

V2X Sensor-Sharing for Cooperative and Automated Driving

RATIONALE

Accurate knowledge of road conditions, road obstacles, and road users is required for Roadside Units (RSUs) and V2X vehicles to make safe and efficient driving decisions. Cooperative and automated driving through vehicle-to-vehicle, vehicle-to-RSU, or RSU-to-vehicle communication requires accurate knowledge of the driving environment. Defining a V2X message structure and information elements for RSUs and vehicles to exchange information on detected objects and road users is a prerequisite for these capabilities.

TABLE OF CONTENTS

1.	SCOPE.....	3
2.	REFERENCES.....	3
2.1	Applicable Documents	3
2.1.1	SAE Publications.....	3
2.1.2	IEEE Publications.....	3
2.1.3	TSI-ITS Publications	4
2.1.4	American Association of State Highway and Transportation Officials Publications	4
2.2	Related Publications	4
2.2.1	5GAA Publications	4
3.	TERMS AND DEFINITIONS	4
3.1	Definitions	4
3.2	Abbreviations and Acronyms	5
4.	CONCEPT OF OPERATION AND SYSTEM DESCRIPTION.....	6
4.1	SSS System Overview	6
4.2	SSS Use cases	7
4.2.1	Overview	7
4.2.2	Detection and Notification of Unequipped Entities (Vehicles, VRUs, Objects).....	8
4.2.3	Security	14
4.2.4	System-Level Security Assumptions.....	14
4.2.5	Security Concept of Operations	14
4.2.6	Security Needs.....	14
4.2.7	Data Source Authenticity and Authorization	14
4.2.8	Data Integrity and Availability.....	14
4.2.9	User Privacy.....	14
5.	SSS APPLICATION PROTOCOL AND PARAMETERS	15
5.1	Introduction	15
5.2	Basic SDSM Protocol.....	15
5.2.1	Object Detection State	15

SAE Executive Standards Committee Rules provide that: "This report is published by SAE to advance the state of technical and engineering sciences. The use of this report is entirely voluntary, and its applicability and suitability for any particular use, including any patent infringement arising therefrom, is the sole responsibility of the user."

SAE reviews each technical report at least every five years at which time it may be revised, reaffirmed, stabilized, or cancelled. SAE invites your written comments and suggestions.

Copyright © 2022 SAE International

All rights reserved. No part of this publication may be reproduced, stored in a retrieval system or transmitted, in any form or by any means, electronic, mechanical, photocopying, recording, or otherwise, without the prior written permission of SAE.

TO PLACE A DOCUMENT ORDER: Tel: 877-606-7323 (inside USA and Canada)
 Tel: +1 724-776-4970 (outside USA)
 Fax: 724-776-0790
 Email: CustomerService@sae.org
 http://www.sae.org

SAE WEB ADDRESS:

Full document details: SAE J3224_202208

For more information on this standard, visit
https://www.sae.org/standards/content/J3224_202208/

Documents

Document Sharing Hub

5.2.2	SDSM Transmission State.....	15
5.3	Other Requirements for SSS	16
5.3.1	SDSM Detected Object Reported Positions and Timestamps.....	16
5.3.2	SDSM Reference Position and Coordinate System	16
5.3.3	SDSM Detected Object Coordinate System	18
5.3.4	Detected Object Accuracy and Confidence	20
5.3.5	Reference Clock.....	20
5.3.6	SDSM Quality of Service Parameters.....	20
6.	SSS MESSAGE SETS.....	21
6.1	Message: MSG_SensorDataSharingMessage (SDSM)	21
6.1.1	SDSM ASN.1	21
7.	OTHER REQUIREMENTS.....	26
7.1	Positioning and Timing Requirements	26
7.1.1	Position Determination	26
7.2	SDSM Transmission Requirements.....	26
7.2.1	SDSM Transmission Contents	26
7.2.2	Minimum Transmission Criteria	26
7.3	Security and Privacy Requirements.....	29
7.3.1	Data Integrity and Data Source Authenticity and Authorization.....	29
7.3.2	User Privacy.....	29
7.4	Security Management (SECMGNT).....	30
8.	VARIABLES AND PARAMETER SETTINGS.....	30
9.	NOTES.....	30
9.1	Revision Indicator.....	30
APPENDIX A	DESCRIPTION OF INFORMATION ELEMENTS.....	31
APPENDIX B	STANDARDS PROFILES	40
APPENDIX C	SECURITY PROFILE.....	42
APPENDIX D	MISBEHAVIOR CONSIDERATIONS (INFORMATIVE)	46
APPENDIX E	SECURITY ANALYSIS AND SSP DESIGN (INFORMATIVE)	47
APPENDIX F	HIGH DEFINITION DATA SHARING (INFORMATIVE)	49
Figure 1	SSS system.....	7
Figure 2	Basic SDSM states	15
Figure 3	SDSM reported timestamps and positions.....	16
Figure 4	Vehicle reference position.....	17
Figure 5	RSU reference position	17
Figure 6	VRU reference position	17
Figure 7	HV Earth-fixed axes	18
Figure 8	Detected object position offset.....	19
Figure 9	Detected vehicle.....	19
Figure 10	Detection of obstacle by host vehicle.....	20
Table 1	Minimum criteria for SDSM transmission.....	26
Table 2	Minimum criteria for SDSM transmission, detected object common data	27
Table 3	Minimum criteria for SDSM transmission, detected vehicle data.....	28
Table 4	Minimum criteria for SDSM transmission, detected VRU data	28
Table 5	Minimum criteria for SDSM transmission, detected obstacle data	29
Table 6	SSS parameters.....	30

1. SCOPE

This SAE Standard describes the concept of operation, use cases, and message flows to create a Sensor Sharing Service (SSS). This service enable RSUs and V2X¹ vehicles to share information about their localized driving environment. This work defines message structure, V2X entity requirements, and information elements to describe detected objects to facilitate sensor sharing.

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 J670	Vehicle Dynamics Terminology
SAE J2735	V2X Communications Message Set Dictionary
SAE J2945	Dedicated Short Range Communication (DSRC) Systems Engineering Process Guidance for SAE J2945/X Documents and Common Design Concepts™
SAE J2945/1	On-Board System Requirements for V2V Safety Communications
SAE J2945/5	Service Specific Permissions and Security Guidelines for Connected Vehicle Applications
SAE J2945/9	Vulnerable Road User Safety Message Minimum Performance Requirements
SAE J3016	Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles
SAE J3161/1	On-Board System Requirements for LTE-V2X V2V Safety Communications

2.1.2 IEEE Publications

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

NOTE: This report incorporates certain IEEE specifications by reference. ESSENTIAL IPRs (Intellectual Property Rights) have been declared to IEEE. All information statements and licensing declarations of ESSENTIAL IPRs received by IEEE are publicly available via the IEEE IPR Online Database, which can be found at <https://standards.ieee.org/about/sasb/patcom/patents/>.

IEEE 1609.2-2016	IEEE Standard for Wireless Access in Vehicular Environments - Security Services for Applications and Management Messages
IEEE 1609.12-2019	IEEE Standard for Wireless Access in Vehicular Environments (WAVE) - Identifier Allocations

¹ In this document, the term "V2X" refers to 3GPP cellular V2X (PC5), DSRC, or other short-range communications technologies meeting the requirements of the application.

