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SURFACE VEHICLE STANDARD

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

RATIONALE

Although the first version of this document defines common LTE-V2X design elements and radio profile for V2V, V2I, and I2V communication in 20 MHz channel, there are potential improvements in the LTE-V2X system that can boost the performance of the V2X applications. The new version of the document updates recommendations, improvements, and clarifications as needed by different V2X applications.

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1. SCOPE

This SAE Standard describes a reference system architecture based on LTE-V2X technology defined in the set of ETSI standards based on 3GPP 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 and IEEE 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
SAE J3268	Listing of Provider Service Identifiers and Associated Application Technical Reports

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 documents are from the set of ETSI standards based on 3GPP Release 14 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 136 201	Evolved Universal Terrestrial Radio Access (E-UTRA); LTE physical layer; General description (Release 14) [3GPP TS 36.201]
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]

ETSI TS 136 385	V2X services Management Object (MO) (Release 14) [3GPP TS 36.385]
ETSI TS 136 211	Evolved Universal Terrestrial Radio Access (E-UTRA); Physical channels and modulation (Release 14) [3GPP TS 36.211]

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

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	IEEE Standard for Wireless Access in Vehicular Environments - Security Services for Applications and Management Messages
IEEE Std 1609.3	IEEE Standard for Wireless Access in Vehicular Environments (WAVE) - Networking Services
IEEE Std 1609.12	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 (distribution), re-provisioning, and revocation of digital certificates (i.e., certificate management uses a PKI but its requirements boil down to applications and use cases in V2X).

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

3.4 CHANNEL

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

3.5 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).

3.6 DATA PLANE

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

3.7 DEVICE

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

3.8 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.

3.9 DRIVER

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

3.10 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).

3.11 HEAVY VEHICLE

Vehicles with a FHWA vehicle classification of 5 to 13.

3.12 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.

3.13 V2X INFRASTRUCTURE

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

3.14 V2X Vehicle

A vehicle equipped with devices enabling interoperable direct short-range broadcast communication using 3GPP-defined LTE-V2X Rel-14 PC5 mode to convey safety- and mobility-enhancing messages. The V2X vehicle defined and used in this standard does not include networked communications or commercial connected vehicle applications.

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 PUBLIC SAFETY VEHICLE

An equipped vehicle actively engaged in emergency response and announcing so to others. This type of vehicle is presumed to be equipped with an on-board unit specialized for public safety (“PSOBU”).

NOTE 1: When not engaged in public safety operations, the vehicle that had taken on this role reverts to the behaviors associated with its basic vehicle class and type.

NOTE 2: When an equipped vehicle is engaged in an emergency response, the BSM includes data frames and elements that provides information to nearby vehicles about the presence of public safety vehicle. These extra data frames and elements can be found in 5.1.5 of SAE J3161/1.

3.26 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.

3.27 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.

3.28 SAFETY VEHICLE

A vehicle used for emergency or incident management.

3.29 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.

3.30 SYNTAX

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

3.31 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)

3.32 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)

3.33 TRANSIT VEHICLE

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

3.34 User Equipment (UE)

3.35 Any device used directly by an end-user to communicate with other devices. In this document, UE is capable of LTE-V2X communication and refers to the LTE-V2X radio that is included both in OBU and RSU.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.

3.36 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
EARFCN	Evolved-UTRA Absolute Radio Frequency Channel Number
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
MTU	Maximum Transmission Unit
NHTSA	National Highway Traffic Safety Administration
NIST	National Institute for Standards and Technology

NTCIP	National Transportation Communications for ITS Protocols
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
PSC	Provider Service Context
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
TAM	Tolling Advertisement Message
TUM	Tolling Usage Message
TUMack	Tolling Usage Message Acknowledgement
TCP	Transmission Control Protocol
TIM	Traveler Information Message
TMDD	Traffic Management Data Dictionary
UE	User Equipment
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.

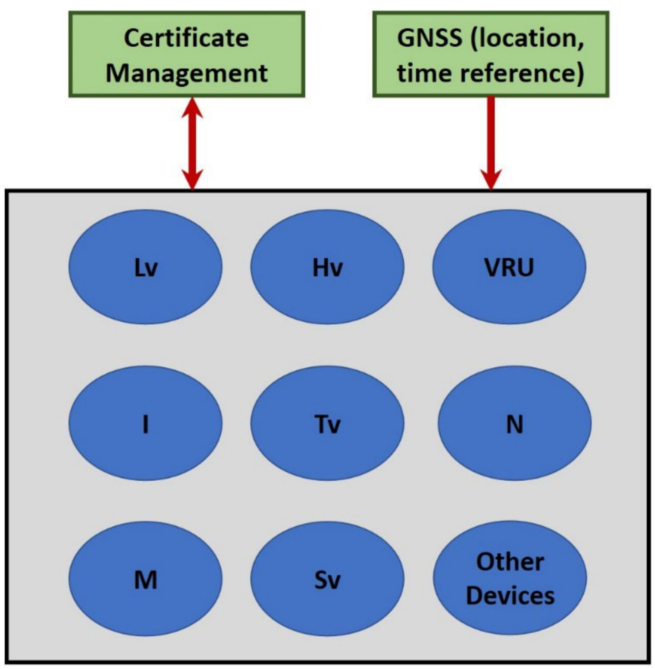

Figure 1 - Connected transportation (system of systems)

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.

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.

[2] Bidirectional arrow in mean bidirectional communication link.

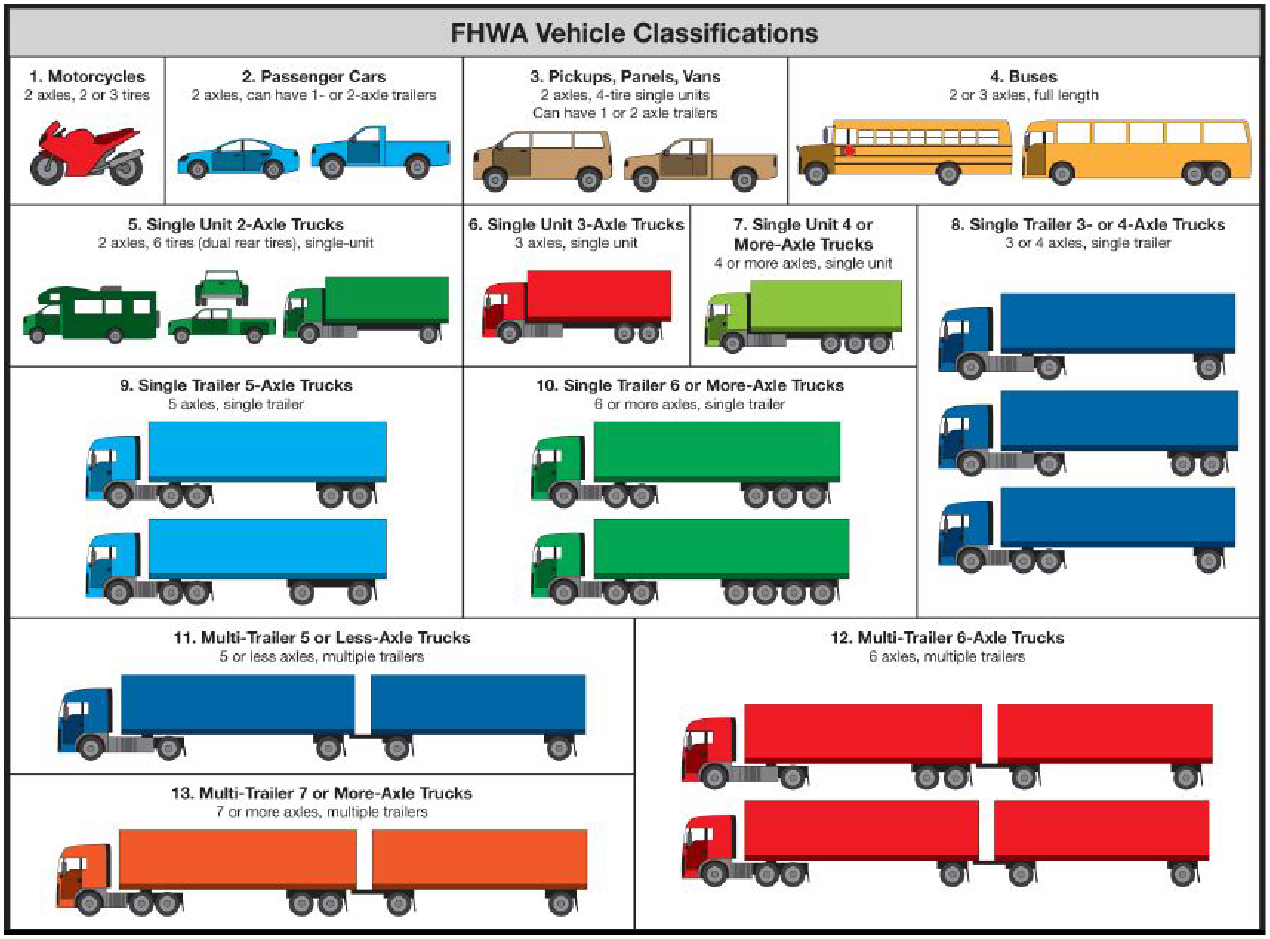

Figure 2 - Vehicle classification using FHWA 13 - category scheme

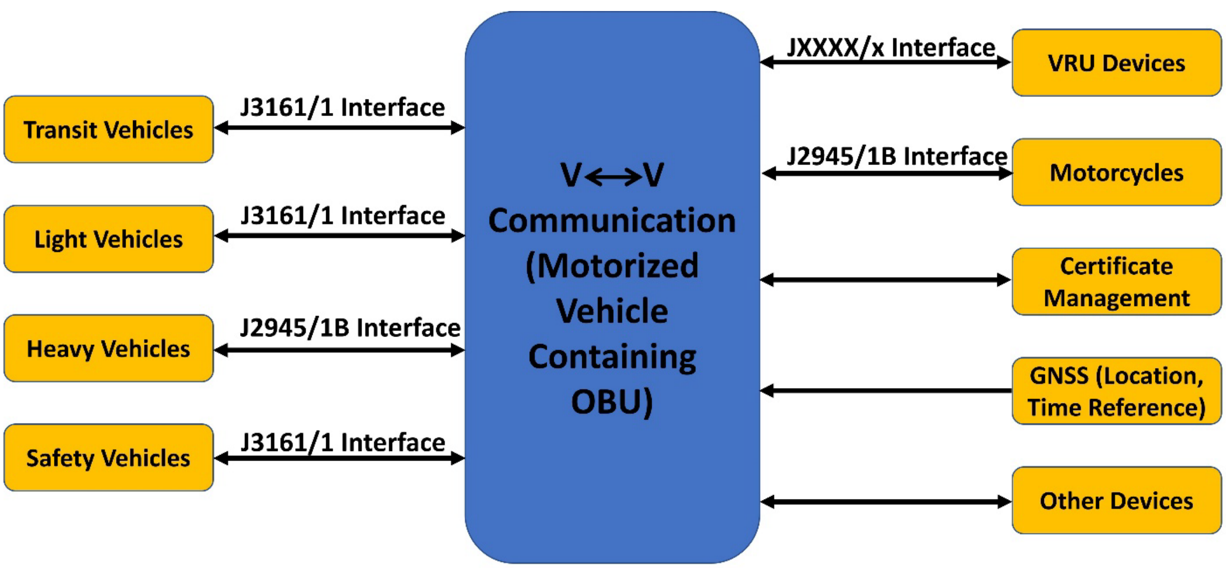

Figure 3 - Vehicle-to-vehicle (V2V) context diagram for LTE-V2X

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.

- 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.

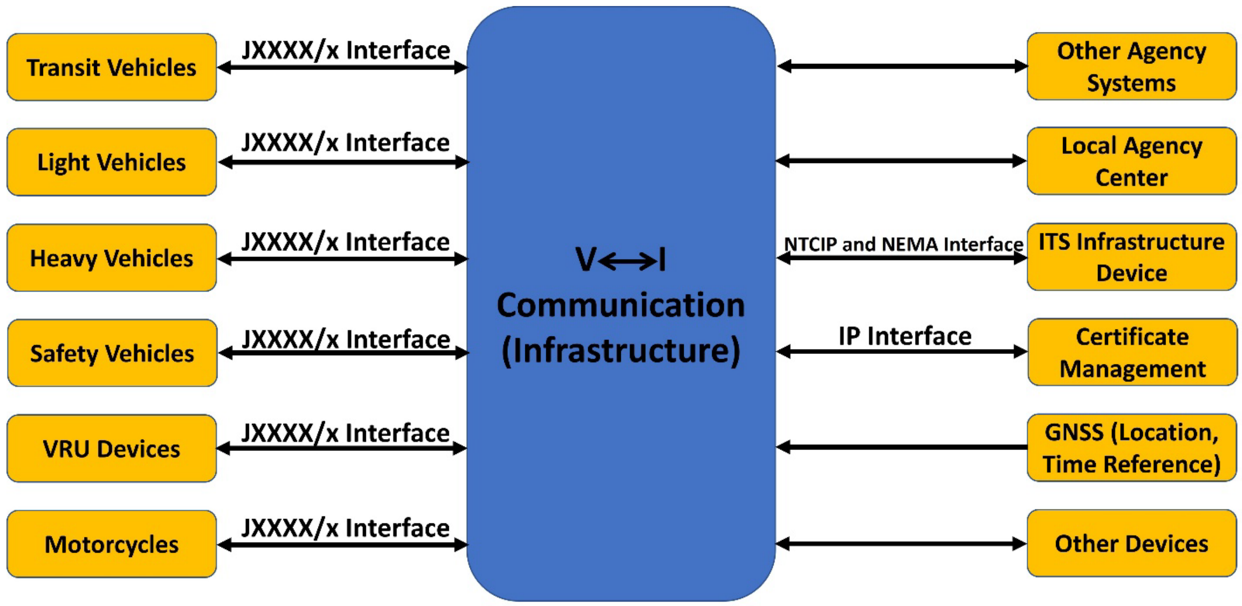

Figure 4 - Vehicle-to-infrastructure (V2I) context diagram[3]

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, roadside units, signal controllers, and other transportation regulating or monitoring devices.

5.3 LTE-V2X System Architecture

LTE-V2X is defined by the set of ETSI standards based on 3GPP Release 14, 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 PC5 Sidelink (Mode 4) communication which is specified in the set of ETSI standards based on 3GPP Release 14.

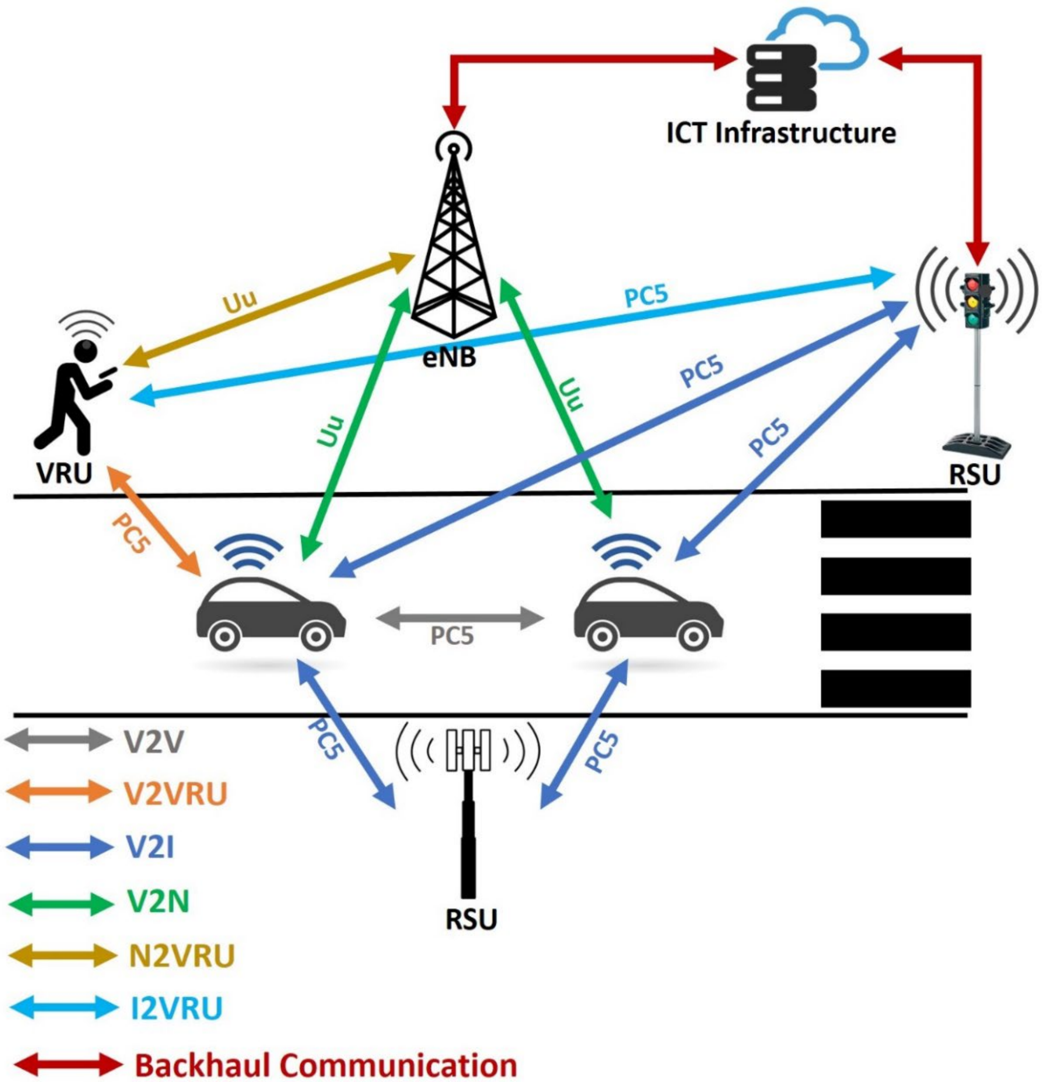

Figure 5 - LTE-V2X system architecture

5.4 V2X Communication Interface

The Non-IP V2X messages shall be transmitted over the LTE-V2X interface as a wireless access in vehicular environments (WAVE) short message (WSM) using the WAVE short message protocol (WSMP) specified in IEEE 1609.3 without IEEE 802.3 ethertype.

