SAE INTERNATIONAL

SURFACE VEHICLE STANDARD

J3224™ AUG2022

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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.

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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 V2X[1] 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 Documetns 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.

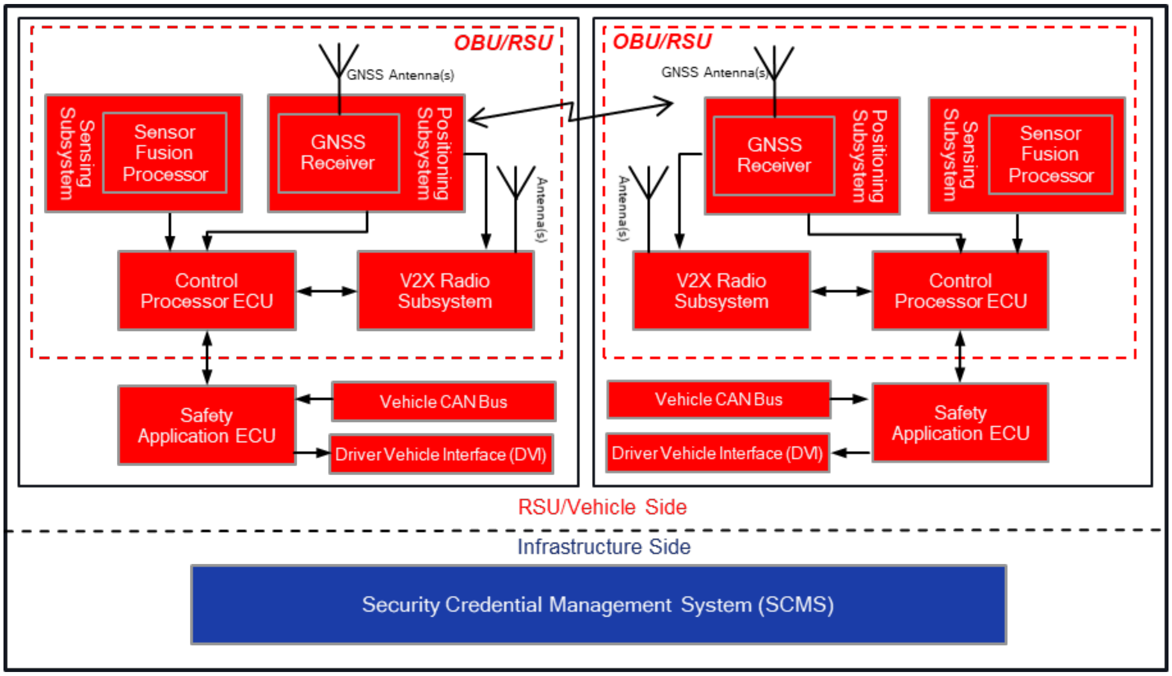


Figure 1 - SSS system

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:

a. Use case name.

b. Overview.

c. Brief description.

d. Road environment.

e. Participants, including active participants (equipped) or passive participants (unequipped).

f. Participant roles.

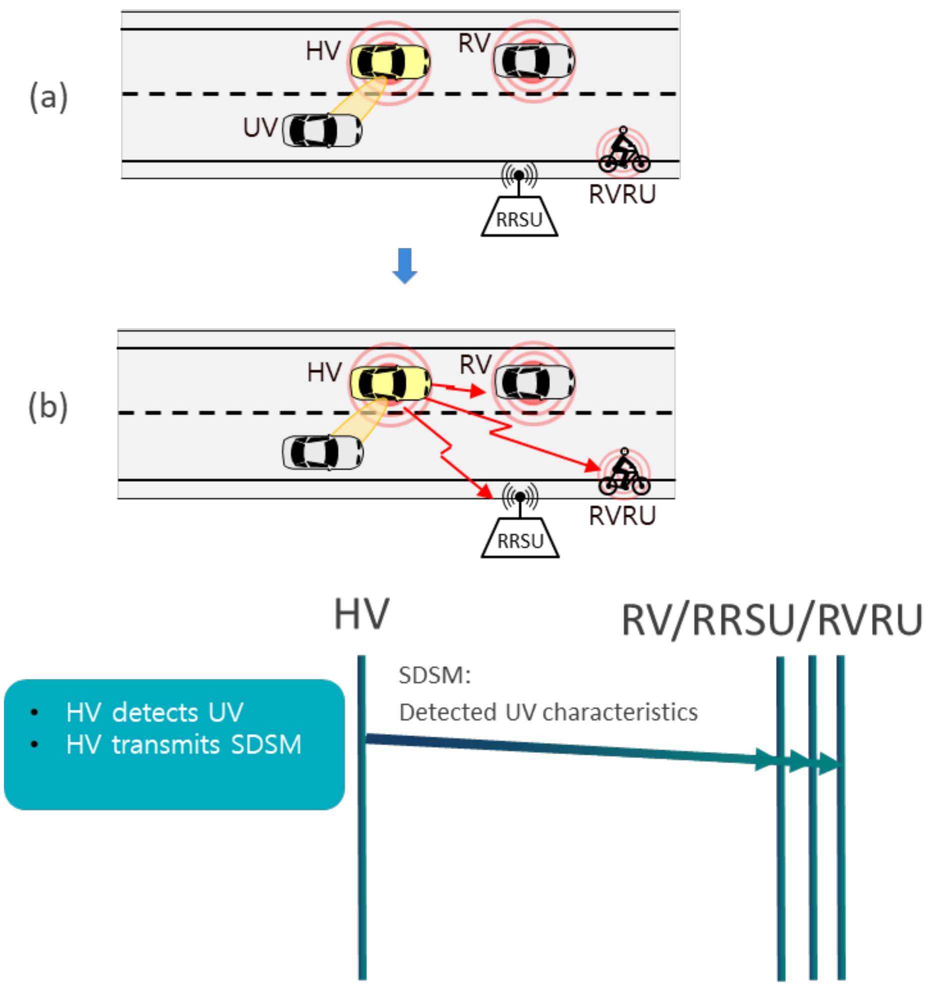
g. Assumptions and preconditions.