2.1.3 TSI-ITS Publications

Available from ETSI, 650, route des Lucioles, F-06921, Sophia Antipolis Cedex, France www.etsi.org, Tel: +33 49294420.

NOTE: This report incorporates certain ETSI/3GPP specifications by reference. ESSENTIAL IPRs (Intellectual Property Rights) have been declared to ETSI. All information statements and licensing declarations of ESSENTIAL IPRs received by ETSI are publicly available via the ETSI IPR Online Database, which can be found at <https://ipr.etsi.org/DynamicReporting.aspx>.

ETSI-TS 102 723-8 V1.1.1 (2016-04) Intelligent Transport Systems (ITS); OSI Cross-Layer Topics; Part 8: Interface between Security Entity and Network and Transport Layer

2.1.4 American Association of State Highway and Transportation Officials Publications

"A Policy on Geometric Design of Highways and Streets," American Association of State Highway and Transportation Officials, 2018, 7th Edition.

2.2 Related Publications

The following publications are provided for information purposes only and are not a required part of this SAE Technical Report.

2.2.1 5GAA Publications

Available from 5GAA, Head Office Neumarkter, Str. 21 81673, Munich Germany, Tel: +49 89 54909680, www.5gaa.org.

C-V2X Use Cases Volume II Examples and Service Level Requirements, 5GAA Automotive Association White Paper.

3. TERMS AND DEFINITIONS

3.1 Definitions

HOST VEHICLE (HV): The vehicle about which a given use case may be constructed. The host vehicle can be a transmitting vehicle, or 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.

HOST RSU (HRSU): The RSU about which a given use case may be constructed. The HRSU can be a transmitting RSU, or a receiving RSU, or both—this distinction is made clear in the use case description. There is typically one HRSU in any use case.

REMOTE VEHICLE (RV): A vehicle which plays a supporting role in the use case by interacting with the HV, HRSU, RRSU or other RVs in some way. Each remote vehicle can be a transmitting vehicle, or a receiving vehicle, or both—this distinction is made clear in the use case description.

REMOTE RSU (RRSU): An RSU which plays a supporting role in the use case by interacting with the HV, RVs, HRSU or RRSU in some way. Each RRSU can be a transmitting RSU, or a receiving RSU, or both—this distinction is made clear in the use case description.

REMOTE VRU (RVRU): A VRU which plays a supporting role in the use case by interacting with the HV, RVs, HRSU or RRSU in some way. An RVRU can be a transmitting VRU, or a receiving VRU, or both—this distinction is made clear in the use case description.

UNEQUIPPED VEHICLE (UV): A vehicle which cannot transmit or receive any V2X messages.

UNEQUIPPED VRU (UVRU): A VRU which cannot transmit or receive any V2X messages.

VULNERABLE ROAD USER (VRU): A road user who is not occupying a vehicle such as a passenger car, motorcycle, public transit vehicle, or train. Pedestrians, cyclists, children, elderly, disabled people, and road workers are particularly vulnerable to serious injury or death when involved in a motor-vehicle-related collision (refer to SAE J2945/9).

3.2 Abbreviations and Acronyms

BSM	Basic Safety Message
CA	Certificate Authority
CAN	Controller Area Network
cm	Centimeter
DE	Data Element
DF	Data Frame
DVI	Digital Visual Interface
EC	Elliptic Curve
ECU	Electronic Control Unit
GNSS	Global Navigation Satellite Systems
HRSU	Host RSU
HV	Host Vehicle
IE	Information Element
IEEE	Institute of Electrical and Electronics Engineers
m	Meters
ms	Millisecond
N/A	Not Applicable
OBU	On-Board Unit
PII	Personally Identifiable Information
PSID	Provider Service ID
PDU	Protocol Data Unit
QOS, QoS	Quality of Service
RF	Radio Frequency
RRSU	Remote Roadside Unit
RSU	Roadside Unit
RV	Remote Vehicle
RVRU	Remote Vulnerable Road User
SCMS	Security Credential Management System

SDSM	Sensor Data Sharing Message
SSP	Service Specific Permissions
SSS	Sensor Sharing Service
TBR	To Be Resolved
UV	Unequipped Vehicle
UVRU	Unequipped VRU
V2V	Vehicle-to-Vehicle
V2X	Vehicle-to-Everything (used as a general term for all communications based on SAE J2735)
VRU	Vulnerable Road User

4. CONCEPT OF OPERATION AND SYSTEM DESCRIPTION

4.1 SSS System Overview

Sensor sharing is the dissemination of information of detected objects by vehicles and RSUs over V2X to other V2X entities. The data shared can include descriptions of the detected object characteristics, such as size, location, and motion state through transmission of a Sensor Data Sharing Message (SDSM). An SDSM is transmitted by an HV, RV, or RSU, to surrounding HVs, RVs, RSUs, or RVRUs. Each SDSM can include one or more detected road users or road features. Detected road users can be vehicles or VRUs, and detected road features can include objects or obstacles. [Appendix F](#) provides an informational description of sensors sharing of high definition data, consisting of data streaming over a separate communication channel. In this standard, description of high definition data is informational only.

An SAE J3224-capable vehicle or SAE J3224-capable RSU has awareness of surrounding V2X-capable vehicles through receipt of their transmitted basic safety messages (BSMs). SAE J3224-capable vehicles and SAE J3224-capable RSUs will not transmit SDSMs about vehicles that they have received a BSM from, as such vehicles are already capable of transmitting relevant data about themselves to other V2X vehicles.

[Figure 1](#) illustrates the components of the SSS system and its interfaces. The SSS system typically consists of multiple subsystem components, which may be discrete or integrated depending on the implementation. [Figure 1](#) illustrates the following subsystems within the system:

- V2X Radio Subsystem: Transmits and receives SSS messages. The system can include one or more V2X radio subsystems and still comply with this standard, as long as it meets the performance requirements herein.
- Positioning Subsystem: The subsystem that includes a Global Navigation Satellite System (GNSS) receiver and provides vehicle position, heading, speed, and time information. The system may augment and enhance positioning using additional information and components, which are not shown in [Figure 1](#). Examples of these are speed data from the Controller Area Network (CAN) bus, dead reckoning sensors, and optical/camera based systems.
- Control Processor Electronic Control Unit (ECU): Executes software that generates SSS messages for transmission according to the requirements in this standard.
- Sensing Subsystem: Vehicle- or RSU-mounted sensors providing information on the environment external to the vehicle or RSU.
- Sensor Fusion: Combination and analysis of sensor data to determine detected object static and dynamic characteristics.

- Antennas: Support radio frequency (RF) links for the V2X radio and GNSS receiver.
- Security Credential Management System (SCMS): An infrastructure-based SCMS is responsible for generating and delivering the security certificates that are used in the message verification process. The SCMS can also revoke certificates that cannot be trusted by placing them on a certificate revocation list that the SCMS distributes to all systems.

SSS systems communicate amongst themselves using the V2X Radio Subsystem as an interface. The SSS system can interface to a Safety Application ECU that detects threats and issues alerts through a Driver-Vehicle Interface (DVI). The DVI can provide visual, audible, and/or haptic alerts. The SSS system can also interface with the vehicle CAN bus to obtain vehicle status information. The safety application ECU, CAN bus, and DVI are outside the scope of this standard.