The IP messages shall be transmitted over LTE-V2X interface using IPv6 specified in IEEE 1609.3 without IEEE 802.3 ethertype.

The PICS statements from Table D.4 of IEEE 1609.3 shall be applied.

V2X messages shall be transmitted in LTE band 47 using EARFCN 55140 with a 20 MHz channel width[5]. This corresponds to 5905 to 5925 MHz; this is Channel 183 using the IEEE 802.11 designations. The security is compliant with IEEE 1609.2.

The over-the-air interface shall be compliant with the set of ETSI standards based on 3GPP Release 14.

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[5] The 20 MHz bandwidth is divided into 10 subchannels. Depending on the size of V2X message, the LTE-V2X radio uses different number of subchannels and MCS values for transmission of the V2X message.

5.5 SAE Standards Series Supporting ITS Communication Using LTE-V2X

The SAE Standards series, which 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.[6] 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.

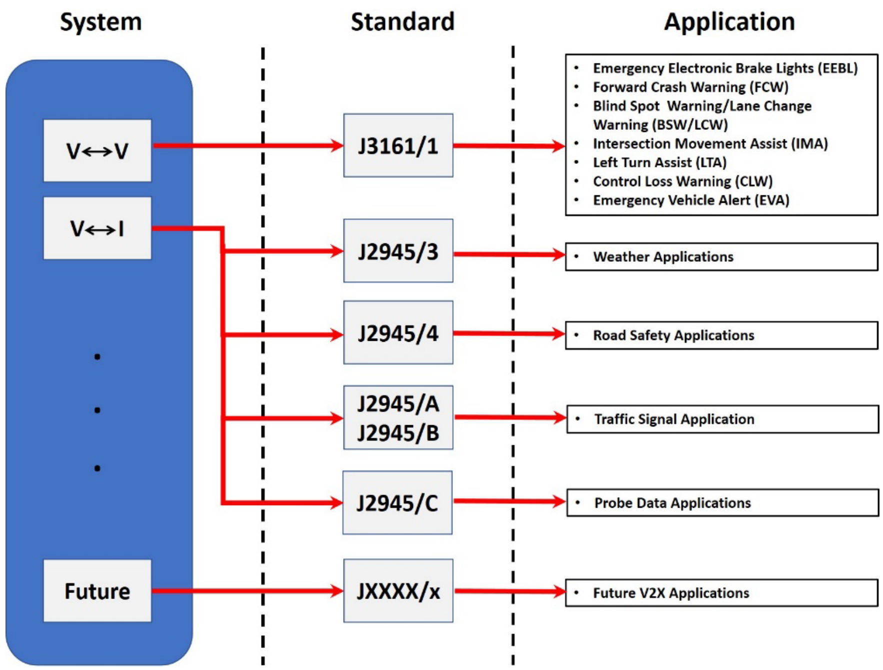

Figure 6 - Relationship of system and SAE Standards[7]

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), Wi-Fi, or Bluetooth—the focus of this standard is on LTE-V2X (specified in the set of ETSI standards based on 3GPP Release 14).

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[6] 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.

[7] Some of the SAE V2X application standards listed in the figure have not completed ballot process at the time of this document's publication.

6.1.1 LTE-V2X Communication

An LTE-V2X system uses the protocols specified in the set of ETSI standards based on 3GPP 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, 30 MHz bandwidth (corresponding to 5895 to 5925 MHz) has been allocated for deployment of ITS applications, which is divided into 2 channels:

1. LTE band 47 using EARFCN 55140 with a 20 MHz channel width which corresponds to 5905 to 5925 MHz (also known as Channel 183 by IEEE).

2. LTE band 47 using EARFCN 54990 with a 10 MHz channel width which corresponds to 5895 to 5905 MHz (also known as Channel 180 according to IEEE standards)

However, the focus of this standard is only the 20 MHz channel (corresponds to 5905 to 5925 MHz).

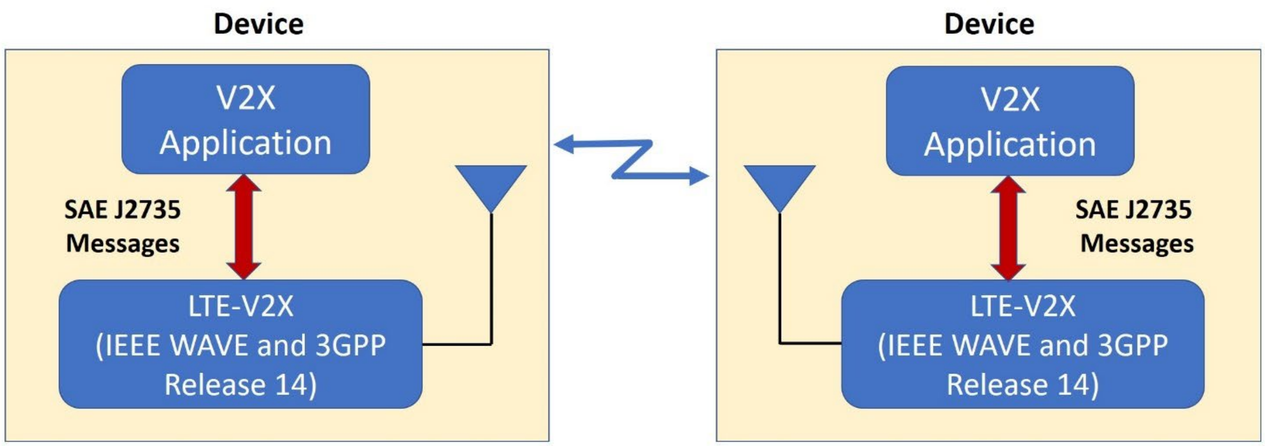

Figure 7 - Use of LTE-V2X for SAE J2735 message set

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, the SAE V2X applications exchange their SAE J2735 messages, which are secured and transported by the WAVE and ETSI LTE-V2X.

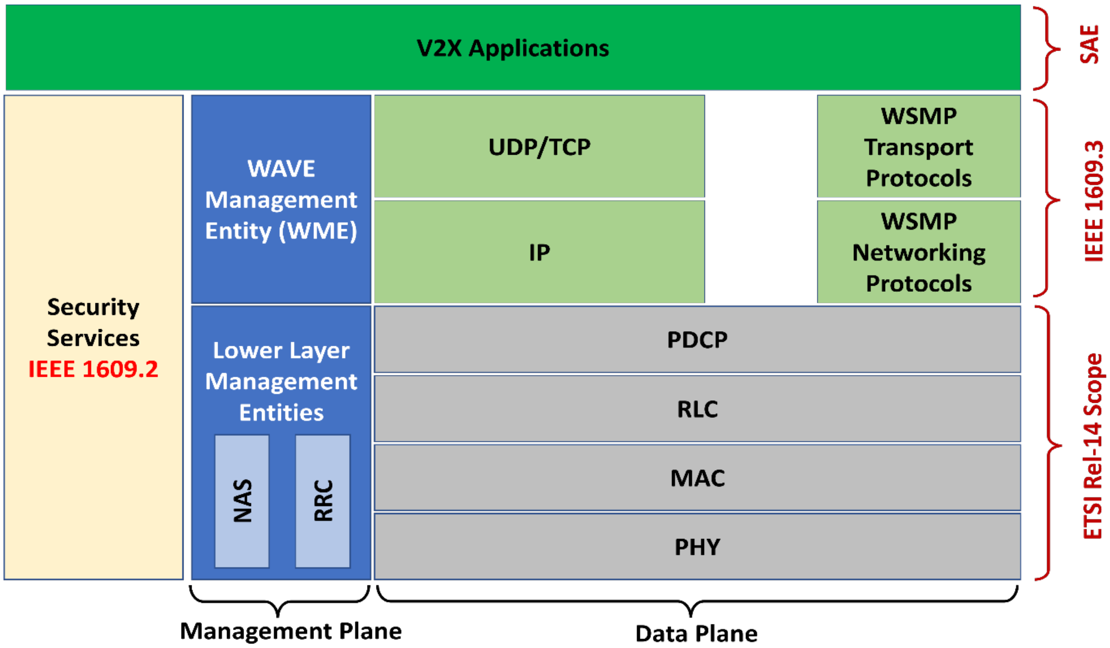

Figure 8 - LTE-V2X protocol stack

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 - Identifiers. This standard specifies 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 recorded by the IEEE Registration Authority. PSID values used by specific SAE technical reports are recorded in those information reports. A consolidated list of PSID values used by SAE technical reports is available in SAE J3268.

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 J3161/1 standards). PSIDs used for identifying services in the WSA and testing purposes are also included because those PSIDs are also relevant to SAE V2X application 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.

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 EARFCN 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 EARFCN 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 "technical report" column identifies the SAE and IEEE standard that includes the application.

Table 1 - Example messages/applications in LTE-V2X

Message	Source and Destination Device	Technical Report[8]
BSM	V2V	SAE J3161/1 SAE J2945/1B
SPAT	I2V	SAE J2735
MAP	I2V	SAE J2735
RTCM	I2V	SAE J2735
RWM	I2V	SAE J2945/3
WSA	I2V	IEEE 1609.3
RSM	I2V	SAE J2945/4
TIM	I2V	SAE J2735
SSM	I2V	SAE J2735
SRM	V2I	SAE J2735
TAM	I2V	SAE J3217
TUM	V2I	SAE J3217
TUMack	I2V	SAE J3217

Infrastructure-based applications may use WSMP or IP to exchange data from/to infrastructure. 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.

[8] 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 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 IPv6-based services, the IPv6 service parameters) to access the service. One device may transmit multiple WSAs to offer services of one or more criticalities (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 advertised 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 IPv6 protocol stack. Each device using IP must have at least one IPv6 address. IPv6 provides the ability to route information through a network to a destination IPv6 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.

6.2.1.2 WSMP-Based Advertised Services

LTE-V2X message may be sent over the 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 EARFCN 55140 with a 20 MHz channel width, the OBU can start exchanging application data. This data/message exchange may be over IPv6 or WSMP and is shown in Figure 9. An example of this service type could be electronic toll collection or weigh-station bypass.

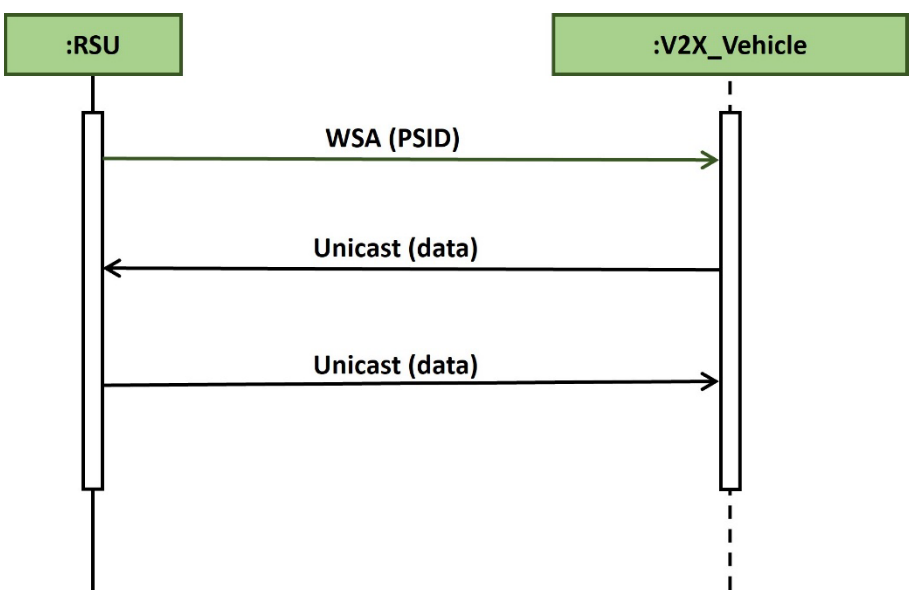

Figure 9 - Local advertised service

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 V2X 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.

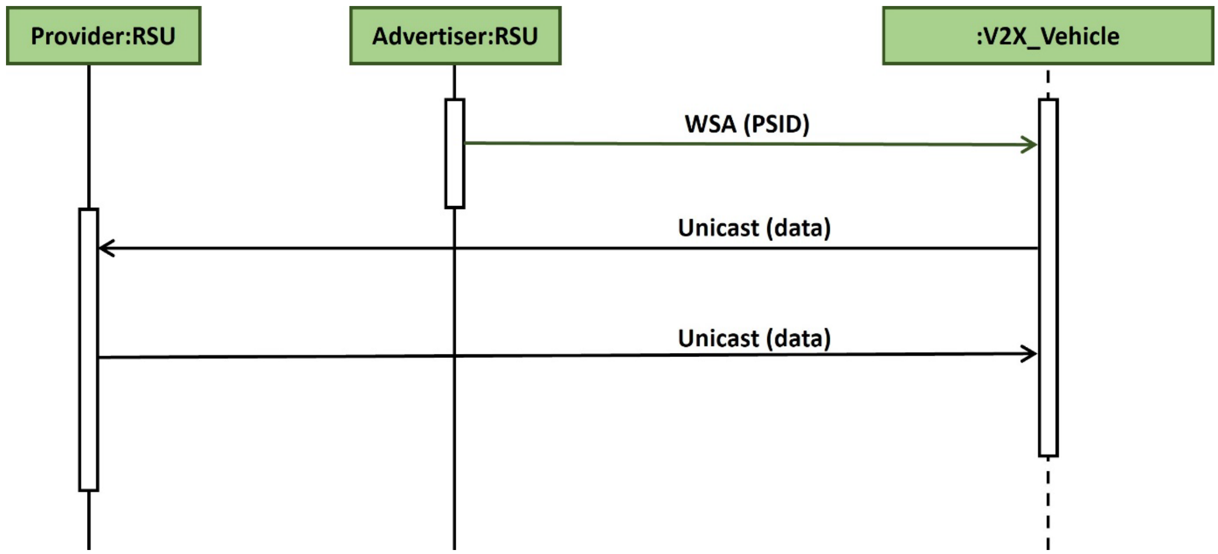

Figure 10 - Separate provider and advertiser

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 EARFCN 55140 with a 20 MHz channel width. Examples of this service type may include applications that use SPAT messages.

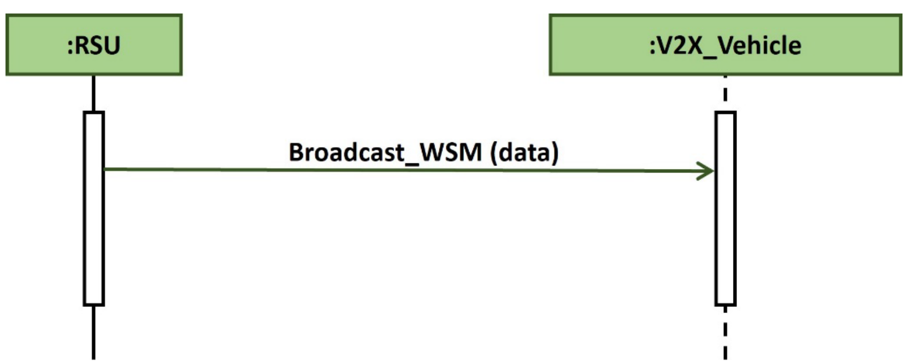

Figure 11 - I2V broadcast service

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 V2X vehicles (or between V2X 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.

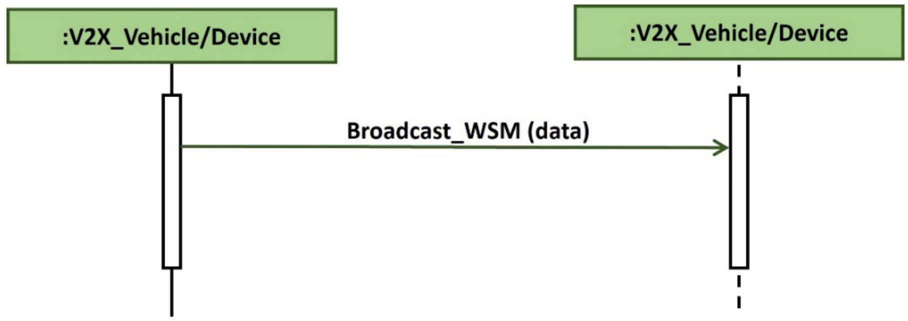

Figure 12 - V2V broadcast service

6.3 WAVE Service Advertisement (WSA) Profile and Guidance

WAVE standards provide several communications management features, the most significant of which is the WAVE Service Advertisement (WSA). The WSA allows Provider devices to announce the services being offered in the local area and enabling OBUs to recognize and access those services. IEEE Std 1609.3 specifies four WSA segments, which may be populated as needed, which are described below.

