



SURFACE VEHICLE STANDARD	J3161™	JUL2024
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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
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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/tmguid/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 ("PSOBV").

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 interdisciplinary 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
PDCCP	Packet Data Convergence Protocol
PDCCP 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.

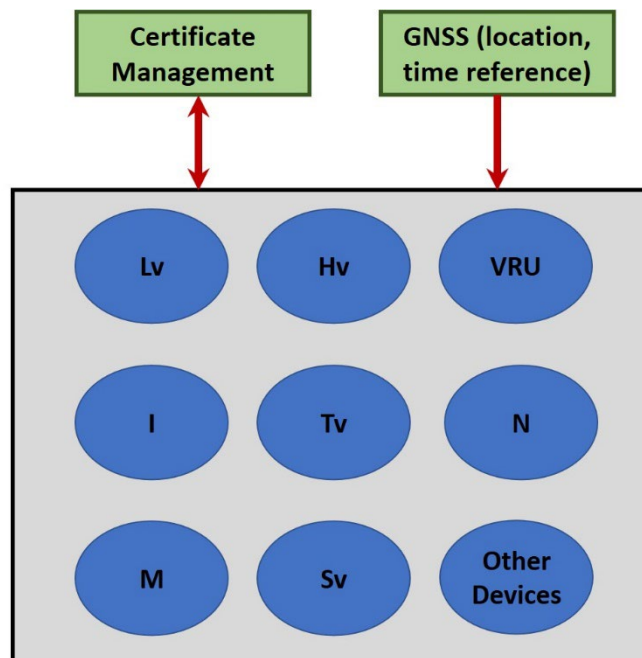


Figure 1 - Connected transportation (system of systems)

Systems:

- a. Vehicle system ($V \leftrightarrow V$)²
- b. Infrastructure system ($V \leftrightarrow I$)
- c. Network system ($V \leftrightarrow N$)
- d. Light vehicle (Lv) system ($V \leftrightarrow Lv$, $Lv \leftrightarrow I$)
- e. Heavy vehicle (Hv) system ($V \leftrightarrow Hv$, $Hv \leftrightarrow I$)
- f. Transit vehicle (Tv) system ($V \leftrightarrow Tv$, $Tv \leftrightarrow I$)
- g. Motorcycle (M) system ($V \leftrightarrow M$, $M \leftrightarrow I$)
- g. Safety vehicle (Sv) system ($V \leftrightarrow Sv$, $Sv \leftrightarrow I$)
- h. Vulnerable road user system ($V \leftrightarrow VRU$, $N \leftrightarrow VRU$, $VRU \leftrightarrow I$)
- 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.