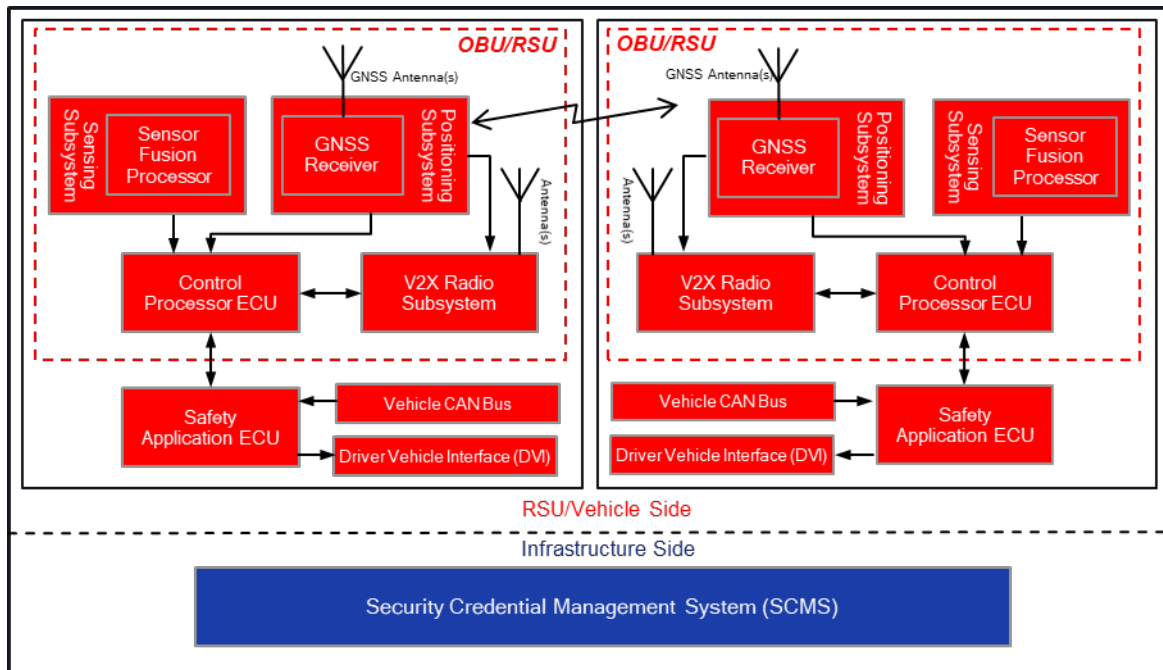


Figure 1 - SSS system

4.2 SSS Use cases

4.2.1 Overview

This section introduces the use cases for the Sensor Sharing Service (SSS). One category of application scenario and corresponding requirements is defined: detection and notification of unequipped entities (vehicles, VRUs, objects).

Template for use case description is defined with items as below:

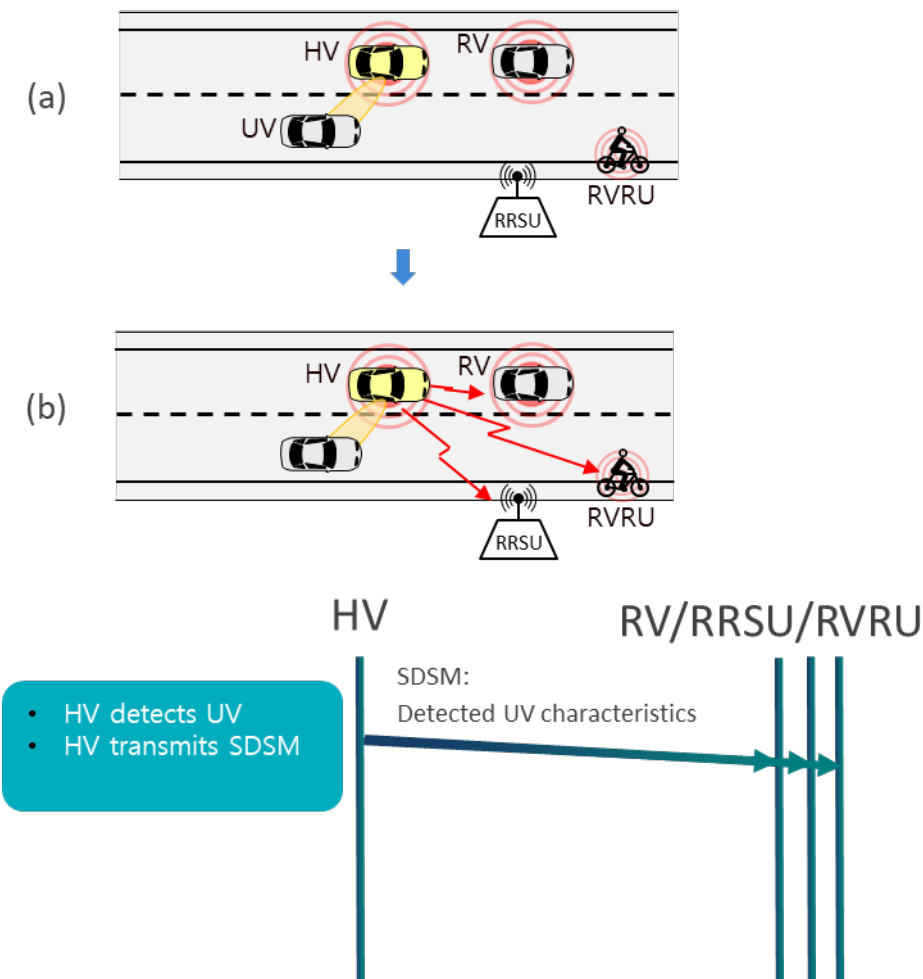
- Use case name.
- Overview.
- Brief description.
- Road environment.
- Participants, including active participants (equipped) or passive participants (unequipped).
- Participant roles.
- Assumptions and preconditions.

h. Use case flow illustrations.

i. Use case flow description.

4.2.2 Detection and Notification of Unequipped Entities (Vehicles, VRUs, Objects)

4.2.2.1 Detection of an Unequipped Vehicle by a Host Vehicle

Use case name	Detection of an unequipped vehicle by a host vehicle
Overview	Host vehicle (HV) detects and shares the presence of an unequipped vehicle (UV)
Brief description	The HV detects a UV in its vicinity; after determining key aspects of the detected vehicle's static and dynamic characteristics (e.g., position, heading, speed, etc.), that information is collected into a SDSM and transmitted to RRSUs, RVs, and RVRUs
Road environment	Urban Rural Highway
Participants	Vehicles, RSUs
Participants roles	There are five participant roles involved in this use case: - Host Vehicle (HV): Vehicle detecting UV and sharing UV characteristics via SDSM - Unequipped Vehicle (UV): Vehicle detected - Remote Vehicle (RV): Recipient of the SDSM - Remote Roadside Unit (RRSU): Recipient of the SDSM - Remote VRU (RVRU): Recipient of the SDSM
Assumptions and preconditions	HV, RV, RVRU, RRSU participate and are equipped
Use case flow illustrations	 The diagram illustrates the detection and notification process in two parts: (a) and (b). In part (a), a Host Vehicle (HV) is shown on a road, detecting an Unequipped Vehicle (UV). The UV is shown with a red circle around it, indicating detection. In part (b), the HV is shown transmitting the SDSM (Detected UV characteristics) to the RV, RRSU, and RVRU. The SDSM is shown as a red arrow pointing from the HV to the RV, RRSU, and RVRU. A legend indicates: HV detects UV, HV transmits SDSM. The SDSM is then transmitted to the RV, RRSU, and RVRU.
Use case flow description	a. HV detects a UV, determines its static and dynamic characteristics, and collects this information into a SDSM b. HV transmits an SDSM to surrounding entities (RVs, RRSUs, RVRUs) to notify them of the detected UV