- **Header**. The WSA header includes a version number (that allows receiving devices to ignore WSAs they could not parse), a counter (that allow receiving devices to ignore duplicate WSAs), and optional fields such as transmitter location, which may provide further information to the receiving device as to the relevance of the WSA contents.

- **Service Info**. There is one instance of Service Info for each advertised service, each with a PSID value that allows a receiver to evaluate whether the WSA contains a service of interest, and a pointer to an instance of Channel Info to indicate how to access the service. Optional fields carry other information that help the receiver either evaluate or access the advertised service. In particular the Provider Service Context (PSC) is a PSID-dependent octet string that may be used to indicate additional info about the specifics of the advertised service. For example, a traffic information application could indicate the most recent update time in the PSC, so Users would know whether they need to refresh their data.

- **Channel Info**. There may be multiple instances of Channel Info, each providing the parameters of a radio channel. The most significant parameter is a number identifying the radio channel (i.e., frequency/bandwidth) to be used. Other parameters govern physical channel access.

- **WAVE Routing Advertisement**. If the Provider offers an IP routing service, it includes the WAVE Routing Advertisement (WRA) segment, which provides all the IP configuration parameters (e.g., router and domain name server addresses) needed for IP communication. Without this, a more time-consuming router discovery mechanism, better suited to wired networks, would have to be used.

WSAs can be used to advertise services on the same channel or other channels. An RSU operating in this channel should generate a single broadcast, specifically an IEEE 1609.2 signed version 3 WAVE Service Advertisement, as defined in IEEE Std. 1609.3. The WSA header should be configured accordingly. Additionally, all WSAs used in SAE V2X Application J-standards are LTE-V2X broadcasts.

The WSA consists of two key segments: Service Info and Channel Info (refer to IEEE 1609.3 for details). These segments always exist in WSAs used by SAE V2X application standards. They provide essential information such as the PSID and the service channel used to access the service. If a field is not included in the set of fields identified in this standard, it is omitted for any SAE V2X application standard that references this standard. Any fields defined in IEEE 1609.3 that are not addressed by this standard are either omitted from the WSA or set to the IEEE 1609.3 defaults (if the parameter cannot be omitted).

This standard utilizes various parameters to build a WSA profile. Some parameters directly translate to fields present in the transmitted WSA, such as PSID. Others are solely used for determining how to transmit the WSA, like the WSA Channel Identifier.

The IEEE 1609.3 WSA shall only be transmitted when there is at least one application service to advertise, even if there is just the WRA IP link [REQ-J3161-WSA-001].

6.3.1 Restricted Parameters

WSA on the channels specified in Table 2 shall never include any of the followings:

1. WSA Channel Identifier: This parameter is used by the sender of the WSA to determine which channel to use for transmitting the WSA.

2. Repeat Rate: This parameter is the number of WSAs transmitted within a 5-second interval and is not included in the transmitted WSA. It is used by the sender of the WSA to determine how often to transmit the WSA.

3. LTE-V2X WSAs shall never include RCPI thresholds (not included per IEEE 1609.3 Table M.3)

WSA transmitted on channels specified in Table 2 shall never include any of the above parameters [REQ-J3161-WSA-002].

6.3.2 Required Parameters

Required WSA data elements to be included in each transmitted WSA:

1. 3D location (Wave Information Element ID #6)[9] with the antenna location of WSA transmitter[10]

2. Compact Time Confidence (Wave Information Element ID #25)[11]

3. Service Info Segment Parameters

    a. Provider Service Identifier: This parameter is set according to the advertised service(s). A single WSA may contain multiple ServiceInfo fields, each of which will contain a single PSID

    b. WSA Count Threshold Interval: The sliding time window over which WSAs are counted (present only if WSA Count Threshold is present).

    c. WSA Count Threshold: The minimum number of WSAs that must be received during WSA Count Threshold Interval for an OBU to execute the service.

    d. Provider Service Context (PSC) (optional): This parameter may be specified by appropriate SAE V2X application standard. The ServiceInfo may contain a PSC in addition to the PSID if the application specification associated with the PSID permits or requires it.

4. Channel Info Segment Parameters (applies to all services on a given LTE-V2X channel):

    a. Service Channel Identifier: This parameter is set to the Service Channel Number to be used to exchange the application data/messages.

    b. Transmit Power: This parameter is the maximum transmit power applied by the service user for transmitting data to the service provider. Adaptive power control is outside the scope of this standard, and user devices may use a fixed power up to the maximum indicated within the WSA.

NOTE: Any data element not required in 6.3.2, and not prohibited in 6.3.1 is optionally allowed as needed by the applications. As mentioned earlier, PSC is an optional data element and is required only by specific applications.

WSA transmitted on channels specified in Table 2 shall include all the above parameters [REQ-J3161-WSA-003].

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[9] Wave Information Element ID values are specified in IEEE Std 1609.3.
[10] 3D location is in the WSA header.
[11] Compact time confidence is in the WSMP that is carrying the WSA.

6.3.3 WSA Parameters Enabling IPv6-Based Service

Several WSA fields may be added into the WSA if the RSU supports IPV6 connections to applications running on the RSU and/or to servers beyond it on the internet or LAN beyond the RSU.

1. IPv6 Address: The IPv6 address of the service host

2. Service Port: The port number (for TCP or UDP)

3. Provider MAC Address (optional): The MAC address of the provider (used only if the provider is different than the advertiser)

4. WRA (optional): contains information necessary for a network or cloud-based IPv6 service

WSA may include the **LTEv2xChannelInfo** extended Channel Info element. In this case, the Info element shall contain the fields pMax, minPeriodicity, maxSpeed, MaxRange, maxCbr and shall not contain any other OPTIONAL fields [REQ-J3161-WSA-004].

RCPI Threshold as described in IEEE Std 1609.3 shall not be included [REQ-J3161-WSA-005].

6.3.4 Advertised Services Profile

Parameters described in 6.3 are used to implement this profile, as well as other parameters such as transmit power and data rate. Table 2 provides the base profile for a WSMP-based and IP-based advertised services.

Table 2 - Base Advertised Services Profile

Parameter	Recommended Setting	Notes
Basic Parameters (local WSMP and local & network IP-based services)		
WSA Transmit Power	Set by system implementer	May vary from installation to installation
WSA Data Rate		
WSA Channel Identifier	183	WSA is transmitted on channel 183.
Repeat Rate	10 (transmitted 10 times in a 5 second interval) to 5 (transmitted 5 times in a 5 second interval)	Generally transmitted once every 500 ms to once per second, depending on the needs identified in a corresponding SAE V2X application standard
PSID	Application specific	Refer to associated application specification for details
PSC	Application specific	Refer to associated application specification for details
Service Channel Identifier	Application specific or set by system implementer	Per SAE J3161 or other SAE Application specification
Channel Access	Application Specific	Switched or Immediate and Extended
Transmit Power	Application Specific	Power in dBm
IP Service Parameters (not used if WSMP-based)		
IPv6 Address	Set by system implementer	
Service Port	Set by system implementer	
Provider MAC address	Set by system implementer	Used only if separate provider and advertiser
WRA (optional)		
Router Lifetime	Set by system implementer (may vary from installation to installation)	
IP Prefix		
Prefix Length		
Default Gateway		
Primary DNS		
Secondary DNS		Optional
Gateway MAC Address		Optional

6.3.5 Optional Range and Link Quality Based Profiles for Advertised Services

The profile in Table 3 can be used to be optionally added to the advertised services profile to control range and/or communication link quality associated with the service.

Table 3 - Range and Link Quality Profile for Advertised Services

Parameter	Recommended Setting	Notes
WSA Count Threshold	2	Receive two WSAs
WSA Count Threshold Interval	35	Within 3.5 seconds

NOTE: With these settings, the OBU needs to receive two WSAs within 3.5 seconds to execute the advertised service.

6.3.6 WSA Security Profile

WSA shall use the IEEE Std 1609.2 security profile for WSA, as specified in IEEE Std 1609.3 Annex H [REQ-J3161-WSA-006].

6.3.7 WSA Transmission Requirements

WSAs shall not be transmitted more frequently than 2 Hz and the signature shall not be older than 5 seconds. The WSA shall be transmitted with full certificate (not digest) attached [REQ-J3161-WSA-007].

NOTE: WSA should be transmitted at 1 Hz, unless required to be transmitted at higher rate by other applications or performance standards. However, 2 Hz is the upper limit for WSA transmission.

An RSU transmitting a WSA that is that is expecting to support any unicast or IPv6 applications should disable the T5000 timer (L2 SRC randomization) or set it to the largest supported value [REQ-J3161-WSA-008].

See Table 5 for the PSID (from SAE J3268) and Destination Layer-2 ID for the WSA. The Service ID “handle” in the ETSI TS 124 385 v2x.xml shall have a decimal value of 134, linked to the L2 DST specified [REQ-J3161-WSA-009].

7. LTE-V2X FUNCTIONALITY

This section describes the physical layer, channel access procedure, and unicast addressing. It also describes how to improve the packet reception by mitigating the repetitive collisions in LTE-V2X.

7.1 LTE-V2X

As it is stated in 5.3, this document focuses on LTE-V2X PC5 mode 4, which is also commonly referred to as 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 encompasses various fields, including MCS, RBs, and information about resource reservation intervals and retransmission, among other relevant data. 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 (see ETSI TS 136 211 9.3.2 and 9.4.2).

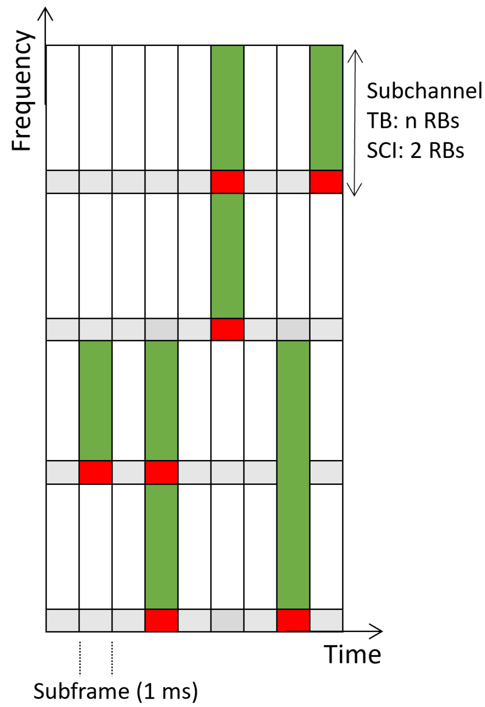

Figure 13 - LTE-V2X sub-channelization

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) OneShot 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 cellular tower coverage. 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 shall 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.

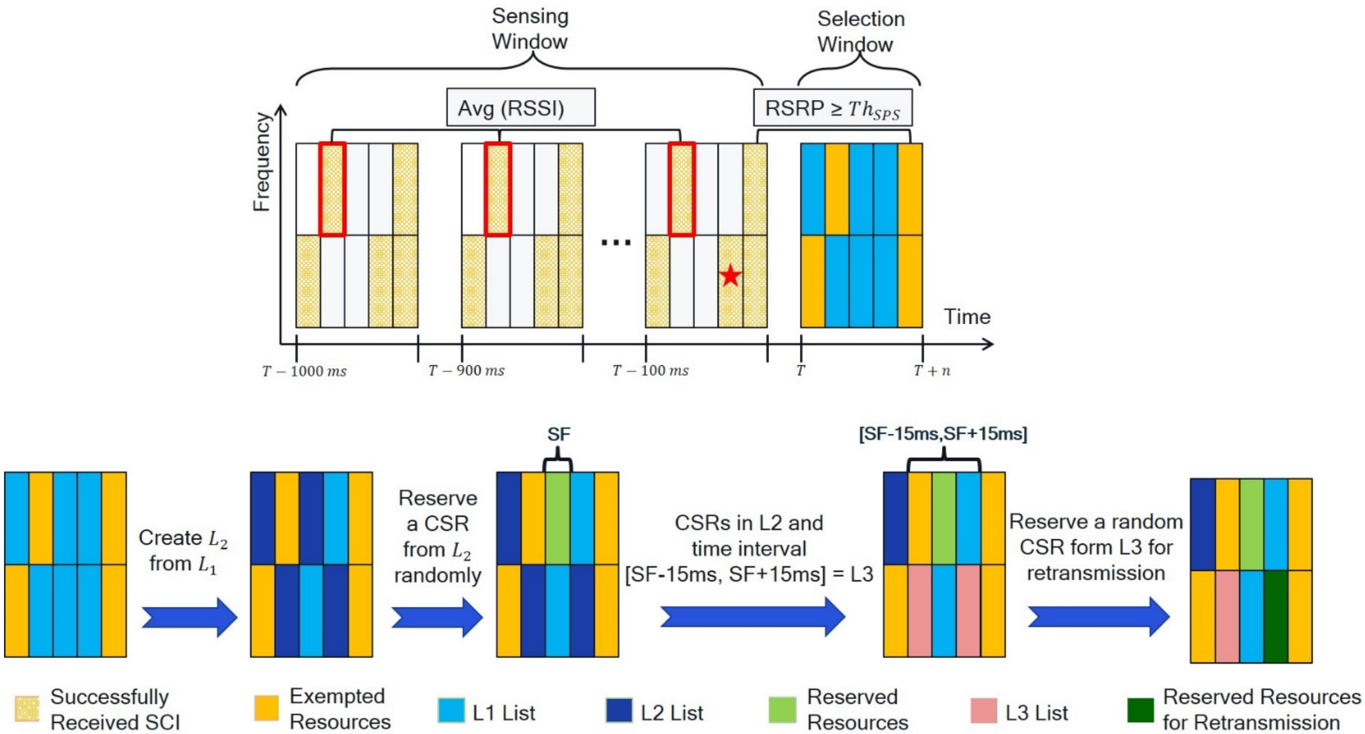

Figure 14 - Illustration of semi-persistent scheduling (SPS) algorithm

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 ("Th_{sps}"). 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 at the resource selection stage helps avoid packet collisions between devices 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 creates 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 SPS 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 priority and 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 one-shot transmission is an important implementation design decision because more frequent one-shot transmissions of large packets increase the likelihood of packet collision and loss of high priority traffic packets is undesirable. Therefore, this document provides following guidelines that aids in mapping the traffic flows to the SPS flows.

Each traffic flow is primarily characterized by three key parameters: (1) packet size, (2) periodicity, and (3) PPPP value. It is only logical to map higher resource-consuming and higher priority traffic to the SPS flows. Therefore, to facilitate the comparison of the traffic flows, the packet size parameter is converted into the number of subchannels required per packet transmission. Then, combing this with the periodicity of the traffic, we determine the number of subchannels required per second (NSCRPS) for each traffic flow. Note that NSCRPS is an indicator of the time-frequency resources consumed by each traffic flow. Now, the traffic flows with the two highest NSCRPS can simply be mapped to the two SPS flows. However, if there are more than two such traffic flows, then the tie is resolved by comparing the traffic priority and periodicities. The traffic flows are then mapped to the SPS flows in the following preferential order: (1) Higher priority, lower period, (2) Higher priority, higher period, (3) Lower priority, lower period, and (4) Lower priority, higher period. However, if there are still more than two candidate traffic flows that can be mapped to the two SPS flows, then the traffic flows can be chosen arbitrarily.

Following the above guidelines, the probability of packet collision due to the one-shot transmission of a high resource-consuming traffic can be minimized, thereby improving the overall performance. Some preliminary simulation studies have also confirmed the effectiveness of these guidelines for the SPS flow usage.

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.

For periodic messages where the radio uses SPS resource reservation, the system shall generate each message within a tolerance of ±2 ms of its scheduled generation time. [REQ-3161-SPS-001].

7.3.2 One-Shot

One-shot transmission is mainly used for critical event-based packet transmissions (e.g., critical BSM). However, it can also be used for periodic packets as well in scenarios where both SPS flows are in use, and the radio still requires transmission for another traffic flow. 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.

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

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[12] 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. The transmitter also listens to the skipped SPS resources and checks if there is any decodable packet from other transmitters using the skipped SPS flow.

- If there is a decodable packet corresponding to other UEs' SPS Tx in the skipped SPS flow, it means that another transmitter is using the same resources. To avoid repetitive packet collision, radio shall select new resources and reset the ResourceReselectionCtr and OneShotCtr.

- If there is not a decodable packet corresponding to other UEs' SPS Tx in the skipped SPS flow, this means there is no collision and there is no need to select new resources. In this case 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, and the radio shall continue to use the SPS flow.

NOTE 1: A packet is considered decodable if the SCI can be decoded with a correct checksum.

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.

If both ResourceReselectionCtr and OneShotCtr become zero simultaneously, the transmitter shall

- Skip the SPS flow and transmit the next packet using one-shot transmission.

- Then, determine if there is decodable packet in the skipped SPS flow.