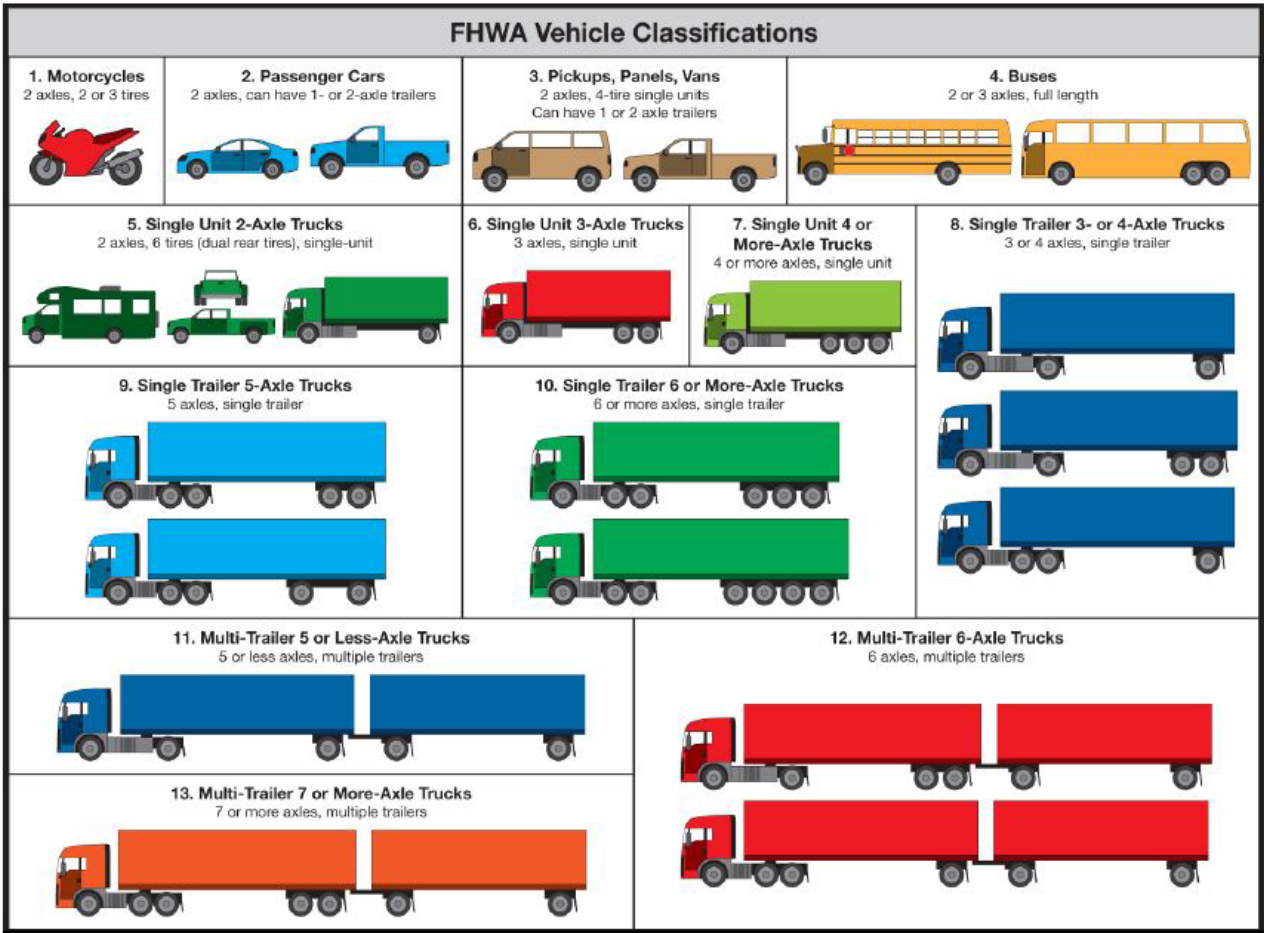


Figure 2 - Vehicle classification using FHWA 13 - category scheme

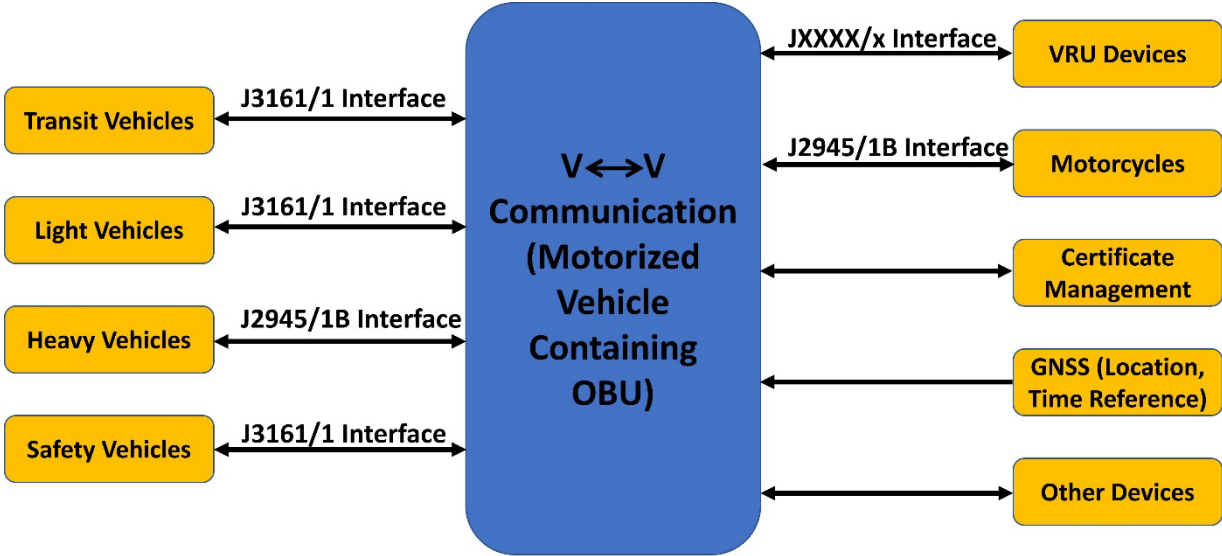


Figure 3 - Vehicle-to-vehicle (V2V) context diagram for LTE-V2X

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.