4.2.2.2 Detection of an Unequipped Vehicle by an HRSU

Use case name	Detection of an unequipped vehicle by an HRSU
Overview	Host RSU (HRSU) detects and shares the presence of a UV
Brief description	An HRSU detects a UV in its vicinity; after determining key aspects of the UV's static and dynamic characteristics (e.g., position, heading, speed, etc.), that information is collected into an SDSM and transmitted to RVs or RVRUs
Road environment	Urban Rural Highway
Participants	Vehicles, RSUs
Participants roles	There are four participant roles involved in this use case: ▪ Host Roadside Unit (HRSU): Detects the UV and sharing UV characteristics via SDSM ▪ Unequipped Vehicle (UV): Vehicle detected ▪ Remote Vehicle (RV): Recipient of the SDSM ▪ Remote VRU (RVRU): Recipient of the SDSM
Assumptions and preconditions	RV, RVRU, HRSU participate and are equipped
Use case flow illustrations	The diagram illustrates the use case flow in two parts, (a) and (b), and a summary flow. (a) shows a road with a dashed center line. An Unequipped Vehicle (UV) is in the left lane, and a Remote Vehicle (RV) is in the right lane. An HRSU (Host Roadside Unit) is positioned on the right side of the road, and an RVRU (Remote VRU) is on the left side. A yellow cone of detection from the HRSU points to the UV. (b) shows the same scene, but with red arrows indicating communication from the HRSU to both the RV and the RVRU. Below the road diagrams, a summary flow is shown. On the left, under the label 'HRSU', a blue box contains the steps: • HRSU detects UV • HRSU transmits SDSM A blue arrow points from this box to the right, where a vertical line represents the 'RV/RVRU'. Above this arrow, the text 'SDSM: Detected UV characteristics' is displayed.
Use case flow description	a. HRSU detects a UV, determines its static and dynamic characteristics, and collects this information into a SDSM b. HRSU sends an SDSM to surrounding entities (RVs, RVRUs) to notify them of the detected UV

4.2.2.3 Detection of UVRU by a Host Vehicle

Use case name	Detection of UVRU by an host vehicle
Overview	Host vehicle (HV) detects and shares the presence of a UVRU
Brief description	The HV detects a UVRU in its vicinity; after determining key aspects of the UVRU's static and dynamic characteristics (e.g., position, heading, speed, etc.), that information is collected into an SDSM and transmitted to RRSUs and RVs
Road environment	Urban Rural Highway
Participants	Vehicles, RSUs, UVRUs
Participants roles	There are four participant roles involved in this use case: ▪ Host Vehicle (HV): Vehicle detecting UVRU and sharing UVRU characteristics via SDSM ▪ Unequipped Vulnerable Road User (UVRU): Detected by HV ▪ Remote Vehicle (RV): Recipient of the SDSM ▪ Remote Roadside Unit (RRSU): Recipient of the SDSM
Assumptions and preconditions	HV, RV, RSU participate and are equipped
Use case flow illustrations	The diagram illustrates the use case flow in two parts, (a) and (b), and a summary flow. (a) Detection: A Host Vehicle (HV) is shown on a road, detecting an Unequipped Vulnerable Road User (UVRU) who is crossing the road. A Remote Roadside Unit (RRSU) is also present on the road. A yellow cone of vision from the HV indicates the detection of the UVRU. (b) Sharing: The HV is shown sharing the detected UVRU characteristics via SDSM to the RV and the RRSU. A red arrow points from the HV to the RV, and a red arrow points from the HV to the RRSU. Summary Flow: HV (Host Vehicle) is on the left, and RV/RRSU (Remote Vehicle/Remote Roadside Unit) is on the right. - A blue box contains the steps: • HV detects UVRU • HV transmits SDSM - A green arrow labeled "SDSM: Detected UVRU characteristics" points from the HV to the RV/RRSU.
Use case flow description	a. HV detects a UVRU, determines its static and dynamic characteristics, and collects this information into a SDSM b. HV sends an SDSM to surrounding entities (RVs, RRSUs) to notify them of the detected UVRU

4.2.2.4 Detection of a UVRU by an RSU

Use case name	Detection of a UVRU by an RSU
Overview	HRSU detects and shares the presence of a UVRU
Brief description	An RSU detects a UVRU in its vicinity; after determining key aspects of the UVRU's static and dynamic characteristics (e.g., position, heading, speed, etc.), that information is collected into an SDSM and transmitted to RVs
Road environment	Urban Rural Highway
Participants	Vehicles, RSUs, UVRUs
Participants roles	There are three participant roles involved in this use case: ▪ Unequipped Vulnerable Road User (UVRU): Detected by HRSU ▪ Remote Vehicle (RV): Recipient of the SDSM ▪ Host Roadside Unit (HRSU) Detects the UVRU and shares UVRU characteristics via SDSM
Assumptions and preconditions	RV and HRSU participate and are equipped
Use case flow illustrations	The diagram illustrates the use case flow in two parts, (a) and (b), and a summary flow. (a) shows a Host Roadside Unit (HRSU) on the left, represented by a yellow cone-shaped sensor field. A Vulnerable Road User (UVRU), represented by a pedestrian icon, is within this field. A Remote Vehicle (RV), represented by a car icon, is on the right. The HRSU is detecting the UVRU. (b) shows the HRSU and RV. A red arrow points from the HRSU to the RV, indicating the transmission of an SDSM (Safety Data Set Message). Below the diagrams, a summary flow is shown with two vertical lines representing the HRSU and RV. A blue box on the left contains the steps: • HRSU detects UVRU • HRSU transmits SDSM An arrow points from the HRSU line to the RV line, labeled "SDSM: Detected UVRU characteristics".
Use case flow description	a. HRSU detects a UVRU, and determines its static and dynamic characteristics, and collects this information into a SDSM b. HRSU sends an SDSM to surrounding entities (RVs, RSUs) to notify them of the detected UVRU