  - If there is a decodable packet corresponding to other UEs' SPS Tx in the skipped SPS granted resources, the transmitter shall release the current SPS reservation and select new resources.

  - If there is no decodable packet corresponding to other UEs' SPS Tx in the skipped SPS granted resources, the transmitter shall determine whether the current SPS resources are going to be kept using the probResourceKeep-r14, and based on the decision selects new resources or keeps the current resources and reset both counters.

NOTE 2: 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.

NOTE 3: The resources used for one-shot and SPS transmission respectively are always non-overlapping and determined through a separate selection procedure.

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[12] This document recommends the use of transmit diversity. Examples of transmit diversity include switch diversity or cyclic delay diversity.

NOTE 4: If the packet cannot be fitted in the SPS flow, the transmitter shall skip the SPS flow and has the option to drop the packet or send the packet through one-shot transmission.

NOTE 5: If the SPS flow is skipped for sl-ReselectAfter consecutive transmissions, then the radio shall select new resources.

Figure 15 shows the detailed transmission scheme for SPS + One-Shot and Table 5 describes the range of OneShotCtr and ResourceReselectionCtr.

Table 4 - Range of OneShotCtr and ResourceReselectionCtr

Index	Parameter	Value	Description
1	SPSCtrMin	10, 5	Minimum SPS flow counter value for ResourceReselectionCtr. Value 10 is assigned to SPS flows with the resource reservation interval equal to 50 ms. Value 5 is assigned to SPS flows with the resource reservation interval equal to or greater than 100 ms.
2	SPSCtrMax	30, 15	Maximum SPS flow counter value for ResourceReselectionCtr. Value 30 is assigned to SPS flows with the resource reservation interval equal to 50 ms. Value 15 is assigned to SPS flows with the resource reservation interval equal to or greater than 100 ms.
3	OneShotCtrMin	4, 2	Minimum one-shot counter value for OneShotCtr. Value 4 is assigned to SPS flows with the resource reservation interval equal to 50 ms. Value 2 is assigned to SPS flows with the resource reservation interval equal to or greater than 100 ms.
4	OneShotCtrMax	12, 6	Maximum one-shot counter value for OneShotCtr. Value 12 is assigned to SPS flows with the resource reservation interval equal to 50 ms. Value 6 is assigned to SPS flows with the resource reservation interval equal to or greater than 100 ms.

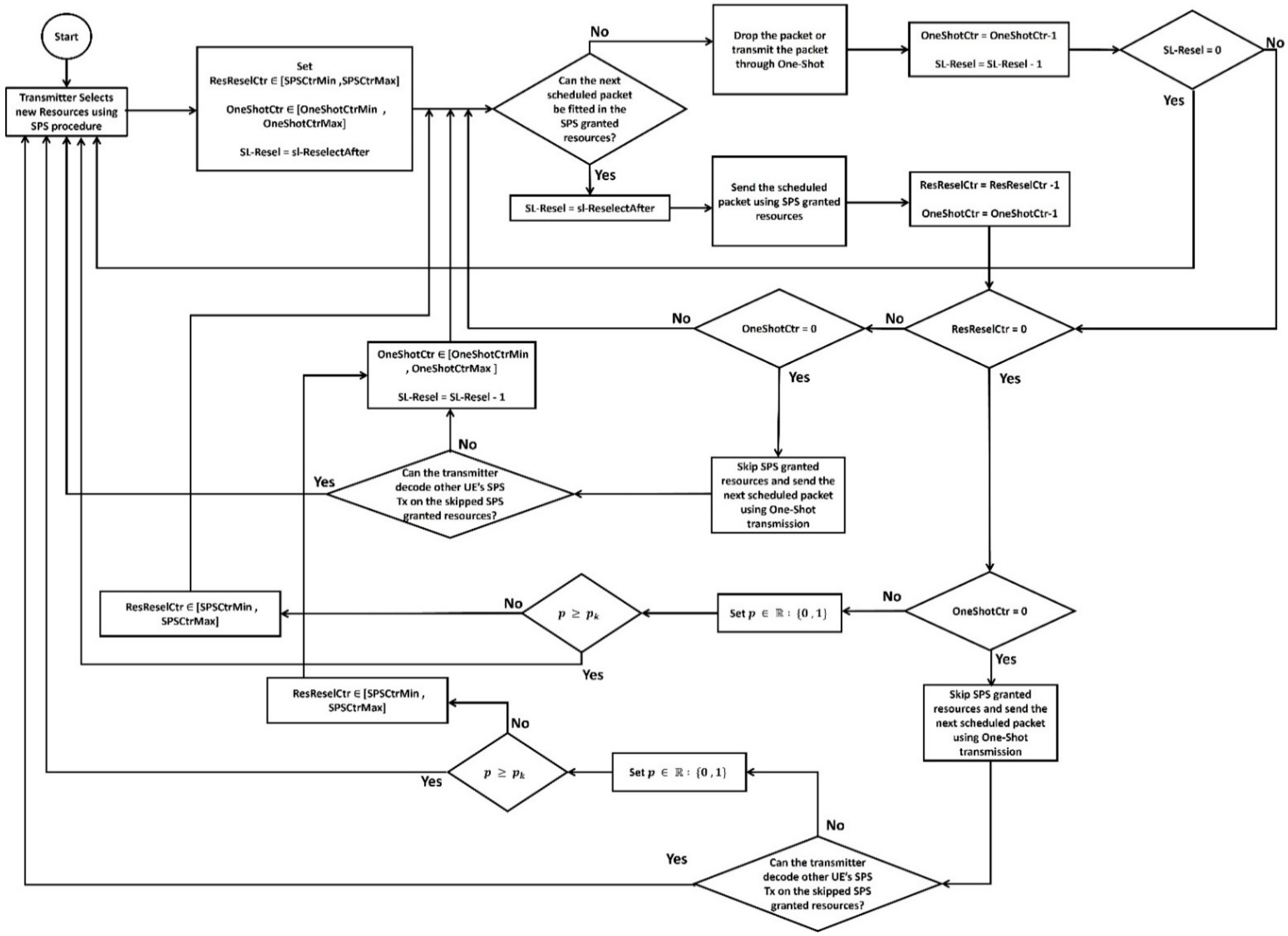

Figure 15 - SPS + One-Shot scheme

7.4 Sidelink Synchronization Signal (SLSS)

LTE-V2X is a synchronous communication system, necessitating the need for UEs to synchronize their transmission and reception to establish a sidelink connection. To achieve this, LTE-V2X utilizes a source (GNSS, eNB, or SyncRef UE) for time and frequency synchronization. In most cases, GNSS is used as the primary synchronization source. However, in scenarios where no GNSS time source is available due to signal obstruction (e.g., tunnels or parking garages) the UEs cannot communicate with each other (see Figure 1) unless another source of time synchronization is available.

Figure 16 - Without a synchronization source signal, UEs cannot communicate with each other

In the set of ETSI standards based on 3GPP Release 14 and Release 15, Sidelink Synchronization Signal (SLSS) is defined to provide an alternative source of time synchronization for scenarios where the GNSS is not available. A UE can transmit SLSS and Physical Sidelink Broadcast Channel (PSBCH) for supporting synchronization in the sidelink. The UE serving as a synchronization reference is referred to as a SyncRef UE. The SyncRef UE transmits synchronization information in the sidelink to expand the synchronization coverage of the source and provides nearby UEs with same sidelink timing reference. This enables sidelink communication between the UEs in scenarios where the GNSS signal is weak or unavailable.

As shown in Figure 17, for transmission of SLSS 6 RBs are needed in a subframe which consists of:

1. Primary Sidelink Synchronization Signal (PSSS)

2. Secondary Sidelink Synchronization Signal (SSSS)

3. Physical Sidelink Broadcast Channel (PSBCH)

4. Demodulation Reference Signal (DMRS)

NOTE: PSSS and SSSS are jointly referred to as SLSS.

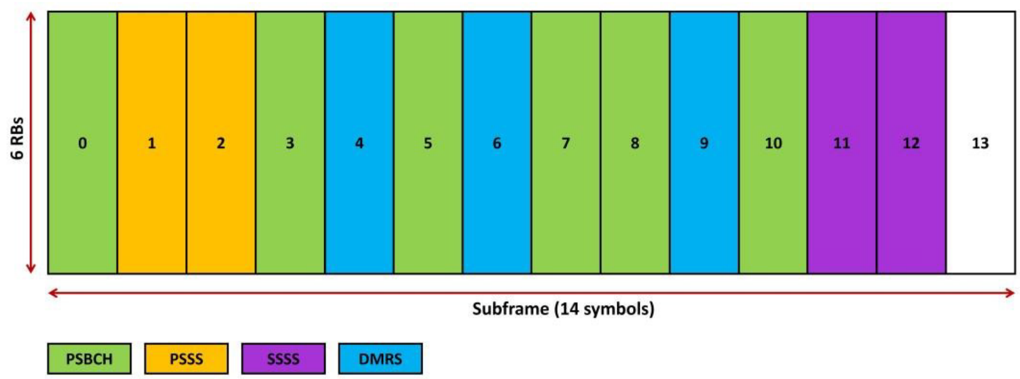

Figure 17 - Demonstration of different symbols in SLSS transmission procedure

The set of ETSI standards based on 3GPP Release 14 and Release 15 allows two configurations for SLSS+ PSBCH transmission using 2 or 3 SLSS syncs offset. In SLSS configuration using 2 syncs offset (see Figure 3), there are 2 subframes per 160 ms allocated for SLSS+ PSBCH transmission while in configuration using 3 syncs offset (see Figure 4) there are 3 subframes per 160 ms allocated for SLSS+ PSBCH transmission.

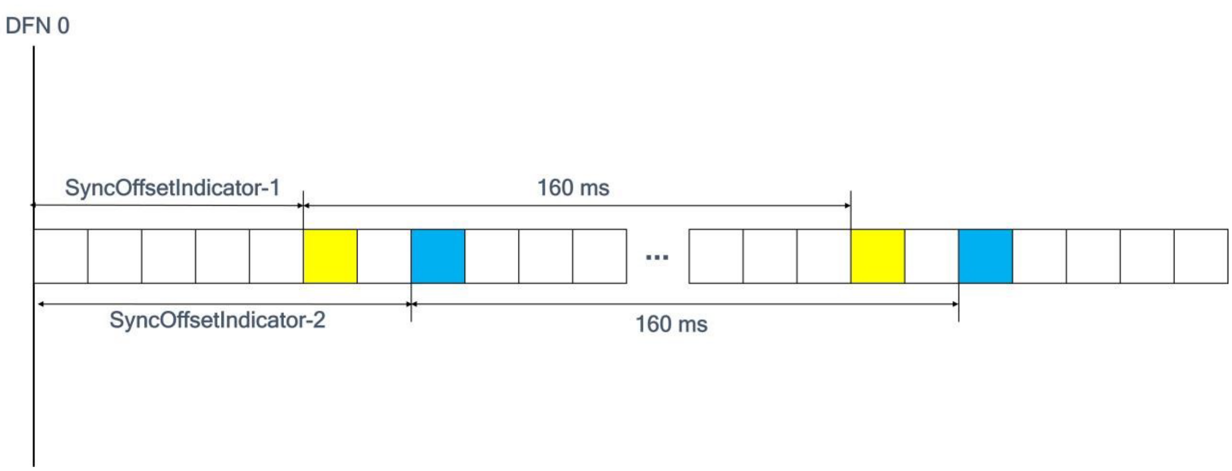

Figure 18 - SLSS configuration using two syncs offset

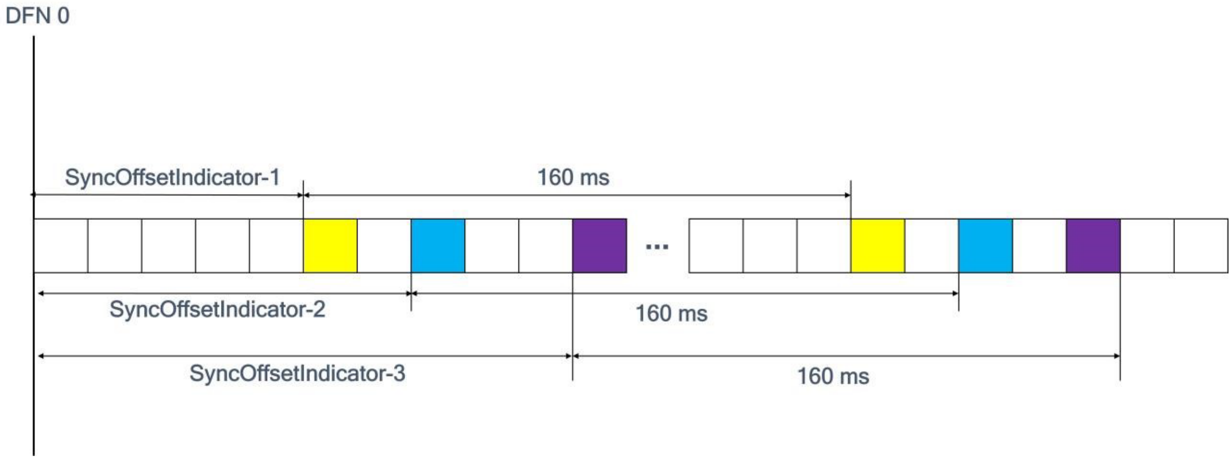

Figure 19 - SLSS configuration using three syncs offset

In this standard, SLSS+ PSBCH transmission shall be allowed only for RSUs that intend to send SLSS signal from fixed locations and OBUs shall not transmit the SLSS+ PSBCH.

NOTE: As it is shown in Figures 18 and 19, since the radio needs to reserve some subframes for SLSS+ PSBCH Tx/Rx, the logical subframe numbers will be changed.

NOTE 1: Based on the defined SLSS parameters in this document, the synchronization reference signals are prioritized as:

1. GNSS
2. UE directly synchronized to GNSS
3. UE indirectly synchronized to GNSS
4. The remaining UEs have the lowest priority
5. UE's own internal clock

7.4.1 Requirement on RSUs Transmitting SLSS+ PSBCH

If an RSU is installed in a location serving areas with expected GNSS coverage gaps (e.g., tunnels, and parking garages), it must adhere to additional constraints when configured to transmit SLSS+ PSBCH. The RSU shall transmit signed WSA as described below [REQ-J3161-SLSS-001]:

1. Shall sign the WSA at least once per second and provide microsecond accurate IEEE 1069.2 message signature generation time.

2. RSU's reference clock shall be accurate to within 1 ms of the UTC reference.

3. Compact time confidence (defined in the IEEE 1609.3) shall be populated.

4. In the specific case where an RSU serves areas with limited or no GNSS coverage, It is acceptable to generate a WSA without including any specific "service info" segment.

7.5 ProSe per Packet Priority (PPPP) for V2X Communication

In LTE-V2X, each message 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.

7.6 Packet Delay Budget (PDB)

In LTE-V2X, PDB is defined as the maximum delay that a packet can tolerate once it is received by the modem from an application stack and is generally based on the priority of the packet generated.

7.7 Destination Layer-2 ID (Normative)

This section defines LTE-V2X broadcast and unicast addressing.

7.7.1 Broadcast Addressing

The mapping from SAE J2735 Message ID or application group (i.e., 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[13], for V2X messages defined in SAE J2735, the most significant byte of destination Layer-2 ID will be set to 0x01 and other two bytes will be set to Message ID defined in SAE J2735 [REQ-J3161-PSID-001].

  Examples:

  - If Message ID is 0x13, then the destination Layer-2 ID will be set to 0x010013.
  - If Message ID is 0x2B, then the destination Layer-2 ID will be set to 0x01002B.

- For V2X messages defined in IEEE 1609.2 and IEEE 1609.3, the most significant byte of destination Layer-2 ID shall be set to 0x00 and other two bytes shall be set to the PSID [REQ-J3161-PSID-002].

  Examples:

  - If PSID of IEEE message is 0x88, then the destination Layer-2 ID will be set to 0x000088.
  - If PSID of IEEE message is 0x1000, then the destination Layer-2 ID will be set to 0x001000.

- For V2X messages not defined in SAE J2735, IEEE 1609.2, or IEEE 1609.3, the destination Layer-2 ID is left to be determined by the other standards.

[13] For example, in SAE J3161/1, destination Layer-2 ID for BSM does not follow the mapping and is set to 0xFFFFFF while the Message ID is 0x14.

Table 5 lists the Message ID, and corresponding destination Layer-2 ID for different message types. The Destination Layer-2 IDs in Table 5 is either defined in other standard documents or using the mapping scheme above and shall be used for deployment of corresponding V2X messages in Channel 183.

Table 5 - Mapping between PSID and Destination Layer-2 ID for different messages

Message	PSID Hex	Message ID Hex (SAE J2735)	Destination Layer-2 ID	Description
SPAT	0x82	0x13	0x010013	Per SAE J3161
MAP	0x204097	0x12	0x010012	Per SAE J3161
RTCM	0x81	0x1C	0x01001C	Per SAE J3161
SRM	0x204096	0x1D	0x01001D	Per SAE J3161
SSM	0x204095	0x1E	0x01001E	Per SAE J3161
TIM	0x83	0x1F	0x01001F	Per SAE J3161
RSM	0x83	0x21	0x010021	Per SAE J3161
RWM	0x204099	0x22	0x010022	Per SAE J3161
WSA	0x87	N/A	0x000087	Per SAE J3161
P2PCD	0x88	N/A	0x000088	Per SAE J3161
CRL	0x1000	N/A	0x001000	Per SAE J3161
BSM	0x20	0x14	0xFFFFFF	Destination Layer-2 ID is defined in SAE J3161/1

7.7.2 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.