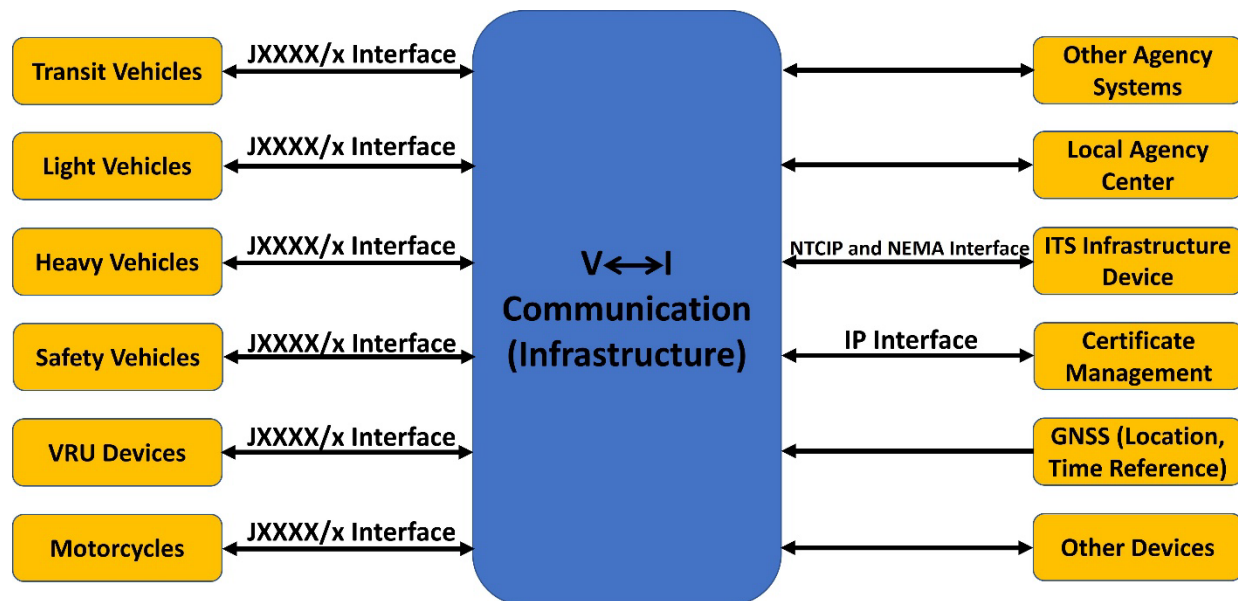


Figure 4 - Vehicle-to-infrastructure (V2I) context diagram³

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.