4.2.2.5 Detection of an Obstacle by a Host Vehicle

Use case name	Detection of an obstacle by a host vehicle
Overview	HV detects and shares the presence of an obstacle
Brief description	The HV detects an obstacle in its vicinity; after determining the static and dynamic characteristic of the obstacle, that information is collected into an SDSM and transmitted to RRSUs and RVs
Road environment	Urban Rural Highway
Participants	Vehicles, RSUs, obstacles
Participants roles	There are four participant roles involved in this use case: ▪ Host Vehicle (HV): Detects obstacle and shares obstacle characteristics via SDSM ▪ Obstacle: Detected by HV ▪ Remote Vehicle (RV): Recipient of the SDSM ▪ Remote Roadside Unit (RRSU): Recipient of the SDSM
Assumptions and preconditions	HV, RV RSU participate and are equipped
Use case flow illustrations	The diagram illustrates the process in two parts, (a) and (b). In part (a), an HV is shown on a road with a yellow sensor cone detecting an obstacle (represented by a red starburst). An RV is also on the road. Below the road, an RRSU is shown with a blue arrow pointing down to part (b). In part (b), the HV is still detecting the obstacle. Red arrows indicate the transmission of an SDSM from the HV to both the RV and the RRSU. Below the road, a diagram shows the HV and RV/RRSU entities. A teal box on the left contains the text: '• HV detects an obstacle' and '• HV transmits SDSM'. A teal arrow points from the HV entity to the RV/RRSU entity, labeled 'SDSM: Detected Obstacle characteristics'.
Use case flow description	a. HV detects an obstacle, and determines its static and dynamic characteristics, and collects this information into a SDSM b. HV sends an SDSM to surrounding entities (RVs, RRSU) to notify them of the detected obstacle

4.2.2.6 Detection of an Obstacle by an HRSU

Use case name	Detection of an obstacle by an HRSU
Overview	HRSU detects and shares the presence of an obstacle
Brief description	An HRSU detects an obstacle in its vicinity; after determining static and dynamic characteristics of the obstacle, that information is collected into an SDSM and transmitted to other RVs
Road environment	Urban Rural Highway
Participants	Vehicles, RSUs
Participants roles	There are three participant roles involved in this use case: ▪ Obstacle: Detected by the HRSU ▪ Remote Vehicle (RV): Recipient of the SDSM ▪ Host Roadside Unit (HRSU): Detects obstacle and shares obstacle characteristics via SDSM.
Assumptions and preconditions	For below diagram, all vehicles are assumed V2X-capable
Use case flow illustrations	The diagram illustrates the process in two parts: (a) and (b). Part (a) shows a Host Roadside Unit (HRSU) on a road detecting an obstacle (represented by a red starburst). A yellow beam of detection is shown from the HRSU to the obstacle. A Remote Vehicle (RV) is also on the road, with a red circle around it indicating its detection range. Part (b) shows the HRSU transmitting a signal (red line) to the RV, indicating the detected obstacle. Below the road diagrams, a separate diagram shows the message structure. A blue box contains the text: • HRSU detects an obstacle • HRSU transmits SDSM A blue arrow points from the HRSU to the RV, labeled 'SDSM: Detected Obstacle characteristics'.
Use case flow description	- HRSU detects an obstacle, and determines its static and dynamic characteristics, and collects this information into a SDSM - HRSU sends an SDSM to surrounding entities (RVs) to notify them of the detected obstacle

4.2.3 Security

4.2.4 System-Level Security Assumptions

- a. The SDSM is sent via broadcast or groupcast.
- b. It is helpful/necessary for a receiver of SDSMs as well as BSMs to be able to correlate these different types of messages as coming from the same vehicle. This results in a decrease in privacy for a sender who is sending both types of message, as receivers will learn more information with more confidence about the sender than in the case where SDSMs and BSMs from the same sender are harder to correlate. The security assumption is that it is sufficient to give a system participant the options of (1) sending SDSMs and BSMs that are easily correlated, or (2) if they are concerned about the extra privacy loss from SDSM, simply not sending SDSMs, i.e., that it is not necessary to specify a mechanism where a sender sends SDSMs and BSMs that are in some sense hard to correlate. The reasoning behind the assumption is that SDSMs and BSMs will be relatively straightforward to correlate based on their content anyway, and as such a mechanism that makes them slightly harder to correlate will be difficult to be specify and relatively ineffective.

NOTE: TemporaryID may be used by a receiver to identify with high confidence that an SDSM and a BSM were sent by the same sender.

4.2.5 Security Concept of Operations

The security needs for these use cases are described in this section. These security constraints reflect the sensitive nature of certain data, which is necessary to protect (e.g., sensor data, or Personally Identifiable Information (PII)) from attacks. No Service-Specific Permissions (SSP)-based authorizations are defined (SSP can be omitted).

In addition to the security needs identified in the following sections, implementers should consider how to detect a misbehaving application and the impact of such misbehavior upon the correct functionality of the other participants' applications. Potential considerations are described in [Appendix D](#). Note that additional misbehaviors may be identified by implementors of this standard.

4.2.6 Security Needs

4.2.7 Data Source Authenticity and Authorization

The system needs to provide a mechanism to authenticate sources of data and verify that they are authorized to send such data.

4.2.8 Data Integrity and Availability

The system needs to provide a mechanism to allow a relying party to determine whether that data has been changed since it was generated, and to determine whether it is timely.

Availability needs: The system needs to provide best-effort transportation of data such that there is a reasonable likelihood that a receiver receives data in a timely manner to alert them to potential hazards that cannot be detected by other means. However, intermittent failures in the service are acceptable.

The system needs to provide its service without requiring all possible senders to send at all possible times.

4.2.9 User Privacy

The SSS system needs to provide a mechanism to allow users to opt out of participation.

The SSS system needs to provide its service without requiring senders to provide an explicit persistent identity to other participants.

The SSS system needs to provide its service without requiring the recipients of data to store PII about the sender.

For OBUs, the SSS system needs to provide a mechanism to make it difficult to identify that two distinct messages originating from the same service came from the same sender, if those messages are sent at “sufficiently” different times and places (for some definition of sufficiently different). In other words, the system needs to make it difficult to track users over a wide area without recording all (or a large part) of their messages.

For RSUs, there are no privacy concerns regarding its SSS system.

5. SSS APPLICATION PROTOCOL AND PARAMETERS

5.1 Introduction

This section defines the SSS application protocol requirements and associated parameters for the use cases defined in [4.2](#).

5.2 Basic SDSM Protocol

The states of the SDSM protocol are illustrated in [Figure 2](#).

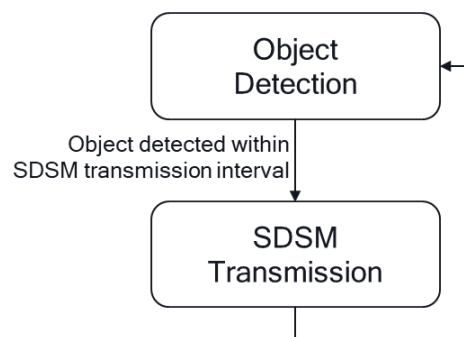


Figure 2 - Basic SDSM states

In all SSS states, HVs and RVs shall exchange Basic Safety Messages (BSMs), as specified in SAE J3161/1 or SAE J2945/1, in order to enhance situational awareness.

5.2.1 Object Detection State

In the object detection state an HV or HRSU identifies objects in its field of view using its sensors and determines the static and dynamic characteristics of those detected objects. The static and dynamic characteristics may be determined by data from a single sensor or from the fusion of data from multiple sensors. If the HV or HRSU does not detect any objects within the SDSM transmission interval, it remains in the object detection state and does not transmit an SDSM.

5.2.2 SDSM Transmission State

In the SDSM Transmission state, the HV or HRSU transmits an SDSM. An SDSM is transmitted at a frequency of vSDSMrate.