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 6, 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[14]), this standard focuses on defining V2V, V2I, and I2V traffic. Hence, V2X messages are dividing into seven traffic families as described below. Application standards shall comply with the minimum PPPP value and minimum PDB for different traffic classes which is defined in Table 6. Application standards can define higher PPPP values than what is defined in Table 2.

Table 6 - 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	50 ms	100 ms	100 ms	100 ms	100 ms	100 ms	100 ms
Example Messages	Critical BSM, BSM from Public Safety Vehicle	BSM	RSM, MAP, TIM, SSM/SRM for preemption	SPAT, RTCM	TAM, TUM, TUMack, SSM/SRM for priority	RWM	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.

[14] This standard does not recommend deployment of V2P traffic in LTE band 47 using EARFCN 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.

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 message types and traffic families which is indicated in Table 7.

Table 7 - Associating traffic families to message types

Message	Source and Destination Device	Technical Report[15]	Traffic Family	Recommended PPPP
BSM	V2V	SAE J3161/1 SAE J2945/1B	Critical/Essential V2V	2, 5
SPAT	I2V	SAE J2735	Essential I2V	5
MAP	I2V	SAE J2735	Critical I2V	3
RTCM	I2V	SAE J2735	Essential I2V	5
RWM	I2V	SAE J2945/3	Low Priority	7
WSA	I2V	IEEE 1609.3	See the footnote	See the footnote[16]
RSM	I2V	SAE J2945/4	Critical I2V	3
TIM	I2V	SAE J2735	Critical I2V	3
SRM[17]	V2I	SAE J2735	Critical V2I/Transactional	3, 6
SSM[18]	I2V	SAE J2735	Critical I2V/Transactional	3, 6
TAM	I2V	SAE J3217	Transactional	6
TUM	V2I	SAE J3217	Transactional	6
TUMack	I2V	SAE J3217	Transactional	6

[15] 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.
[16] PPPP value of WSA is application specific and shall take the value of the lowest PPPP of messages that are being advertised.
[17] 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).
[18] 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 9 [REQ-J3161-RSRP-001].

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 11).
  - The second set of parameters needs to be used when speed is below the configured threshold (see Table 12)
- 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 1 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.

8.2.7 Requirement from ETSI (Normative)

This section specifies the requirements from the set of ETSI standards based on 3GPP Release 14 to support V2V operation as specified in this document. In general, the scope of communications capabilities used by this document is limited to "non-operator managed" [ETSI TS 123 285] V2X Sidelink communications. A universal subscriber identity module (USIM) and radio access network (RAN) infrastructure are not required to implement the functionality specified in this document.

- The PC5 radio subsystem shall implement the user equipment (UE) as specified in the set of ETSI standards based on 3GPP Release 14 to the extent necessary to support V2X Sidelink communications [ETSI TS 136 321, ETSI TS 136 201].

- For V2X communications, the PC5 radio subsystem shall use V2X Sidelink communications, as specified in ETSI TS 136 321. There is no infrastructure or serving cell. The radio subsystem is assumed to be pre-authorized for the region in which it operates, which in the case of SAE J3161 is the United States.

NOTE: UE has no serving cell means the system does not require a cellular communications infrastructure. Autonomous resource selection using mode 4 is implemented by selecting resource blocks for transmission based on energy sensing of resource blocks (RBs) already in use and priority associated with the information in those RBs [ETSI TS 136 213].

- For V2X communications, the PC5 radio subsystem shall use the UE procedure for determining subframes and resource blocks for transmitting PSSCH and reserving resources for Sidelink transmission mode 4 [ETSI TS 136 213, ETSI TS 136 321].

- For non-IP packets, the 3-bit SDU-type field in the ETSI PDCP header shall be set to 011, indicating non-IP. For IP packets, the 3-bit SDU-type field in the ETSI PDCP header shall be set to 000. The 16-bit PDCP-SN-size shall be used. PGK identity, PTK identity, and PDCP SN shall be set to 0.

- The V2X message family encoding shall be set to the value of 0x01 indicating IEEE 1609.

- The PC5 radio subsystem shall use RLC UM (unacknowledged mode) and the 5-bit RLC SN size. UM window size shall be set to 16. HARQ reordering is possible for STCH reception.

- The 4-bit V field in the ETSI MAC header shall be set to 0011, indicating a 24-bit DST field.

- The 24-bit destination layer-2 ID in the ETSI MAC header shall be set according to Table 5.

- The PC5 radio subsystem shall use the preconfiguration parameters as specified in Tables 8 to 15. [ETSI TS 136 213, ETSI TS 136 321].

- The peak EIRP shall be +33 dBm unless modified by regulatory authorities.

- Packets shall be transmitted using one of two methods specified below.
  - Event-based transmission (commonly known as One-Shot transmissions).
  - Semi persistent scheduling (SPS) method + One-Shot (as described in 7.3.3).

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 6, in this standard the V2X messages have three directional flow types (e.g., V2V, V2I, and I2V). Although two different parameter sets are defined based on the source of the traffic, some parameters are common between all traffic flows. These parameters for all LTE-V2X devices operating on Channel 183 shall be set per Table 8 [REQ-J3161-RRC-001].

Table 8 - LTE-V2X PC5 common communication parameters

Index	Pre-Configuration Parameter (3GPP Information Element)	Value	Explanation of Information Elements
1	profile0x0001-r12	FALSE	Legacy from D2D, not needed for LTE V2X.
2	profile0x0002-r12	FALSE	Legacy from D2D, not needed for LTE V2X.
3	profile0x0004-r12	FALSE	Legacy from D2D, not needed for LTE V2X.
4	profile0x0006-r12	FALSE	Legacy from D2D, not needed for LTE V2X.
5	profile0x0101-r12	FALSE	Legacy from D2D, not needed for LTE V2X.
6	profile0x0102-r12	FALSE	Legacy from D2D, not needed for LTE V2X.
7	profile0x0104-r12	FALSE	Legacy from D2D, not needed for LTE V2X.
8	carrierFreq-r12	55140 (5915 MHz)	ARFCN-ValueEUTRA-r9b (Channel 183 in IEEE 802.11).
9	maxTxPower-r12	BSM from Public Safety Vehicles[19]: 26 dBm Other traffics: 23 dBm	Maximum allowed conducted transmission power at the radio device's port to the antenna cable. Note: ETSI allows ±2 dBm tolerance at the radio port. Note: When a public safety vehicle is not engaged in public safety operations, the vehicle that had taken on this role reverts to the behaviors associated with its basic vehicle class and type (e.g., lower transmission power).
10	sl-bandwidth-r12	N100	Total number of RBs across 20 MHz (N100 -> 100).
11	subframeAssignmentSL-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.
12	reserved-r12	0000000000000000000	
13	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.
14	sl-Subframe-r14	11111111111111111111	Indicates the subframe bitmap indicating resources used for PC5 sidelink communication. Each bit corresponds to one subframe (1 ms). Bit 1 means that the corresponding subframe can be used for LTE-V2X communication. Set to all ones, which means all subframes are available for LTE-V2X communication. Bitmap length is a factor of 10240. The bitmap has a finite length and represents a block of time. So, is repeated to infinity to represent time.

[19] When a public safety vehicle is not engaged in public safety operations, the vehicle that had taken on this role reverts to the behaviors associated with its basic vehicle class and type.

Index	Pre-Configuration Parameter (3GPP Information Element)	Value	Explanation of Information Elements
15	adjacencyPSCCH-PSSCH-r14	TRUE	Indicates whether a UE always transmits PSCCH and PSSCH in adjacent RBs (indicated by TRUE). This parameter appears only when a pool is configured such that a UE transmits PSCCH and the associated PSSCH in the same subframe.
16	sizeSub-channel-r14	N10	Indicates the number of PRBs of each sub-channel in the corresponding resource pool. The value n5 denotes five PRBs, n6 denotes six PRBs, and so on. Here the sub-channel size is ten PRBs.
17	numSub-channel-r14	n10	Indicates the number of sub-channels in the corresponding resource pool. The value n5 denotes five sub-channels, n6 denotes six sub-channels, and so on. Here there will be ten sub-channels in the resource pool.
18	startRB-Sub-channel-r14	0	Indicates the lowest RB index of the sub-channel with the lowest index.
19	dataTxParameters-r14	BSM from Public Safety Vehicles: 26 dBm Other traffics: 23 dBm	Conducted transmission power at the radio device’s port to the antenna cable. Note: ETSI allows ±2 dBm tolerance at the radio port. Note: When a public safety vehicle is not engaged in public safety operations, the vehicle that had taken on this role reverts to the behaviors associated with its basic vehicle class and type (e.g., lower transmission power).
20	restrictResourceReservationPeriod-r14	V0dot5, V1, V2, V3, V4, V5, V6, V7, V8, V9, V10	Indicates which values are allowed for the signaling of the resource reservation period in PSCCH. V0 means there is no reservation. V1 -> 100 ms, which means that the next resource in the same SPS flow will occur after exactly 100 ms at the same PRBs. V2, V3, …, V10 corresponds to 200 ms, 300 ms …, 1000 ms, respectively. Note: For better performance, resource reservation period of an SPS flow should be the same as the message generation interval.
21	probResourceKeep-r14	v0dot8	Indicates the probability with which the UE keeps the current resource when the resource reselection counter reaches zero for sensing-based UE autonomous resource selection (refer to ETSI TS 136 321). V0dot8 means UE keeps the current resource with probability 0.8 and reselect to a new resource with probability 0.2.
22	sl-ReselectAfter-r14	n6	Indicates the number of consecutive skipped SPS granted resources before triggering resource reselection for V2X PC5 sidelink communication (refer to ETSI TS 136 321).
23	SL-ThresPSSCH-RSRP-List-r14	Table 9	This information element is essentially an 8*8 matrix (64 elements). It is an 8*8 table of transmitting packet priority versus receiving packet priority and RSRP exclusion threshold that needs to be added for any of those combinations. In this case, the parameter is a sequence of 64 entries. In this document, 36 of the 64 entries are used and are configured with values given in Table 9.

Index	Pre-Configuration Parameter (3GPP Information Element)	Value	Explanation of Information Elements
Entries from 29 to 37 are part of SLSS configuration. SLSS transmission shall be Enabled just for RSUs which are desired to send SLSS with fixed location and shall be Disabled for OBUs and other RSUs [REQ-J3161-SLSS-001]. UEs with SLSS configuration have different logical subframe indices compared to UEs without SLSS configuration, rendering a non-interoperable system. Therefore, this standard does not assume coexistence of UEs with and without SLSS configurations. If there is a UE without SLSS configuration, that UE would be required to be reconfigured with SLSS configuration so all UEs are using the same logical subframe indexing. NOTE 1: SLSS transmission and reception (synchronization) are optional features in this document. SLSS configuration serves the purpose of allowing synchronization through SLSS in the system and ensuring the same logical subframe indexing across all the UEs. NOTE 2: If an OBU is synchronized through SLSS, it should use high speed parameters provided in Tables 12 and 17.			
24	gnss-Sync-r14	TRUE	Indicates the allowed synchronization reference(s) which is (are) allowed to use the configured resource pool. In this case, it is a GNSS sync source.
25	syncPriority-r14	GNSS	Indicates the synchronization priority order. If this field is set to GNSS, the UE shall prioritize GNSS over the UE directly synchronized to eNB; if this field is set to eNB, the UE shall prioritize the UE directly synchronized to eNB over GNSS.
26	syncOffsetIndicator1-r14	0	The parameter indicates subframe location of the first SLSS resource in a SLSS period. For V2X sidelink communication, synchronization resources are present in those SFN and subframes which satisfy the relation: (SFN*10+ *Subframe Number*) mod 160 = *SL-OffsetIndicatorSync*.
27	syncOffsetIndicator2-r14	80	The parameter indicates subframe location of the second SLSS resource in a SLSS period. For V2X sidelink communication, synchronization resources are present in those SFN and subframes which satisfy the relation: (SFN*10+ *Subframe Number*) mod 160 = *SL-OffsetIndicatorSync.*
28	syncTxParameters-r14	SLSS Tx Enabled: 23 dBm SLSS Tx Disabled: -126 dBm	The parameter is conducted power used for SLSS transmission. The syncTxParameters-r14 shall be set to 23 dBm for the UEs transmitting SLSS and should be set to the lowest possible value for UEs not transmitting SLSS.
29	filterCoefficient-r14	fc0	Specifies the filtering coefficient for RSRP measurements used to calculate path loss, as specified in ETSI TS 136 213, clause 5.1.1.1. Value fc0 corresponds to k = 0, fc1 corresponds to k = 1, and so on.
30	syncRefMinHyst-r14	dB0	Hysteresis when evaluating a SyncRef UE using absolute comparison. Value *dB0* corresponds to 0 dB, *dB3* to 3 dB and so on.
31	syncTxThreshOoC-r14	SLSS Tx Enabled: 11 SLSS Tx Disabled: 0	Value 0 corresponds to -110 dBm, value 1 to -105 dBm, value 2 to -100 dBm, and so on (i.e., in steps of 5 dBm) until value 10, which corresponds to -60 dBm, while value 11 corresponds to +infinity. If *syncTxThreshOoC* is included in *SL-V2X-Preconfiguration*; and the UE is not directly synchronized to GNSS, and the UE has no selected SyncRef UE or the S-RSRP measurement result of the selected SyncRef UE is below the value of *syncTxThreshOoC,* transmit SLSS. Note: Even though setting *syncTxThreshOoC-r14* to zero allows the OBU to transmit SLSS, it is a non-functional place holder value for this parameter. To avoid OBU from transmitting SLSS, the radio shall disable SLSS transmission.

Index	Pre-Configuration Parameter (3GPP Information Element)	Value	Explanation of Information Elements
32	syncRefDiffHyst-r14	SLSS Tx Enabled: dBinf SLSS Tx Disabled: dB6	Hysteresis when evaluating a SyncRef UE using relative comparison. Value *dB0* corresponds to 0 dB, *dB3* to 3 dB and so on, value *dBinf* corresponds to infinite dB. UE switches to the strongest candidate SyncRef UE if the S-RSRP of the strongest candidate SyncRef UE exceeds the minimum requirement ETSI TS 136.133 by syncRefMinHyst and the candidate SyncRef UE belongs to the same priority group as the current SyncRef UE and the S-RSRP of the strongest candidate SyncRef UE exceeds the S-RSRP of the current SyncRef UE by *syncRefDiffHyst*.

Table 9 - RSRP exclusion threshold (dBm per RE) for different transmitting packet priority versus receiving packet priority

	Rx PPPP=2	Rx PPPP=3	Rx PPPP=5	Rx PPPP=6	Rx PPPP=7	Rx PPPP=8
Tx PPPP=2	-126	-116	-108	-98	-94	-90
Tx PPPP=3	-126	-116	-108	-98	-94	-90
Tx PPPP=5	-126	-116	-108	-98	-94	-90
Tx PPPP=6	-126	-116	-108	-98	-94	-90
Tx PPPP=7	-126	-116	-108	-98	-94	-90
Tx PPPP=8	-126	-116	-108	-98	-94	-90

8.4 V2V and V2I Communication System Parameters

- Table 10 describes the V2V/V2I-specific parameters:
- Speed-based configuration set (index element 1 to 3 in Table 10).
- Channel busy ratio (CBR) configuration set (index elements from 4 to 29 in Table 10).
- Priority-based configuration set (index elements from 30 to 53 in Table 10).

OBUs transmitting in Channel 183 shall set their RRC parameters per Table 10 [REQ-J3161-OBU-001].