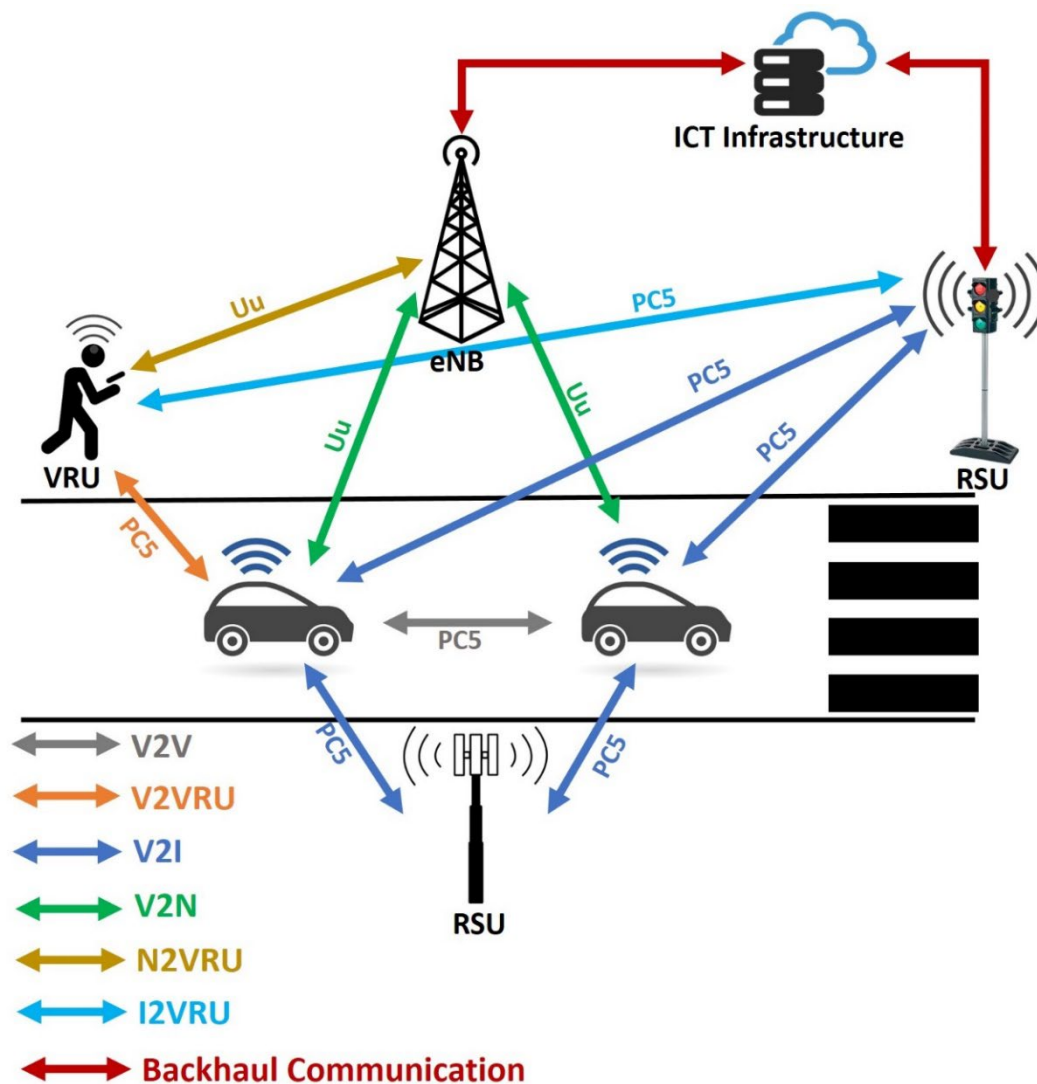


Figure 5 - LTE-V2X system architecture

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 width⁵. 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.

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.

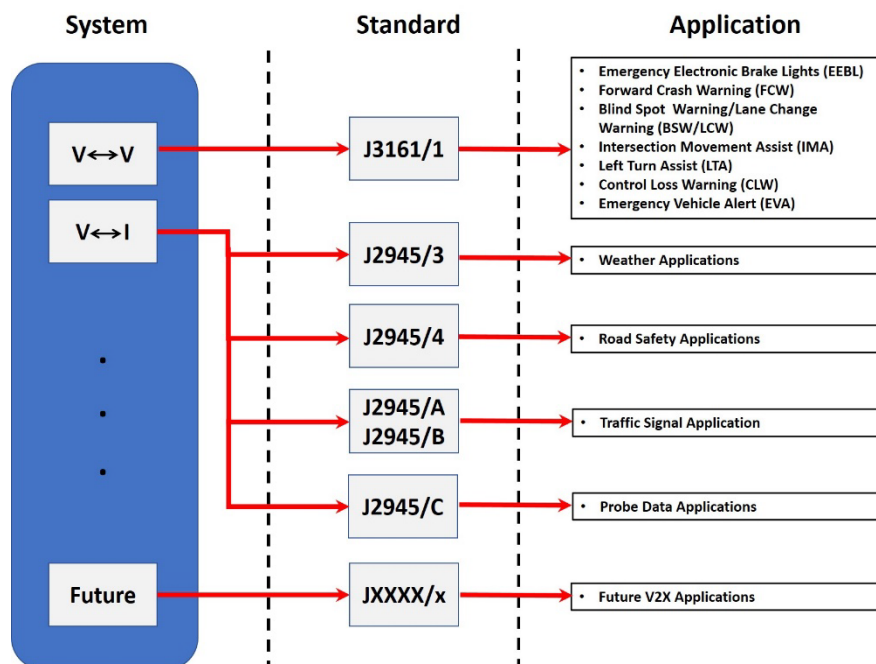


Figure 6 - Relationship of system and SAE Standards⁷

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).

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).