5.3 Other Requirements for SSS

5.3.1 SDSM Detected Object Reported Positions and Timestamps

Each SDSM includes a reference position (*Position3D*) for the vehicle or RSU transmitting the SDSM and an SDSM timestamp (*sDSMTimestamp*) associated with reference position of the sender. The SDSM timestamp corresponds to the time the SDSM originator (vehicle or RSU) establishes its reference position. Each SDSM also includes a position offset (*PositionOffsetXYZ*) and a time offset (*measurementTimeOffset*) for each detected object included in the SDSM. The detected object time offset (*measurementTimeOffset*) corresponds to the moment the SDSM originator detects the object, and is defined as a temporal offset from the SDSM timestamp in ms. Because object detection may occur before or after the SDSM originator establishes its reference position, the *measurementTimeOffset* may be positive or negative. If object detection occurs before the SDSM originator establishes its reference position, the *measurementTimeOffset* shall be negative; otherwise, it shall be positive. The detected object position is reported in *PositionOffsetXYZ* as a relative position with respect to the SDSM originator's reference position. The relationship between the SDSM reported timestamps is shown in part A of [Figure 3](#), and the relationship between SDSM reported positions is shown in part B of [Figure 3](#). Each SDSM includes only one SDSM timestamp and reference position, but includes as many detected object timestamp-position offset pairs as there are detected objects in the message. Each SDSM shall include object detections from the current SDSM transmission interval, or the immediately preceding SDSM transmission interval (the latter may occur when, for example, an object detection occurs proximate to the SDSM transmission and the SDSM originator includes this detection in the next transmission interval).

NOTE: It is expected an SDSM originator may conduct multiple detections of an object within a transmission interval. Determination of which detection is included in an SDSM is left to the originator.

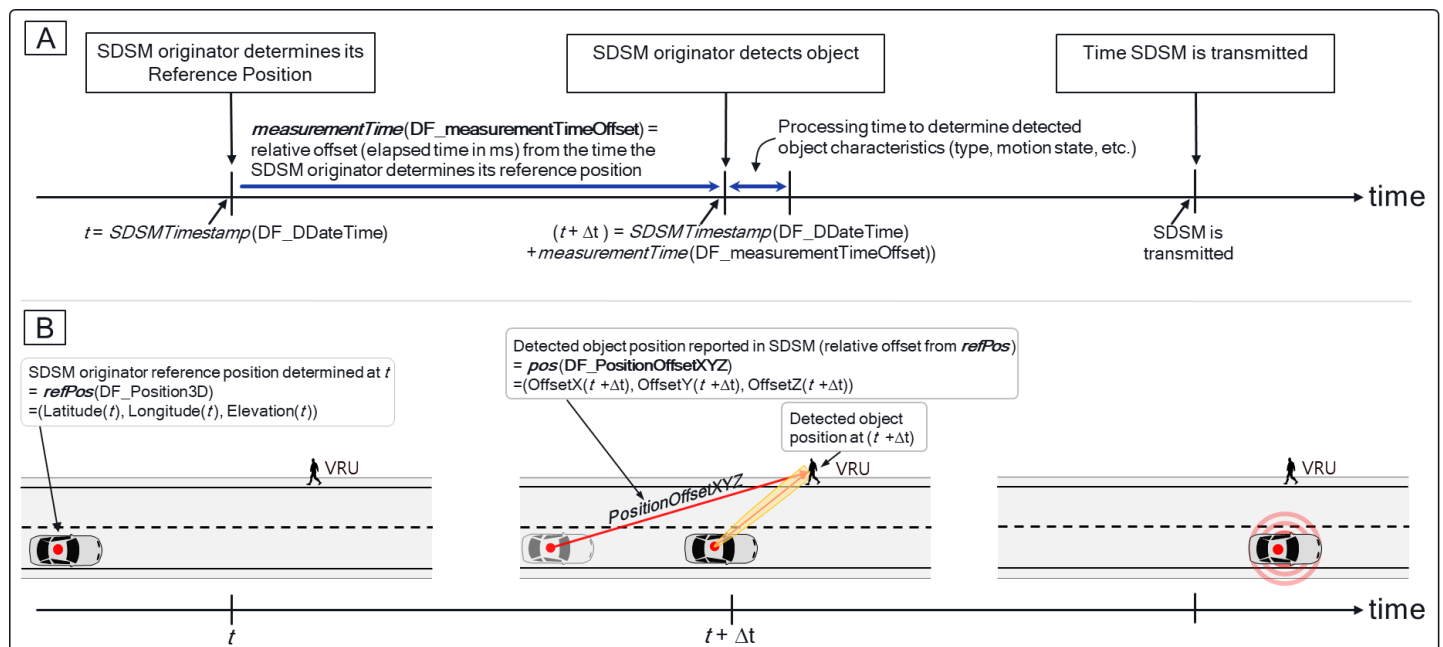


Figure 3 - SDSM reported timestamps and positions

5.3.2 SDSM Reference Position and Coordinate System

An SDSM uses the reference position and coordinate system in SAE J2735, as shown in [Figure 4](#), where the X_v axis corresponds to the vehicle's forward orientation. The reference position for an HV is the point (latitude, longitude, elevation) projected onto the surface of the roadway (road plane) with reference to the WGS 84 coordinate system and its reference ellipsoid. This point is the center of the rectangle on the road plane, oriented about the vehicle that encompasses the farthest forward, rearward, and side-to-side points on the vehicle, including vehicle original equipment such as outside rear view mirrors.

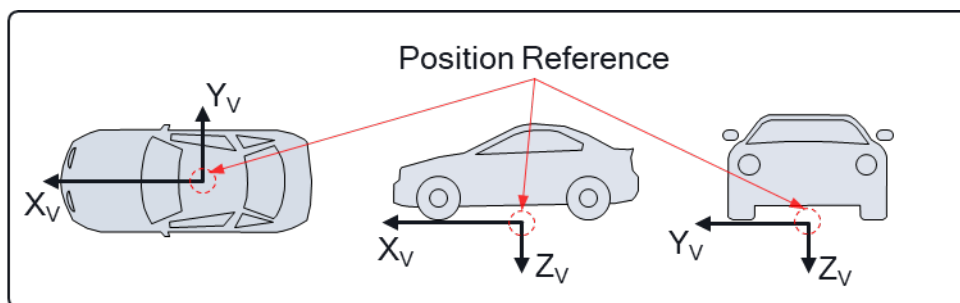


Figure 4 - Vehicle reference position

An HRSU originating an SDSM uses the reference coordinate system shown in [Figure 5](#), where the y-axis corresponds to east and the x-axis corresponds to north. An RSU reference position is selected as an arbitrary point at the RSU location.

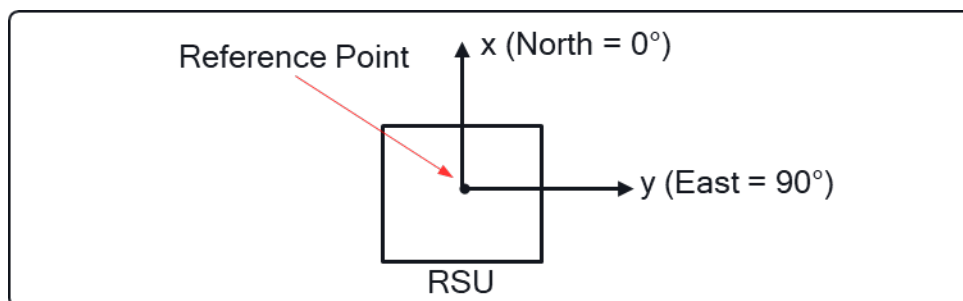


Figure 5 - RSU reference position

The VRU position reported in an SDSM uses the reference position and coordinate system defined in SAE J2735, as shown in [Figure 6](#). The reference position for a VRU is the point (latitude, longitude, elevation) projected onto the surface of the ground plane with reference to the WGS 84 coordinate system and its reference ellipsoid. This point is the center of the rectangle on the ground plane representing the VRU location, oriented about the VRU that encompasses the farthest forward, rearward, and side-to-side points of the VRU.