Table 10 - V2V and V2I specific parameters sets (speed-, CBR-, and priority-based configuration sets)

Index	Pre-Configuration Parameter (ETSI Information Element)	Value	Explanation of Information Elements
1	thresUE-Speed-r14	120 km/h	Indicates UE speed threshold.
2	parametersBelowThres-r14	Table 11	PSSCH transmission parameter for V2V and V2I traffic when speed is below the threshold.
3	parametersAboveThres-r14	Table 12	PSSCH transmission parameter for V2V and V2I traffic when speed is equal or above the threshold.
4	threshS-RSSI-CBR-r14	9	Indicates the S-RSSI threshold for determining the contribution of a sub-channel to the CBR measurement. Value 0 corresponds to -112 dBm, value 1 to -110 dBm, value n to (-112 + n*2) dBm, and so on. Value nine means -94 dBm per sub-channel.
5	maxSL-V2X-CBRConfig2-r14	3	Maximum number of CBR range configurations in pre-configuration for V2X PC5 Sidelink communication congestion control.
6	maxCBR-Level-r14	3	Maximum number of CBR levels. There are three CBR levels in this case.
7	SL-CBR-Levels-Config-r14	30, 65, 100	Indicates CBR thresholds. Value 0 corresponds to 0, value 1 to 0.01 (aka 1%), value 2 to 0.02, and so on. Here the three CBR levels are 0.3, 0.65, and 1.
8	maxSL-V2X-TxConfig2-r14	3	Maximum number of TX parameter configurations in pre-configuration for V2X PC5 sidelink communication congestion control. In this case, there are three levels. The number of CBR-based TX parameter configurations equals to the number of CBR levels.
NOTE 1: Entries from 9 to 15 apply to PPPP 2, 3, 5, 6, 7, and 8, with CBR < 0.3.			
9	cr-Limit-r14	1000	CR-limit for CBR < 0.3 and PPPP 2. Indicates the maximum limit on the occupancy ratio on a sub-channel basis. Value 0 corresponds to 0, value 1 to 0.0001, value 2 to 0.0002, and so on (i.e., in steps of 0.0001) until value 10000, which corresponds to 1. The period of Cr-limit is 1 second. With ten sub-channels every ms, one will have a maximum of 10000 sub-channels every 1000 ms. Setting a CR-limit to 1000 is equal to CR-Limit of 10%. This is the first of two SL-CBR-PSSCH-TxConfig-r14 entries. Note: Table 14 lists CR-limits for different priorities and CBR levels.
10	cr-Limit-r14	1000	CR-limit for CBR < 0.3 and PPPP 3.
11	cr-Limit-r14	800	CR-limit for CBR < 0.3 and PPPP 5
12	cr-Limit-r14	400	CR-limit for CBR < 0.3 and PPPP 6
13	cr-Limit-r14	400	CR-limit for CBR < 0.3 and PPPP 7
14	cr-Limit-r14	400	CR-limit for CBR < 0.3 and PPPP 8
15	tx-Parameters-r14	Table 13	PSSCH transmission parameter for CBR < 0.3.
NOTE 2: Entries from 16 to 22 apply to PPPP 2, 3, 5, 6, 7, and 8, with 0.3 ≤ CBR < 0.65.			
16	cr-Limit-r14	500	CR-limit for 0.3 ≤ CBR < 0.65 and PPPP 2.
17	cr-Limit-r14	500	CR-limit for 0.3 ≤ CBR < 0.65 and PPPP 3.
18	cr-Limit-r14	300	CR-limit for 0.3 ≤ CBR < 0.65 and PPPP 5.
19	cr-Limit-r14	100	CR-limit for 0.3 ≤ CBR < 0.65 and PPPP 6.
20	cr-Limit-r14	50	CR-limit for 0.3 ≤ CBR < 0.65 and PPPP 7.
21	cr-Limit-r14	0	CR-limit for 0.3 ≤ CBR < 0.65 and PPPP 8.
22	tx-Parameters-r14	Table 13	PSSCH transmission parameter for 0.3 ≤ CBR < 0.65.
NOTE 3: Entries from 23 to 29 apply to PPPP 2, 3, 5, 6, 7, and 8, with CBR ≥ 0.65.			
23	cr-Limit-r14	250	CR-limit for CBR ≥ 0.65 and PPPP 2.
24	cr-Limit-r14	250	CR-limit for CBR ≥ 0.65 and PPPP 3.
25	cr-Limit-r14	150	CR-limit for CBR ≥ 0.65 and PPPP 5.
26	cr-Limit-r14	50	CR-limit for CBR ≥ 0.65 and PPPP 6.
27	cr-Limit-r14	0	CR-limit for CBR ≥ 0.65 and PPPP 7.

Index	Pre-Configuration Parameter (ETSI Information Element)	Value	Explanation of Information Elements
28	cr-Limit-r14	0	CR-limit for CBR ≥ 0.65 and PPPP 8.
29	tx-Parameters-r14	Table 13	PSSCH transmission parameter for CBR ≥ 0.65.
30	priorityThreshold-r14	2	Indicates the upper bound of PPPP range which is associated with the configurations of this priority. This configuration is for PPPP of 2.
31	defaultTxConfigIndex-r14	2	Indicates the PSSCH transmission parameters to be used by the UEs which do not have available CBR measurement results, by means of an index to the corresponding entry in tx-ConfigIndexList. Value 0 indicates the first entry in tx-ConfigIndexList. Value 1 indicates the second entry in tx-ConfigIndexList. Value 2 indicates the third entry in tx-ConfigIndexList.
32	cbr-ConfigIndex-r14	0	Indicates the CBR ranges to be used by an index to the entry of the CBR range configuration in cbr-RangeCommonConfigList.
33	tx-ConfigIndexList-r14	0, 1, 2	Indicates the list of the PSSCH transmission parameters and CR limit by the indexes to the entries of the configurations in sl-CBR-PSSCH-TxConfigList. Each index in tx-ConfigIndexList sequentially maps to each CBR range indicated by cbr-ConfigIndex.
34	priorityThreshold-r14	3	Same as above. This configuration is for PPPP of 3.
35	defaultTxConfigIndex-r14	2	Same as above. This configuration is for PPPP of 3.
36	cbr-ConfigIndex-r14	0	Same as above. This configuration is for PPPP of 3.
37	tx-ConfigIndexList-r14	3, 4, 5	Same as above. This configuration is for PPPP of 3.
38	priorityThreshold-r14	5	Same as above. This configuration is for PPPP of 5.
39	defaultTxConfigIndex-r14	2	Same as above. This configuration is for PPPP of 5.
40	cbr-ConfigIndex-r14	0	Same as above. This configuration is for PPPP of 5.
41	tx-ConfigIndexList-r14	6, 7, 8	Same as above. This configuration is for PPPP of 5.
42	priorityThreshold-r14	6	Same as above. This configuration is for PPPP of 6.
43	defaultTxConfigIndex-r14	2	Same as above. This configuration is for PPPP of 6.
44	cbr-ConfigIndex-r14	0	Same as above. This configuration is for PPPP of 6.
45	tx-ConfigIndexList-r14	9,10, 11	Same as above. This configuration is for PPPP of 6.
46	priorityThreshold-r14	7	Same as above. This configuration is for PPPP of 7.
47	defaultTxConfigIndex-r14	2	Same as above. This configuration is for PPPP of 7.
48	cbr-ConfigIndex-r14	0	Same as above. This configuration is for PPPP of 7.
49	tx-ConfigIndexList-r14	12, 13, 14	Same as above. This configuration is for PPPP of 7.
50	priorityThreshold-r14	8	Same as above. This configuration is for PPPP of 8.
51	defaultTxConfigIndex-r14	2	Same as above. This configuration is for PPPP of 8.
52	cbr-ConfigIndex-r14	0	Same as above. This configuration is for PPPP of 8.
53	tx-ConfigIndexList-r14	15, 16, 17	Same as above. This configuration is for PPPP of 8.

Table 11 - PSSCH transmission parameters for speed <120 km/h

Index	Pre-Configuration Parameter (ETSI Information Element)	Value	Explanation of Information Elements
1	minMCS-PSSCH-r14	5 (QPSK)	Minimum MCS index that shall be used.
2	maxMCS-PSSCH-r14	11 (16QAM)	Maximum MCS index that shall be used. Note: MCS 8, 9, 10 are excluded. Note: If the packet is large and does not fit using the maximum MCS, then UE can choose an option between segmentation, event-based transmission, or dropping the packet as per rules mentioned in ETSI TS 136 321, Section 5.14. Additionally, if the choice is to segment the packet, then the segmentation procedure as defined in ETSI TS 136 322 needs to be followed.
3	minSub-channel-NumberPSSCH-r14	2	Indicated the minimum number of sub-channels which may be used for transmissions on PSSCH (refer to ETSI TS 136 213).
4	maxSub-channel-NumberPSSCH-r14	10	Indicated the maximum number of sub-channels which may be used for transmissions on PSSCH (refer to ETSI TS 136 213).
5	allowedRetxNumberPSSCH-r14	both	Indicates the allowed retransmission number for transmissions on PSSCH (refer to ETSI TS 136 213). The value n0 indicates no retransmission for a transport block allowed; the value n1 indicates that the UE shall perform one retransmission for a transport block, and the value both indicates that the UE may select no retransmission or one retransmission for transport block. The UEs shall retransmit packets; however, they may skip retransmission if the CR limit is exceeded either at the time of resource reselection or prior to retransmission. Note: The combination of the primary transmission and the retransmission increases the link budget and is used for Forward Error Correction (FEC).
6	maxTxPower-r14	BSM from Public Safety Vehicles: 26 dBm Other traffics: 23 dBm	Maximum allowed conducted transmission power at the radio device's port to the antenna cable. Note 1: ETSI allows ±2 dBm tolerance at the radio port. Note 2: When a public safety vehicle is not engaged in public safety operations, the vehicle that had taken on this role reverts to the behaviors associated with its basic vehicle class and type (e.g., lower transmission power).

Table 12 - PSSCH transmission parameters for speed ≥120 km/h

Index	Pre-Configuration Parameter (ETSI Information Element)	Value	Explanation of Information Elements
1	minMCS-PSSCH-r14	0 (QPSK)	Minimum MCS index that shall be used.
2	maxMCS-PSSCH-r14	7 (QPSK)	Maximum MCS index that shall be used. Note: If the packet is large and does not fit using the maximum MCS, then UE can choose an option between segmentation, event-based transmission, or dropping the packet as per rules mentioned in ETSI TS 136 321, Section 5.14. Additionally, if the choice is to segment the packet, then the segmentation procedure as defined in ETSI TS 136 322 needs to be followed.
3	minSub-channel-NumberPSSCH-r14	2	Indicated the minimum number of sub-channels which may be used for transmissions on PSSCH (refer to ETSI TS 136 213).
4	maxSub-channel-NumberPSSCH-r14	10	Indicated the maximum number of sub-channels which may be used for transmissions on PSSCH (refer to ETSI TS 136 213).
5	allowedRetxNumberPSSCH-r14	both	Indicates the allowed retransmission number for transmissions on PSSCH (refer to ETSI TS 236 213). The value n0 indicates no retransmission for a transport block allowed; the value n1 indicates that the UE shall perform one retransmission for a transport block, and the value both indicates that the UE may select no retransmission or one retransmission for transport block. The UEs shall retransmit packets; however, they may skip retransmission if the CR limit is exceeded either at the time of resource reselection or prior to retransmission. Note: The combination of the primary transmission and the retransmission increases the link budget and is used for Forward Error Correction (FEC).
6	maxTxPower-r14	BSM from Public Safety Vehicles: 26 dBm Other traffics: 23 dBm	Maximum allowed conducted transmission power at the radio device’s port to the antenna cable. Note1: ETSI allows ±2 dBm tolerance at the radio port. Note2: When a public safety vehicle is not engaged in public safety operations, the vehicle that had taken on this role reverts to the behaviors associated with its basic vehicle class and type (e.g., lower transmission power).

Table 13 - PSSCH transmission parameters

Index	Pre-Configuration Parameter (3GPP Information Element)	Value	Explanation of Information Elements
1	minMCS-PSSCH-r14	0 (QPSK)	Minimum MCS index that shall be used.
2	maxMCS-PSSCH-r14	11 (16QAM)	Maximum MCS index that shall be used. Note: MCS 8, 9, 10 are excluded. Note: If the packet is large and does not fit using the maximum MCS, then UE can choose an option between segmentation, event-based transmission, or dropping the packet as per rules mentioned in ETSI TS 136 321, Section 5.14. Additionally, if the choice is to segment the packet, then the segmentation procedure as defined in ETSI TS 136 322 needs to be followed.
3	minSub-channel-NumberPSSCH-r14	2	Indicated the minimum number of sub-channels which may be used for transmissions on PSSCH (refer to ETSI TS 136 213).
4	maxSub-channel-NumberPSSCH-r14	10	Indicated the maximum number of sub-channels which may be used for transmissions on PSSCH (refer to ETSI TS 136 213).
5	allowedRetxNumberPSSCH-r14	both	Indicates the allowed retransmission number for transmissions on PSSCH (refer to ETSI TS 136 213). The value n0 indicates no retransmission for a transport block allowed; the value n1 indicates that the UE shall perform one retransmission for a transport block, and the value both indicates that the UE may select no retransmission or one retransmission for transport block. The UEs shall retransmit packets; however, they may skip retransmission if the CR limit is exceeded either at the time of resource reselection or prior to retransmission. Note: The combination of the primary transmission and the retransmission increases the link budget and is used for Forward Error Correction (FEC).
6	maxTxPower-r14	BSM from Public Safety Vehicles: 26 dBm Other traffics: 23 dBm	Maximum allowed conducted transmission power at the radio device's port to the antenna cable. Note 1: ETSI allows ±2 dBm tolerance at the radio port. Note 2: When a public safety vehicle is not engaged in public safety operations, the vehicle that had taken on this role reverts to the behaviors associated with its basic vehicle class and type (e.g., lower transmission power).

Table 14 - CR limits for different PPPP levels

	CR-Limit for PPPP = 2	CR-Limit for PPPP = 3	CR-Limit for PPPP = 5	CR-Limit for PPPP = 6	CR-Limit for PPPP = 7	CR-Limit for PPPP = 8
CBR < 0.3	10%	10%	8%	4%	4%	4%
0.3 ≤ CBR < 0.65	5%	5%	3%	1%	0.5%	0%
0.65 ≤ CBR	2.5%	2.5%	1.5%	0.5%	0%	0%

8.5 I2V Communication System Parameters

Table 15 describes I2V-specific parameters:

- Speed-based configuration set for I2V traffic[20] (index element 1 in Table 15).
- Channel busy ratio (CBR) configuration set (index elements from 2 to 24 in Table 15).
- Priority-based configuration set (index elements from 25 to 44 in Table 15).

RSUs transmitting in Channel 183 shall set their RRC parameters per Table 15 [REQ-J3161-RSU-001].

Table 15 - I2V specific parameters sets (speed-, CBR-, and priority-based configuration sets)

Index	Pre-Configuration Parameter (ETSI Information Element)	Value	Explanation of Information Elements
1	thresUE-Speed-r14	120 km/h	Indicates UE speed threshold.
2	parametersBelowThres-r14	Table 11	For I2V traffic, the infrastructure does not know the receiver's speed. So, for I2V traffic, PSSCH transmission parameters do not depend on the speed, and it always uses Table 11.
3	parametersAboveThres-r14	Table 11	PSSCH transmission parameter for V2V and V2I traffic when speed is equal or above the threshold. For I2V traffic, the infrastructure does not know the receiver's speed. So, for I2V traffic, PSSCH transmission parameters do not depend on the speed, and it always uses Table 11.
4	threshS-RSSI-CBR-r14	9	Indicates the S-RSSI threshold for determining the contribution of a sub-channel to the CBR measurement. Value 0 corresponds to -112 dBm, value 1 to -110 dBm, value n to (-112 + n*2) dBm, and so on. Value nine means -94 dBm per sub-channel.
5	maxSL-V2X-CBRConfig2-r14	3	Maximum number of CBR range configurations in pre-configuration for V2X PC5 Sidelink communication congestion control.
6	maxCBR-Level-r14	3	Maximum number of CBR levels. There are three CBR levels in this case.
7	SL-CBR-Levels-Config-r14	30, 65, 100	Indicates CBR thresholds. Value 0 corresponds to 0, value 1 to 0.01 (aka 1%), value 2 to 0.02, and so on. Here the three CBR levels are 0.3, 0.65, and 1.
8	maxSL-V2X-TxConfig2-r14	3	Maximum number of TX parameter configurations in pre-configuration for V2X PC5 sidelink communication congestion control. In this case, there are three levels. The number of CBR-based TX parameter configurations equals to the number of CBR levels.
NOTE 1: Entries from 9 to 14 apply to PPPP 3, 5, 6, 7, and 8, with CBR < 0.3.			
9	cr-Limit-r14	1000	CR-limit for CBR < 0.3 and PPPP 3. Indicates the maximum limit on the occupancy ratio on a sub-channel basis. Value 0 corresponds to 0, value 1 to 0.0001, value 2 to 0.0002, and so on (i.e., in steps of 0.0001) until value 10000, which corresponds to 1. The period of Cr-limit is 1 second. With ten sub-channels every ms, one will have a maximum of 10000 sub-channels every 1000 ms. Setting a CR-limit to 10000 is equal to no restriction. This is the first of two SL-CBR-PSSCH-TxConfig-r14 entries. Note: Table 14 lists CR-limits for different priorities and CBR levels.
10	cr-Limit-r14	800	CR-limit for CBR < 0.3 and PPPP 5
11	cr-Limit-r14	400	CR-limit for CBR < 0.3 and PPPP 6

[20] For I2V traffic, the infrastructure does not know the receiver's speed. So, for I2V traffic, PSSCH transmission parameters does not depend on the speed and it always uses Table 12.

