D, not needed for LTE V2X.
7	profile0x0102-r12	FALSE	Legacy from D2D, not needed for LTE V2X.
8	profile0x0104-r12	FALSE	Legacy from D2D, not needed for LTE V2X.
9	carrierFreq-r12	55140 (5915MHz)	ARFCN-ValueEUTRA-r9b (Channel 183 in IEEE 802.11).
10	maxTxPower-r12	EVA only: 33 dBm Other traffics: 20 dBm	Maximum allowed transmission power, P-max. This is the conducted transmit power, e.g., not including any antenna gain.
11	sl-bandwidth-r12	N100	Total number of RBs across 20 MHz (N100 -> 100).
12	tdd-ConfigSL-r12	None	Configuration specifying TDD uplink downlink configuration in case applicable. This is used for the case LTE PC5 sidelink is deployed in the same channel as LTE uplink in a TDD band in order to protect LTE base station uplink reception. Not currently applicable for LTE-V2X since there is no LTE network deployed in the 5.9 GHz spectrum, hence set to none.
13	reserved-r12	0000000000000000000	
14	maxSL-V2X-RxPoolPreconf-r14	1	Maximum number of RX resource pools for V2X PC5 sidelink communication. In this case, it is set to one pool only.