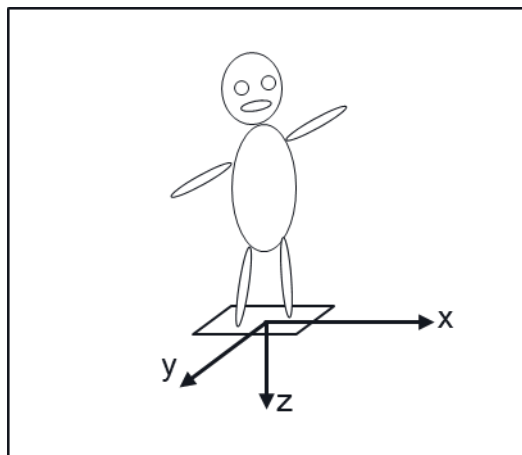


Figure 6 - VRU reference position

5.3.3 SDSM Detected Object Coordinate System

A HV or HRSU originating an SDSM reports a detected object position, velocity, and acceleration in an Earth-fixed coordinate system (x_E , y_E , z_E), with an origin corresponding to the HV or HRSU reference point. The z_E axis is aligned to the gravitational vector, the x_E axis is aligned to WGS 84 north, and the y_E is aligned to east, as shown in [Figure 7](#). As shown in [Figure 8](#), detected object position is reported as an offset from the HV or HRSU reference position along the (x_E , y_E , z_E) axes. Detected object velocity is reported as a scalar speed and heading angle in the (x_E - y_E) plane, and a speed component along the z_E axis. For detected objects, heading describes the direction of the velocity vector in the (x_E - y_E) plane measured from WGS 84 north, and orientation describes the forward pointing direction of the detected object (the positive direction of the detected object body X_v -axis).

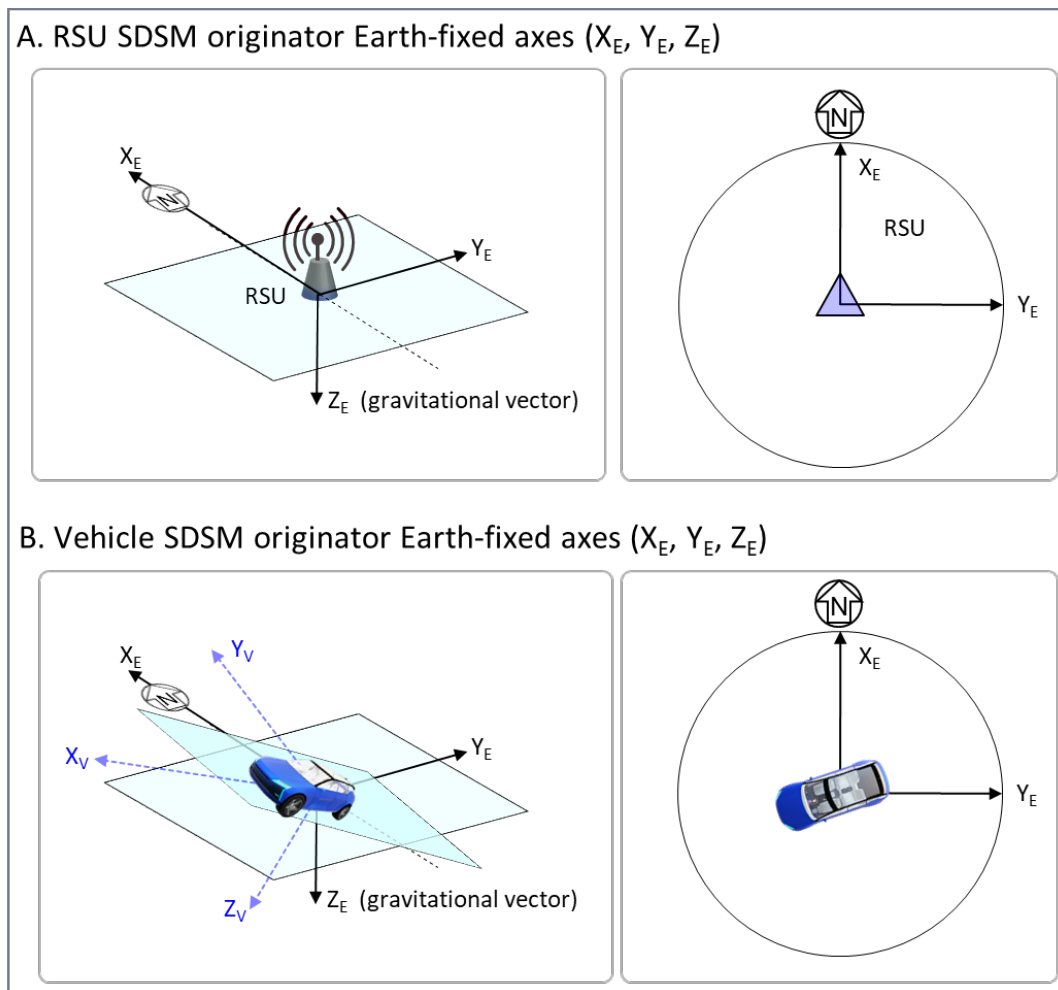


Figure 7 - HV Earth-fixed axes

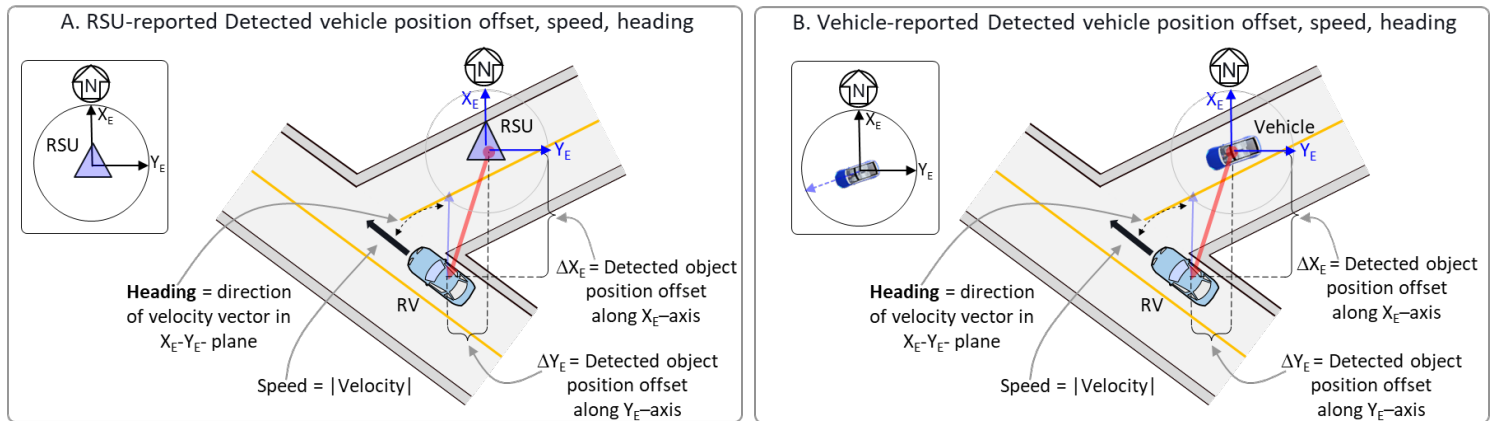


Figure 8 - Detected object position offset

Detected vehicle attitude (pitch, roll, yaw) is reported in an SDSM by the following parameters (see [Figure 9](#)):