Index	Pre-Configuration Parameter (ETSI Information Element)	Value	Explanation of Information Elements
12	cr-Limit-r14	400	CR-limit for CBR < 0.3 and PPPP 7
13	cr-Limit-r14	400	CR-limit for CBR < 0.3 and PPPP 8
14	tx-Parameters-r14	Table 13	PSSCH transmission parameter for CBR < 0.3.
NOTE 2: Entries from 15 to 20 apply to PPPP 3, 5, 6, 7, and 8, with 0.3 ≤ CBR < 0.65.			
15	cr-Limit-r14	500	CR-limit for 0.3 ≤ CBR < 0.65 and PPPP 3.
16	cr-Limit-r14	300	CR-limit for 0.3 ≤ CBR < 0.65 and PPPP 5.
17	cr-Limit-r14	100	CR-limit for 0.3 ≤ CBR < 0.65 and PPPP 6.
18	cr-Limit-r14	50	CR-limit for 0.3 ≤ CBR < 0.65 and PPPP 7.
19	cr-Limit-r14	0	CR-limit for 0.3 ≤ CBR < 0.65 and PPPP 8.
20	tx-Parameters-r14	Table 13	PSSCH transmission parameter for 0.3 ≤ CBR < 0.65.
NOTE 3: Entries from 21 to 26 apply to PPPP 3, 5, 6, 7, and 8, with CBR ≥ 0.65.			
21	cr-Limit-r14	250	CR-limit for CBR ≥ 0.65 and PPPP 3.
22	cr-Limit-r14	150	CR-limit for CBR ≥ 0.65 and PPPP 5.
23	cr-Limit-r14	50	CR-limit for CBR ≥ 0.65 and PPPP 6.
24	cr-Limit-r14	0	CR-limit for CBR ≥ 0.65 and PPPP 7.
25	cr-Limit-r14	0	CR-limit for CBR ≥ 0.65 and PPPP 8.
26	tx-Parameters-r14	Table 13	PSSCH transmission parameter for CBR ≥ 0.65.
27	priorityThreshold-r14	3	Indicates the upper bound of PPPP range which is associated with the configurations of this priority. This configuration is for PPPP of 3.
28	defaultTxConfigIndex-r14	2	Indicates the PSSCH transmission parameters to be used by the UEs which do not have available CBR measurement results, by means of an index to the corresponding entry in tx-ConfigIndexList. Value 0 indicates the first entry in tx-ConfigIndexList. Value 1 indicates the second entry in tx-ConfigIndexList. Value 2 indicates the third entry in tx-ConfigIndexList.
29	cbr-ConfigIndex-r14	0	Indicates the CBR ranges to be used by an index to the entry of the CBR range configuration in cbr-RangeCommonConfigList.
30	tx-ConfigIndexList-r14	0, 1, 2	Indicates the list of the PSSCH transmission parameters and CR limit by the indexes to the entries of the configurations in sl-CBR-PSSCH-TxConfigList. Each index in tx-ConfigIndexList sequentially maps to each CBR range indicated by cbr-ConfigIndex.
31	priorityThreshold-r14	5	Same as above. This configuration is for PPPP of 5.
32	defaultTxConfigIndex-r14	2	Same as above. This configuration is for PPPP of 5.
33	cbr-ConfigIndex-r14	0	Same as above. This configuration is for PPPP of 5.
34	tx-ConfigIndexList-r14	3, 4, 5	Same as above. This configuration is for PPPP of 5.
35	priorityThreshold-r14	6	Same as above. This configuration is for PPPP of 6.
36	defaultTxConfigIndex-r14	2	Same as above. This configuration is for PPPP of 6.
37	cbr-ConfigIndex-r14	0	Same as above. This configuration is for PPPP of 6.
38	tx-ConfigIndexList-r14	6,7, 8	Same as above. This configuration is for PPPP of 6.
39	priorityThreshold-r14	7	Same as above. This configuration is for PPPP of 7.
40	defaultTxConfigIndex-r14	2	Same as above. This configuration is for PPPP of 7.
41	cbr-ConfigIndex-r14	0	Same as above. This configuration is for PPPP of 7.
42	tx-ConfigIndexList-r14	9, 10, 11	Same as above. This configuration is for PPPP of 7.
43	priorityThreshold-r14	8	Same as above. This configuration is for PPPP of 8.
44	defaultTxConfigIndex-r14	2	Same as above. This configuration is for PPPP of 8.
45	cbr-ConfigIndex-r14	0	Same as above. This configuration is for PPPP of 8.
46	tx-ConfigIndexList-r14	12, 13, 14	Same as above. This configuration is for PPPP of 8.

8.6 Transmit SPS Reservation Size and MCS Adjusting

The following are a set of requirements showing how to select the MCS and number of RBs for a given packet size (in Bytes) for an SPS transmission and shall be followed by the LTE-V2X transmitter:

- The packet size used for making the reservation shall be at least the 90^{th} percentile of the expected packet size range [REQ-J3161-SPS_001].
- The radio shall reserve at least two sub-channels [REQ-J3161-SPS_002].
- The radio shall minimize the number of sub-channels in use [REQ-J3161-SPS_003].
- A minimum MCS of five is recommended. Lower MCSs may still be used if the data fits within two sub-channels at that lower MCS. Lower MCSs may also be used if, in the following tables, the packet fits within the same number of RBs at that lower MCS.
- MCS 8, 9, and 10 shall not be used.
- The radio shall not use RBs that occupy a number of sub-channels in the range of more than 50% to less than 100% of the total sub-channels per subframe. This means that if the required number of subchannels are more than half of the bandwidth, always use the full bandwidth [REQ-J3161-SPS_004].
- If a packet is large and does not fit using the maximum allowable MCS and sub-channel limits, then UE shall segment or drop the packet as per rules described in ETSI TS 136 321 section 5.14. The segmentation is not permitted under other circumstances. If the choice is to segment the packet, then the segmentation procedure as defined in ETSI TS 136 322 needs to be followed.
- To prevent excessive MAC segmentation, non-IP WSMP frames shall have a maximum transmission unit (MTU) no larger than 4214 Bytes on RSUs and 2924 Bytes on OBUs. These MTU sizes encompass all WSMP headers. Within each unpadded per-subframe transport block (TB), there are additional RLC & PDCP 3GPP headers for each segment REQ-J3161-MTU_001].

The following tables list the mapping between packet size and (MCS, RB) pairs for 20 MHz bandwidth at low and high speeds per the above recommendations for SPS transmissions. All packet sizes and transport block sizes are in bytes.

Table 16 - 20 MHz low speed (<120 km/h)

Unpadded Transport Block Size (including all headers)	≤ 193	194-233	234-277	278-389	390-421	422-597	598-775	776-1063	1064-1239	1240-1479	1480-2124	2125 ≤
MCS	5	6	7	11	7	11	11	11	6	7	11	Segment or drop
RB	18	18	18	18	27	27	36	48	96	96	96	
Padded Transport Block Size	193	233	277	389	421	597	775	1063	1239	1479	2124	

Table 17 - 20 MHz high speed (≥120 km/h)

Unpadded Transport Block Size (including all headers)	≤ 193	194-233	234-277	278-293	294-349	350-421	422-469	470-549	550-621	622-749	750-1063	1064-1239	1240-1479	1479 ≤
MCS	5	6	7	5	6	7	6	7	6	7	5	6	7	Segment or drop
RB	18	18	18	27	27	27	36	36	48	48	96	96	96	
Padded Transport Block Size	193	233	277	293	349	421	469	549	621	749	1063	1239	1479	

NOTE 2: For One-Shot transmissions, the previous tables are used with the following exceptions for speeds below 120 km/h.

Table 18 - 20 MHz low-speed exceptions for one-shot transmissions (<120 km/h)

Unpadded Transport Block Size (including all headers)	278-293	294-349	350-421
MCS	5	6	7
RB	27	27	27
Padded Transport Block Size	293	349	421

NOTE 3: Please note that Tables 16, 17, and 18 provide MCS value for the transport block. However, the sidelink control information (SCI) always uses QPSK modulation scheme.

9. NOTES

9.1 Revision Indicator

A change bar (I) located in the left margin is for the convenience of the user in locating areas where technical revisions, not editorial changes, have been made to the previous issue of this document. An (R) symbol to the left of the document title indicates a complete revision of the document, including technical revisions. Change bars and (R) are not used in original publications, nor in documents that contain editorial changes only.

PREPARED BY SAE C-V2X TECHNICAL COMMITTEE

APPENDIX A - PPPP TO PDB MAPPING

This an export from ETSI TS 124 385 XML configuration.


```
<V2X>
<V2XoverPC5>
<PPPPtoPDBMappingRule>
      <Rule2>
        <ProSePerPacketPriority>2</ProSePerPacketPriority>
        <PacketDelayBudget>50</PacketDelayBudget>
      </Rule2>
      <Rule3>
        <ProSePerPacketPriority>3</ProSePerPacketPriority>
        <PacketDelayBudget>100</PacketDelayBudget>
      </Rule3>
      <Rule4>
        <ProSePerPacketPriority>4</ProSePerPacketPriority>
        <PacketDelayBudget>100</PacketDelayBudget>
      </Rule4>
      <Rule5>
        <ProSePerPacketPriority>5</ProSePerPacketPriority>
        <PacketDelayBudget>100</PacketDelayBudget>
      </Rule5>
      <Rule6>
        <ProSePerPacketPriority>6</ProSePerPacketPriority>
        <PacketDelayBudget>100</PacketDelayBudget>
      </Rule6>
      <Rule7>
        <ProSePerPacketPriority>7</ProSePerPacketPriority>
        <PacketDelayBudget>100</PacketDelayBudget>
      </Rule7>
      <Rule8>
        <ProSePerPacketPriority>8</ProSePerPacketPriority>
        <PacketDelayBudget>100</PacketDelayBudget>
      </Rule8>
</PPPPtoPDBMappingRule>
</V2XoverPC5>
</V2X>
```

APPENDIX B - ASN.1 FOR OBU

Below is an example ASN.1 file that implements the configuration parameters for OBU.

```
{
  value1 SL-V2X-Preconfiguration-r14 ::=
{
  v2x-PreconfigFreqList-r14
  {
    {
      v2x-CommPreconfigGeneral-r14
      {
        rohc-Profiles-r12
        {
          profile0x0001-r12 FALSE,
          profile0x0002-r12 FALSE,
          profile0x0004-r12 FALSE,
          profile0x0006-r12 FALSE,
          profile0x0101-r12 FALSE,
          profile0x0102-r12 FALSE,
          profile0x0104-r12 FALSE
        },
        carrierFreq-r12 55140,
        maxTxPower-r12 23,
        additionalSpectrumEmission-r12 32,
        sl-bandwidth-r12 n100,
        tdd-ConfigSL-r12
        {
          subframeAssignmentSL-r12 none
        },
        reserved-r12 '00000000 00000000 000'B
      },
      v2x-CommPreconfigSync-r14
      {
        syncOffsetIndicators-r14
        {
          syncOffsetIndicator1-r14 0,
          syncOffsetIndicator2-r14 80
        },
        syncTxParameters-r14 -126,
        syncTxThreshOoC-r14 0,
        filterCoefficient-r14 fc0,
        syncRefMinHyst-r14 dB0,
        syncRefDiffHyst-r14 dB6
      },
      v2x-CommRxPoolList-r14
      {
        {
          sl-Subframe-r14 bs20-r14 : '11111111 11111111 1111'B,
          adjacencyPSCCH-PSSCH-r14 TRUE,
          sizeSubchannel-r14 n10,
          numSubchannel-r14 n10,
          startRB-Subchannel-r14 0,
          dataTxParameters-r14 23
        }
      },
      v2x-CommTxPoolList-r14
      {
        {
          sl-Subframe-r14 bs20-r14 : '11111111 11111111 1111'B,
          adjacencyPSCCH-PSSCH-r14 TRUE,
          sizeSubchannel-r14 n10,
          numSubchannel-r14 n10,
          startRB-Subchannel-r14 0,
          dataTxParameters-r14 23,
          threshS-RSSI-CBR-r14 9,
          cbr-pssch-TxConfigList-r14
          {
            {
              priorityThreshold-r14 2,
              defaultTxConfigIndex-r14 2,
              cbr-ConfigIndex-r14 0,
              tx-ConfigIndexList-r14
              {
```

```
            0,
            1,
            2
          }
        },
        {
          priorityThreshold-r14 3,
          defaultTxConfigIndex-r14 2,
          cbr-ConfigIndex-r14 0,
          tx-ConfigIndexList-r14
          {
            3,
            4,
            5
          }
        },
        {
          priorityThreshold-r14 5,
          defaultTxConfigIndex-r14 2,
          cbr-ConfigIndex-r14 0,
          tx-ConfigIndexList-r14
          {
            6,
            7,
            8
          }
        },
        {
          priorityThreshold-r14 6,
          defaultTxConfigIndex-r14 2,
          cbr-ConfigIndex-r14 0,
          tx-ConfigIndexList-r14
          {
            9,
            10,
            11
          }
        },
        {
          priorityThreshold-r14 7,
          defaultTxConfigIndex-r14 2,
          cbr-ConfigIndex-r14 0,
          tx-ConfigIndexList-r14
          {
            12,
            13,
            14
          }
        },
        {
          priorityThreshold-r14 8,
          defaultTxConfigIndex-r14 2,
          cbr-ConfigIndex-r14 0,
          tx-ConfigIndexList-r14
          {
            15,
            16,
            17
          }
        }
      },
      syncAllowed-r14
      {
        gnss-Sync-r14 true
      }
    }
  },
  p2x-CommTxPoolList-r14
  {
    {
      sl-Subframe-r14 bs10-r14 : '00000000 00'B,
      adjacencyPSCCH-PSSCH-r14 FALSE,
      sizeSubchannel-r14 n4,
      numSubchannel-r14 n1,
      startRB-Subchannel-r14 0,
      dataTxParameters-r14 -126
```

```
        }
      },
      v2x-ResourceSelectionConfig-r14
      {
        pssch-TxConfigList-r14
        {
          {
            thresUE-Speed-r14 kmph120,
            parametersAboveThres-r14
            {
              minMCS-PSSCH-r14 0,
              maxMCS-PSSCH-r14 7,
              minSubChannel-NumberPSSCH-r14 2,
              maxSubchannel-NumberPSSCH-r14 10,
              allowedRetxNumberPSSCH-r14 both,
              maxTxPower-r14 txPower-r14 : 23
            },
            parametersBelowThres-r14
            {
              minMCS-PSSCH-r14 5,
              maxMCS-PSSCH-r14 11,
              minSubChannel-NumberPSSCH-r14 2,
              maxSubchannel-NumberPSSCH-r14 10,
              allowedRetxNumberPSSCH-r14 both,
              maxTxPower-r14 txPower-r14 : 23
            }
          }
        },
        thresPSSCH-RSRP-List-r14
        {
          2,
          2,
          7,
          11,
          11,
          16,
          18,
          20,
          2,
          2,
          7,
          11,
          11,
          16,
          18,
          20,
          2,
          2,
          7,
          11,
          11,
          16,
          18,
          20,
          2,
          2,
          7,
          11,
          11,
          16,
          18,
          20,
          2,
          2,
          7,
          11,
          11,
          16,
          18,
          20,
          2,
          2,
          7,
          11,
          11,
          16,
```

```
          18,
          20,
          2,
          2,
          7,
          11,
          11,
          16,
          18,
          20,
          2,
          2,
          7,
          11,
          11,
          16,
          18,
          20
        },
        restrictResourceReservationPeriod-r14
        {
          v0dot5,
          v1,
          v2,
          v3,
          v4,
          v5,
          v6,
          v7,
          v8,
          v9,
          v10
        },
        probResourceKeep-r14 v0dot8,
        sl-ReselectAfter-r14 n6
      },
      syncPriority-r14 gnss
    }
  },
  cbr-PreconfigList-r14
  {
    cbr-RangeCommonConfigList-r14
    {
      {
        30,
        65,
        100
      }
    },
    sl-CBR-PSSCH-TxConfigList-r14
    {
      {
        cr-Limit-r14 1000,
        tx-Parameters-r14
        {
          minMCS-PSSCH-r14 0,
          maxMCS-PSSCH-r14 11,
          minSubChannel-NumberPSSCH-r14 2,
          maxSubchannel-NumberPSSCH-r14 10,
          allowedRetxNumberPSSCH-r14 both,
          maxTxPower-r14 txPower-r14 : 23
        }
      },
      {
        cr-Limit-r14 500,
        tx-Parameters-r14
        {
          minMCS-PSSCH-r14 0,
          maxMCS-PSSCH-r14 11,
          minSubChannel-NumberPSSCH-r14 2,
          maxSubchannel-NumberPSSCH-r14 10,
          allowedRetxNumberPSSCH-r14 both,
          maxTxPower-r14 txPower-r14 : 23
        }
      },
      {
```

```
        cr-Limit-r14 250,
        tx-Parameters-r14
        {
          minMCS-PSSCH-r14 0,
          maxMCS-PSSCH-r14 11,
          minSubChannel-NumberPSSCH-r14 2,
          maxSubchannel-NumberPSSCH-r14 10,
          allowedRetxNumberPSSCH-r14 both,
          maxTxPower-r14 txPower-r14 : 23
        }
      },
      {
        cr-Limit-r14 1000,
        tx-Parameters-r14
        {
          minMCS-PSSCH-r14 0,
          maxMCS-PSSCH-r14 11,
          minSubChannel-NumberPSSCH-r14 2,
          maxSubchannel-NumberPSSCH-r14 10,
          allowedRetxNumberPSSCH-r14 both,
          maxTxPower-r14 txPower-r14 : 23
        }
      },
      {
        cr-Limit-r14 500,
        tx-Parameters-r14
        {
          minMCS-PSSCH-r14 0,
          maxMCS-PSSCH-r14 11,
          minSubChannel-NumberPSSCH-r14 2,
          maxSubchannel-NumberPSSCH-r14 10,
          allowedRetxNumberPSSCH-r14 both,
          maxTxPower-r14 txPower-r14 : 23
        }
      },
      {
        cr-Limit-r14 250,
        tx-Parameters-r14
        {
          minMCS-PSSCH-r14 0,
          maxMCS-PSSCH-r14 11,
          minSubChannel-NumberPSSCH-r14 2,
          maxSubchannel-NumberPSSCH-r14 10,
          allowedRetxNumberPSSCH-r14 both,
          maxTxPower-r14 txPower-r14 : 23
        }
      },
      {
        cr-Limit-r14 800,
        tx-Parameters-r14
        {
          minMCS-PSSCH-r14 0,
          maxMCS-PSSCH-r14 11,
          minSubChannel-NumberPSSCH-r14 2,
          maxSubchannel-NumberPSSCH-r14 10,
          allowedRetxNumberPSSCH-r14 both,
          maxTxPower-r14 txPower-r14 : 23
        }
      },
      {
        cr-Limit-r14 300,
        tx-Parameters-r14
        {
          minMCS-PSSCH-r14 0,
          maxMCS-PSSCH-r14 11,
          minSubChannel-NumberPSSCH-r14 2,
          maxSubchannel-NumberPSSCH-r14 10,
          allowedRetxNumberPSSCH-r14 both,
          maxTxPower-r14 txPower-r14 : 23
        }
      },
      {
        cr-Limit-r14 150,
        tx-Parameters-r14
        {
          minMCS-PSSCH-r14 0,
```

```
        maxMCS-PSSCH-r14 11,
        minSubChannel-NumberPSSCH-r14 2,
        maxSubchannel-NumberPSSCH-r14 10,
        allowedRetxNumberPSSCH-r14 both,
        maxTxPower-r14 txPower-r14 : 23
      }
    },
    {
      cr-Limit-r14 400,
      tx-Parameters-r14
      {
        minMCS-PSSCH-r14 0,
        maxMCS-PSSCH-r14 11,
        minSubChannel-NumberPSSCH-r14 2,
        maxSubchannel-NumberPSSCH-r14 10,
        allowedRetxNumberPSSCH-r14 both,
        maxTxPower-r14 txPower-r14 : 23
      }
    },
    {
      cr-Limit-r14 100,
      tx-Parameters-r14
      {
        minMCS-PSSCH-r14 0,
        maxMCS-PSSCH-r14 11,
        minSubChannel-NumberPSSCH-r14 2,
        maxSubchannel-NumberPSSCH-r14 10,
        allowedRetxNumberPSSCH-r14 both,
        maxTxPower-r14 txPower-r14 : 23
      }
    },
    {
      cr-Limit-r14 50,
      tx-Parameters-r14
      {
        minMCS-PSSCH-r14 0,
        maxMCS-PSSCH-r14 11,
        minSubChannel-NumberPSSCH-r14 2,
        maxSubchannel-NumberPSSCH-r14 10,
        allowedRetxNumberPSSCH-r14 both,
        maxTxPower-r14 txPower-r14 : 23
      }
    },
    {
      cr-Limit-r14 400,
      tx-Parameters-r14
      {
        minMCS-PSSCH-r14 0,
        maxMCS-PSSCH-r14 11,
        minSubChannel-NumberPSSCH-r14 2,
        maxSubchannel-NumberPSSCH-r14 10,
        allowedRetxNumberPSSCH-r14 both,
        maxTxPower-r14 txPower-r14 : 23
      }
    },
    {
      cr-Limit-r14 50,
      tx-Parameters-r14
      {
        minMCS-PSSCH-r14 0,
        maxMCS-PSSCH-r14 11,
        minSubChannel-NumberPSSCH-r14 2,
        maxSubchannel-NumberPSSCH-r14 10,
        allowedRetxNumberPSSCH-r14 both,
        maxTxPower-r14 txPower-r14 : 23
      }
    },
    {
      cr-Limit-r14 0,
      tx-Parameters-r14
      {
        minMCS-PSSCH-r14 0,
        maxMCS-PSSCH-r14 11,
        minSubChannel-NumberPSSCH-r14 2,
        maxSubchannel-NumberPSSCH-r14 10,
        allowedRetxNumberPSSCH-r14 both,
```

```
          maxTxPower-r14 txPower-r14 : 23
        }
      },
      {
        cr-Limit-r14 400,
        tx-Parameters-r14
        {
          minMCS-PSSCH-r14 0,
          maxMCS-PSSCH-r14 11,
          minSubChannel-NumberPSSCH-r14 2,
          maxSubchannel-NumberPSSCH-r14 10,
          allowedRetxNumberPSSCH-r14 both,
          maxTxPower-r14 txPower-r14 : 23
        }
      },
      {
        cr-Limit-r14 0,
        tx-Parameters-r14
        {
          minMCS-PSSCH-r14 0,
          maxMCS-PSSCH-r14 11,
          minSubChannel-NumberPSSCH-r14 2,
          maxSubchannel-NumberPSSCH-r14 10,
          allowedRetxNumberPSSCH-r14 both,
          maxTxPower-r14 txPower-r14 : 23
        }
      },
      {
        cr-Limit-r14 0,
        tx-Parameters-r14
        {
          minMCS-PSSCH-r14 0,
          maxMCS-PSSCH-r14 11,
          minSubChannel-NumberPSSCH-r14 2,
          maxSubchannel-NumberPSSCH-r14 10,
          allowedRetxNumberPSSCH-r14 both,
          maxTxPower-r14 txPower-r14 : 23
        }
      }
    }
  }
}
```