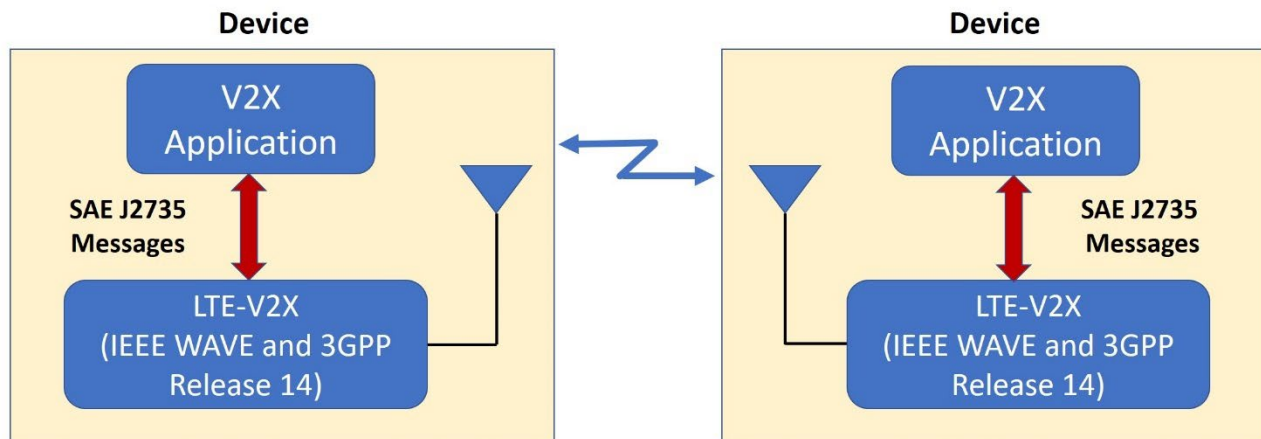


Figure 7 - Use of LTE-V2X for SAE J2735 message set

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.

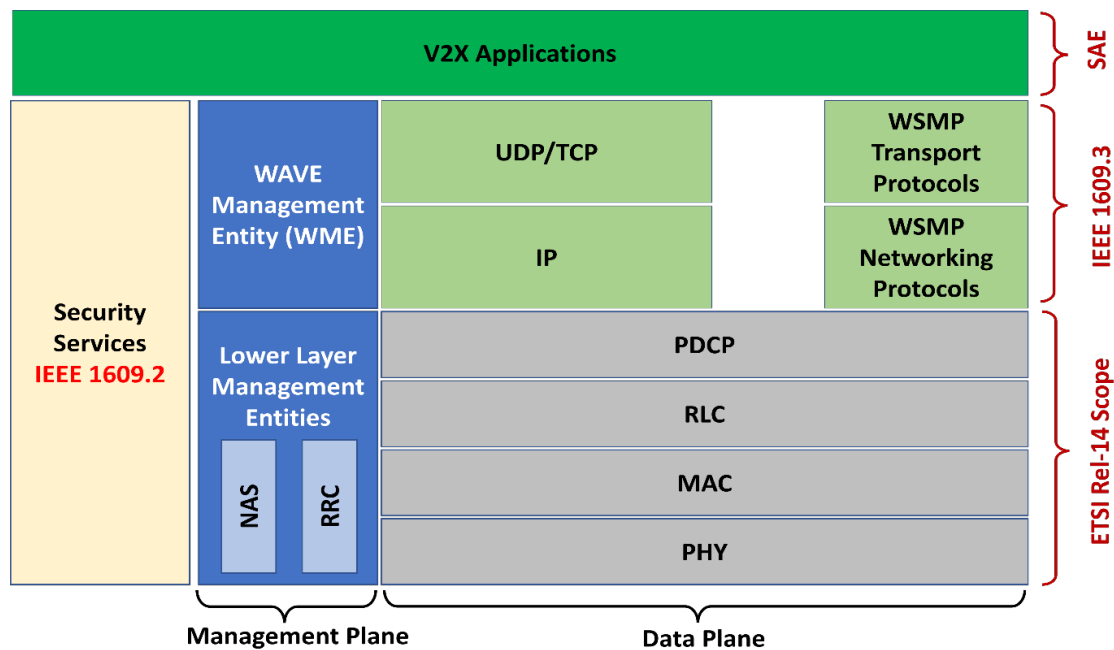


Figure 8 - LTE-V2X protocol stack

- 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.
- 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.
- 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.