- An origin at the detected vehicle reference position, given by an offset (ΔX_E , ΔY_E , ΔZ_E) from the HV/HRSU in the HV/HRSU Earth-fixed axes.
- Detected vehicle pitch, given by the angle between the detected vehicle x_V -axis and the (x_E - y_E) plane.
- Detected vehicle roll, given by the angle between the detected vehicle y_V -axis and the (x_E - y_E) plane.
- Detected vehicle yaw, given by the angle between the x_E -axis and the projection of the x_V -axis to the (x_E - y_E) plane.

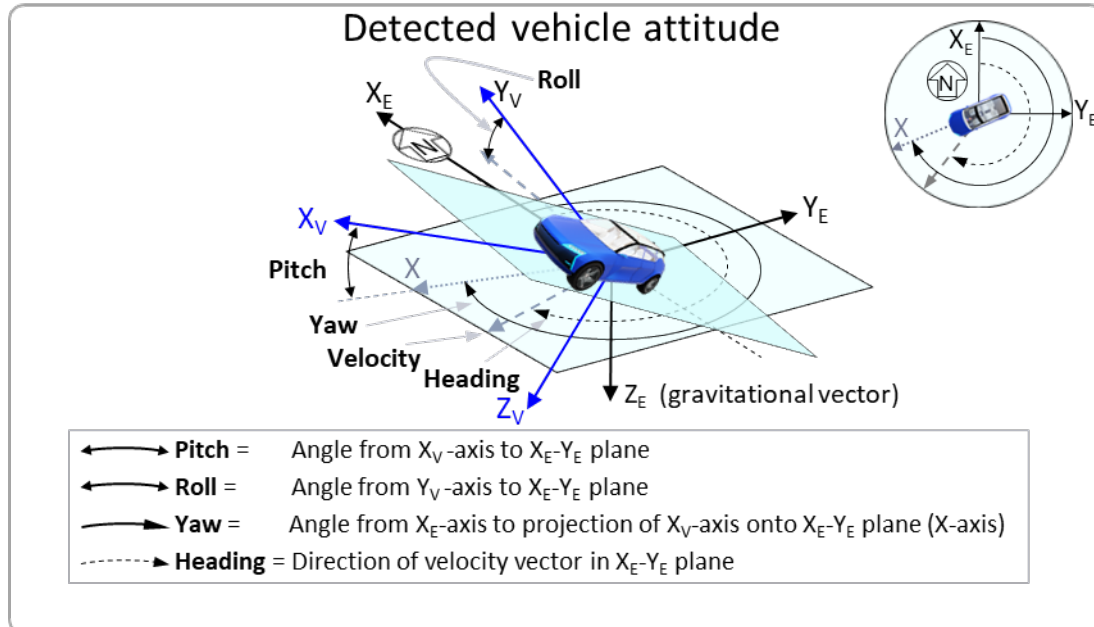


Figure 9 - Detected vehicle

5.3.4 Detected Object Accuracy and Confidence

Each detected vehicle, VRU or object included in an SDSM is described by a set of characteristics determined by the originator of the SDSM. These characteristics may include classification, location, motion state, and other parameters as described in [A.2](#). Each detected characteristic is assigned a data element and/or data frame delineating the accuracy of the detected value, with the accuracy represented as either an enumerated value, or a range (0 to 100). For accuracy values represented using an enumerated value, the accuracy value corresponds to the 95% confidence level, taking into account the current calibration of the sensor(s) used to measure and/or calculate the value.

5.3.5 Reference Clock

An SAE J3224-compliant vehicle, RSU, or VRU shall include a reference clock that conforms to the Coordinated Universal Time (UTC), per the requirements in [Table 1](#).

5.3.6 SDSM Quality of Service Parameters

5.3.6.1 Range

Vehicles and RSUs that use a communication technology supporting range as a QoS parameter may specify a range value, *SDSMrange*, to the lower layer. [Figure 10](#) illustrates this as a variation of use case [4.2.2.5](#).

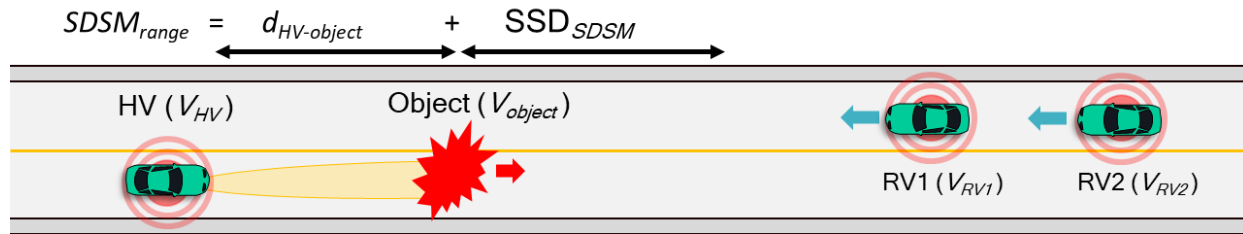


Figure 10 - Detection of obstacle by host vehicle

The *SDSMrange* provided to the lower layer is based on the Sight Stopping Distance (SSD) (refer to “A Policy on Geometric Design of Highways and Streets”), and is a function of the detected object speed, the maximum RV speeds, and the HV to object distance, using the expression given in Equation 1. The calculated *SDSMrange* provides a conservative, minimum range an SDSM application may specify under nominal conditions of dry pavement on a level road to a point where an RV can react to the detected object information in HV’s SDSM and safely stop. An SDSM application may increase or decrease this range based on local weather conditions and/or road surface conditions.

$$\begin{cases} \text{SDSM}_{\text{range}} = d_{\text{HV-object}} + \text{SSD}_{\text{SDSM}} \\ \text{SDSM}_{\text{range}} = d_{\text{HV-object}} + 0.278(V_{\text{BSM,MAX}} + V_{\text{Object,MAX}})t + 0.039 \left(\frac{(V_{\text{BSMs,MAX}} + V_{\text{Object,MAX}})^2}{a} \right) \end{cases} \quad (\text{Eq. 1})$$

where:

$d_{\text{HV-object}}$ = distance from detected object to HV (m)

$V_{\text{BSM,MAX}}$ = maximum speed of vehicles transmitting a BSM, as reported in their respective BSMs (km/h), independent of direction of motion with respect to the HV

$V_{\text{Object,MAX}}$ = maximum speed of detected objects, as determined by HV sensors (km/h)

t = perception reaction time = 2.5 seconds

a = SDSM recipient deceleration rate = 3.4 m/s²