APPENDIX C – ASN.1 FOR RSU

Below is an example ASN.1 that implements the configuration parameters for RSU.

```
{
  value1 SL-V2X-Preconfiguration-r14 ::=
{
  v2x-PreconfigFreqList-r14
  {
    {
      v2x-CommPreconfigGeneral-r14
      {
        rohc-Profiles-r12
        {
          profile0x0001-r12 FALSE,
          profile0x0002-r12 FALSE,
          profile0x0004-r12 FALSE,
          profile0x0006-r12 FALSE,
          profile0x0101-r12 FALSE,
          profile0x0102-r12 FALSE,
          profile0x0104-r12 FALSE
        },
        carrierFreq-r12 55140,
        maxTxPower-r12 23,
        additionalSpectrumEmission-r12 32,
        sl-bandwidth-r12 n100,
        tdd-ConfigSL-r12
        {
          subframeAssignmentSL-r12 none
        },
        reserved-r12 '00000000 00000000 000'B
      },
      v2x-CommPreconfigSync-r14
      {
        syncOffsetIndicators-r14
        {
          syncOffsetIndicator1-r14 0,
          syncOffsetIndicator2-r14 80
        },
        syncTxParameters-r14 23,
        syncTxThreshOoC-r14 11,
        filterCoefficient-r14 fc0,
        syncRefMinHyst-r14 dB0,
        syncRefDiffHyst-r14 dBinf
      },
      v2x-CommRxPoolList-r14
      {
        {
          sl-Subframe-r14 bs20-r14 : '11111111 11111111 1111'B,
          adjacencyPSCCH-PSSCH-r14 TRUE,
          sizeSubchannel-r14 n10,
          numSubchannel-r14 n10,
          startRB-Subchannel-r14 0,
          dataTxParameters-r14 23
        }
      },
      v2x-CommTxPoolList-r14
      {
        {
          sl-Subframe-r14 bs20-r14 : '11111111 11111111 1111'B,
          adjacencyPSCCH-PSSCH-r14 TRUE,
          sizeSubchannel-r14 n10,
          numSubchannel-r14 n10,
          startRB-Subchannel-r14 0,
          dataTxParameters-r14 23,
          threshS-RSSI-CBR-r14 9,
          cbr-pssch-TxConfigList-r14
          {
            {
              priorityThreshold-r14 3,
              defaultTxConfigIndex-r14 2,
              cbr-ConfigIndex-r14 0,
              tx-ConfigIndexList-r14
              {
```

```
            0,
            1,
            2
          }
        },
        {
          priorityThreshold-r14 5,
          defaultTxConfigIndex-r14 2,
          cbr-ConfigIndex-r14 0,
          tx-ConfigIndexList-r14
          {
            3,
            4,
            5
          }
        },
        {
          priorityThreshold-r14 6,
          defaultTxConfigIndex-r14 2,
          cbr-ConfigIndex-r14 0,
          tx-ConfigIndexList-r14
          {
            6,
            7,
            8
          }
        },
        {
          priorityThreshold-r14 7,
          defaultTxConfigIndex-r14 2,
          cbr-ConfigIndex-r14 0,
          tx-ConfigIndexList-r14
          {
            9,
            10,
            11
          }
        },
        {
          priorityThreshold-r14 8,
          defaultTxConfigIndex-r14 2,
          cbr-ConfigIndex-r14 0,
          tx-ConfigIndexList-r14
          {
            12,
            13,
            14
          }
        }
      },
      syncAllowed-r14
      {
        gnss-Sync-r14 true
      }
    }
  },
  p2x-CommTxPoolList-r14
  {
    {
      sl-Subframe-r14 bs10-r14 : '00000000 00'B,
      adjacencyPSCCH-PSSCH-r14 FALSE,
      sizeSubchannel-r14 n4,
      numSubchannel-r14 n1,
      startRB-Subchannel-r14 0,
      dataTxParameters-r14 -126
    }
  },
  v2x-ResourceSelectionConfig-r14
  {
    pssch-TxConfigList-r14
    {
      {
        thresUE-Speed-r14 kmph120,
        parametersAboveThres-r14
        {
          minMCS-PSSCH-r14 5,
```

```
            maxMCS-PSSCH-r14 11,
            minSubChannel-NumberPSSCH-r14 2,
            maxSubchannel-NumberPSSCH-r14 10,
            allowedRetxNumberPSSCH-r14 both,
            maxTxPower-r14 txPower-r14 : 23
          },
          parametersBelowThres-r14
          {
            minMCS-PSSCH-r14 5,
            maxMCS-PSSCH-r14 11,
            minSubChannel-NumberPSSCH-r14 2,
            maxSubchannel-NumberPSSCH-r14 10,
            allowedRetxNumberPSSCH-r14 both,
            maxTxPower-r14 txPower-r14 : 23
          }
        }
      },
      thresPSSCH-RSRP-List-r14
      {
        2,
        2,
        7,
        11,
        11,
        16,
        18,
        20,
        2,
        2,
        7,
        11,
        11,
        16,
        18,
        20,
        2,
        2,
        7,
        11,
        11,
        16,
        18,
        20,
        2,
        2,
        7,
        11,
        11,
        16,
        18,
        20,
        2,
        2,
        7,
        11,
        11,
        16,
        18,
        20,
        2,
        2,
        7,
        11,
        11,
        16,
        18,
        20,
        2,
        2,
        7,
        11,
        11,
        16,
        18,
        20,
        2,
```

```
        2,
        7,
        11,
        11,
        16,
        18,
        20
      },
      restrictResourceReservationPeriod-r14
      {
        v0dot5,
        v1,
        v2,
        v3,
        v4,
        v5,
        v6,
        v7,
        v8,
        v9,
        v10
      },
      probResourceKeep-r14 v0dot8,
      sl-ReselectAfter-r14 n6
    },
    syncPriority-r14 gnss
  }
},
cbr-PreconfigList-r14
{
  cbr-RangeCommonConfigList-r14
  {
    {
      30,
      65,
      100
    }
  },
  sl-CBR-PSSCH-TxConfigList-r14
  {
    {
      cr-Limit-r14 1000,
      tx-Parameters-r14
      {
        minMCS-PSSCH-r14 0,
        maxMCS-PSSCH-r14 11,
        minSubChannel-NumberPSSCH-r14 2,
        maxSubchannel-NumberPSSCH-r14 10,
        allowedRetxNumberPSSCH-r14 both,
        maxTxPower-r14 txPower-r14 : 23
      }
    },
    {
      cr-Limit-r14 500,
      tx-Parameters-r14
      {
        minMCS-PSSCH-r14 0,
        maxMCS-PSSCH-r14 11,
        minSubChannel-NumberPSSCH-r14 2,
        maxSubchannel-NumberPSSCH-r14 10,
        allowedRetxNumberPSSCH-r14 both,
        maxTxPower-r14 txPower-r14 : 23
      }
    },
    {
      cr-Limit-r14 250,
      tx-Parameters-r14
      {
        minMCS-PSSCH-r14 0,
        maxMCS-PSSCH-r14 11,
        minSubChannel-NumberPSSCH-r14 2,
        maxSubchannel-NumberPSSCH-r14 10,
        allowedRetxNumberPSSCH-r14 both,
        maxTxPower-r14 txPower-r14 : 23
      }
    },
```

```
      {
        cr-Limit-r14 800,
        tx-Parameters-r14
        {
          minMCS-PSSCH-r14 0,
          maxMCS-PSSCH-r14 11,
          minSubChannel-NumberPSSCH-r14 2,
          maxSubchannel-NumberPSSCH-r14 10,
          allowedRetxNumberPSSCH-r14 both,
          maxTxPower-r14 txPower-r14 : 23
        }
      },
      {
        cr-Limit-r14 300,
        tx-Parameters-r14
        {
          minMCS-PSSCH-r14 0,
          maxMCS-PSSCH-r14 11,
          minSubChannel-NumberPSSCH-r14 2,
          maxSubchannel-NumberPSSCH-r14 10,
          allowedRetxNumberPSSCH-r14 both,
          maxTxPower-r14 txPower-r14 : 23
        }
      },
      {
        cr-Limit-r14 150,
        tx-Parameters-r14
        {
          minMCS-PSSCH-r14 0,
          maxMCS-PSSCH-r14 11,
          minSubChannel-NumberPSSCH-r14 2,
          maxSubchannel-NumberPSSCH-r14 10,
          allowedRetxNumberPSSCH-r14 both,
          maxTxPower-r14 txPower-r14 : 23
        }
      },
      {
        cr-Limit-r14 400,
        tx-Parameters-r14
        {
          minMCS-PSSCH-r14 0,
          maxMCS-PSSCH-r14 11,
          minSubChannel-NumberPSSCH-r14 2,
          maxSubchannel-NumberPSSCH-r14 10,
          allowedRetxNumberPSSCH-r14 both,
          maxTxPower-r14 txPower-r14 : 23
        }
      },
      {
        cr-Limit-r14 100,
        tx-Parameters-r14
        {
          minMCS-PSSCH-r14 0,
          maxMCS-PSSCH-r14 11,
          minSubChannel-NumberPSSCH-r14 2,
          maxSubchannel-NumberPSSCH-r14 10,
          allowedRetxNumberPSSCH-r14 both,
          maxTxPower-r14 txPower-r14 : 23
        }
      },
      {
        cr-Limit-r14 50,
        tx-Parameters-r14
        {
          minMCS-PSSCH-r14 0,
          maxMCS-PSSCH-r14 11,
          minSubChannel-NumberPSSCH-r14 2,
          maxSubchannel-NumberPSSCH-r14 10,
          allowedRetxNumberPSSCH-r14 both,
          maxTxPower-r14 txPower-r14 : 23
        }
      },
      {
        cr-Limit-r14 400,
        tx-Parameters-r14
        {
```

```
          minMCS-PSSCH-r14 0,
          maxMCS-PSSCH-r14 11,
          minSubChannel-NumberPSSCH-r14 2,
          maxSubchannel-NumberPSSCH-r14 10,
          allowedRetxNumberPSSCH-r14 both,
          maxTxPower-r14 txPower-r14 : 23
        }
      },
      {
        cr-Limit-r14 50,
        tx-Parameters-r14
        {
          minMCS-PSSCH-r14 0,
          maxMCS-PSSCH-r14 11,
          minSubChannel-NumberPSSCH-r14 2,
          maxSubchannel-NumberPSSCH-r14 10,
          allowedRetxNumberPSSCH-r14 both,
          maxTxPower-r14 txPower-r14 : 23
        }
      },
      {
        cr-Limit-r14 0,
        tx-Parameters-r14
        {
          minMCS-PSSCH-r14 0,
          maxMCS-PSSCH-r14 11,
          minSubChannel-NumberPSSCH-r14 2,
          maxSubchannel-NumberPSSCH-r14 10,
          allowedRetxNumberPSSCH-r14 both,
          maxTxPower-r14 txPower-r14 : 23
        }
      },
      {
        cr-Limit-r14 400,
        tx-Parameters-r14
        {
          minMCS-PSSCH-r14 0,
          maxMCS-PSSCH-r14 11,
          minSubChannel-NumberPSSCH-r14 2,
          maxSubchannel-NumberPSSCH-r14 10,
          allowedRetxNumberPSSCH-r14 both,
          maxTxPower-r14 txPower-r14 : 23
        }
      },
      {
        cr-Limit-r14 0,
        tx-Parameters-r14
        {
          minMCS-PSSCH-r14 0,
          maxMCS-PSSCH-r14 11,
          minSubChannel-NumberPSSCH-r14 2,
          maxSubchannel-NumberPSSCH-r14 10,
          allowedRetxNumberPSSCH-r14 both,
          maxTxPower-r14 txPower-r14 : 23
        }
      },
      {
        cr-Limit-r14 0,
        tx-Parameters-r14
        {
          minMCS-PSSCH-r14 0,
          maxMCS-PSSCH-r14 11,
          minSubChannel-NumberPSSCH-r14 2,
          maxSubchannel-NumberPSSCH-r14 10,
          allowedRetxNumberPSSCH-r14 both,
          maxTxPower-r14 txPower-r14 : 23
        }
      }
    }
  }
}
}
```