



SURFACE VEHICLE STANDARD

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

RATIONALE

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

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1. SCOPE

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

1.1 Purpose

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

2. REFERENCES

2.1 Applicable Documents

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

2.1.1 SAE Publications

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

SAE J2735	V2X Communications Message Set Dictionary
SAE J2945/1	On-Board System Requirements for V2V Safety Communications
SAE J3161/1	On-Board System Requirements for LTE-V2X V2V Safety Communications

2.1.2 ETSI/3GPP Publications

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

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

ETSI TS 136 213	Evolved Universal Terrestrial Radio Access (E-UTRA); Physical layer procedures, V14.2.0 (Release 14) [3GPP TS 36.213]
ETSI TS 136 300	Evolved Universal Terrestrial Radio Access (E-UTRA) and Evolved Universal Terrestrial Radio Access Network (E-UTRAN); Overall Description; Stage 2, V14.2.0 (Release 14) [3GPP TS 36.300]
ETSI TS 136 321	Evolved Universal Terrestrial Radio Access (E-UTRA); Medium Access Control (MAC) protocol specification, V14.2.1 (Release 14) [3GPP TS 36.321]
ETSI TS 136 322	Evolved Universal Terrestrial Radio Access (E-UTRA); Radio Link Control (RLC) protocol specification, V14.1.0 (Release 14) [3GPP TS 36.322]

These documents may reference other related ETSI documents.¹

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

2.1.3 IEEE Publications

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

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

IEEE Std 1609.2-2016	IEEE Standard for Wireless Access in Vehicular Environments - Security Services for Applications and Management Messages (as amended by IEEE Std 1609.2a-2017 and IEEE Std 1609.2b-2019)
IEEE Std 1609.3-2020	IEEE Standard for Wireless Access in Vehicular Environments (WAVE) - Networking Services
IEEE Std 1609.12-2019	IEEE Standard for Wireless Access in Vehicular Environments (WAVE) - Identifier Allocations

2.1.4 NTCIP Publications

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

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

2.2 Related Publications

Refer to SAE J2945/1, 2.2.

3. TERMS AND DEFINITIONS

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

3.1 ACTOR

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

3.2 CERTIFICATE AUTHORITY (CA)

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

3.3 CERTIFICATE MANAGEMENT

The definition, ordering, generation, provisioning (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).

3.4 CHANNEL

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

3.5 CONNECTED VEHICLE

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

3.6 CONTEXT DIAGRAM

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

3.7 DATA PLANE

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

3.8 DEVICE

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

3.9 DIALOG

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

3.10 DRIVER

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

3.11 GLOBAL NAVIGATION SATELLITE SYSTEM (GNSS)

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

3.12 HEAVY VEHICLE

Vehicles with a FHWA vehicle classification of 5 to 13.

3.13 HOST VEHICLE (HV)

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

3.14 V2X INFRASTRUCTURE

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

3.15 INTELLIGENT TRANSPORTATION SYSTEM (ITS)

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

3.16 LIGHT VEHICLE

A class 2 or class 3 vehicle as defined by FHWA (https://www.fhwa.dot.gov/policyinformation/tmguidetmg_2013/vehicle-types.cfm) excluding ambulances, law enforcement vehicles, fire department vehicles, and construction vehicles.

3.17 LINK (RF)

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

3.18 MANAGEMENT INFORMATION BASE

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

3.19 MESSAGE

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

3.20 MESSAGE SET

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

3.21 NETWORKING SERVICES

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

3.22 ON-BOARD UNIT (OBU)

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

3.23 PACKET DELAY BUDGET (PDB)

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

3.24 PROVIDER SERVICE CONTEXT (PSC)

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

3.25 REFERENCE LANE

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

3.26 ROADSIDE UNIT (RSU)

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

3.27 SAFETY VEHICLE

A vehicle used for emergency or incident management.

3.28 STANDARDS DEVELOPING ORGANIZATION

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

3.29 SYNTAX

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

3.30 SYSTEM

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

3.31 SYSTEM OF SYSTEMS

Applies to a system-of-interest whose system elements are themselves systems; typically, these entail large scale 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)

3.32 TRANSIT VEHICLE

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

3.33 VALIDATION

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

3.34 VERIFICATION

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

4. ABBREVIATIONS AND ACRONYMS

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

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

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

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

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

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

5. INTRODUCTION TO THE LTE-V2X SYSTEM AND STANDARDS

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

5.1 Intelligent Transportation System (ITS)

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

5.2 Connected Transportation System Context Diagram

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