h. Use case flow illustrations.

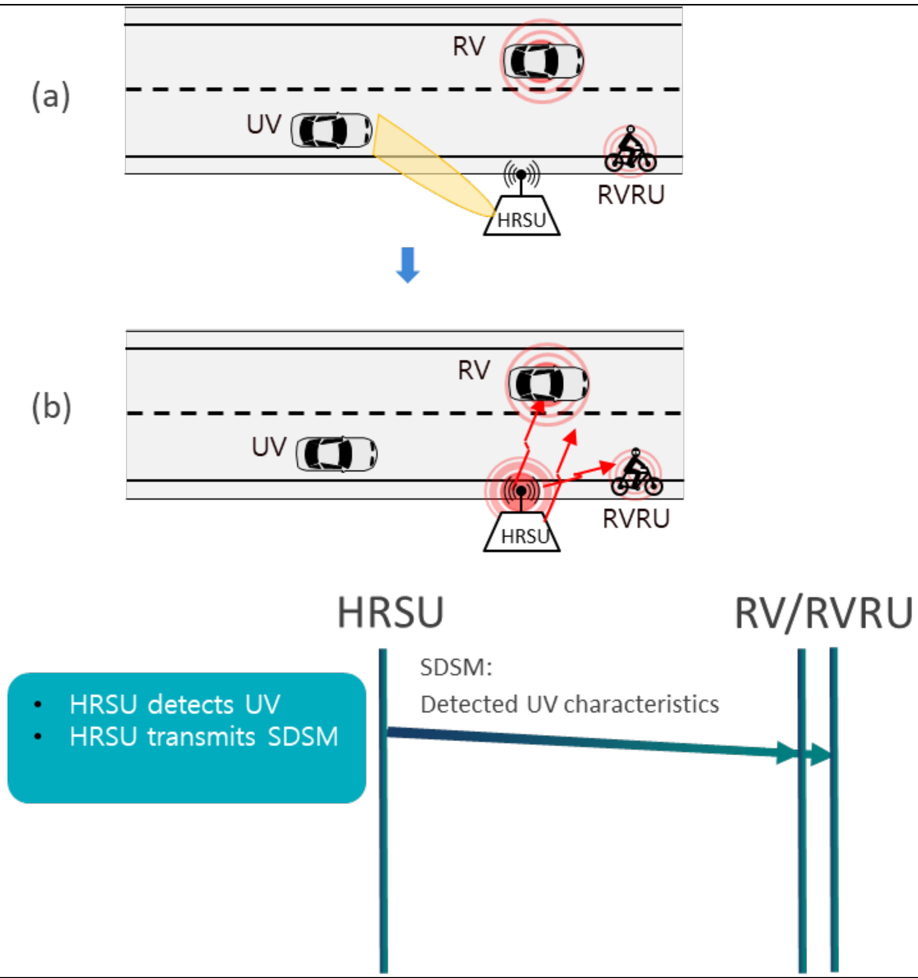
i. Use case flow description.

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

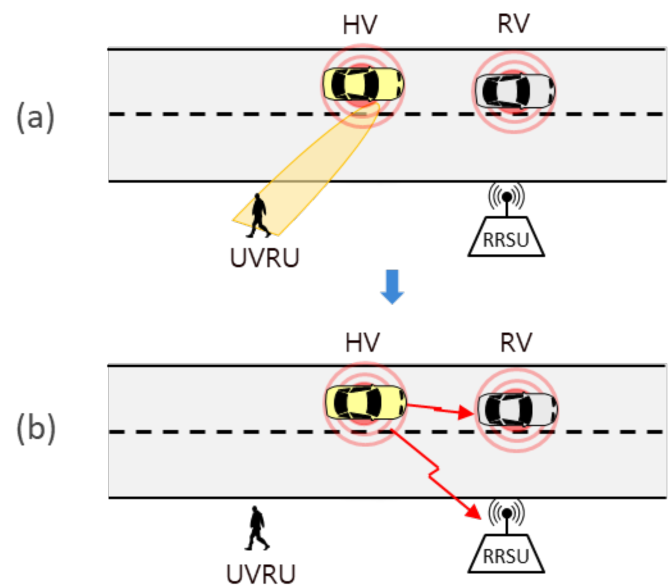
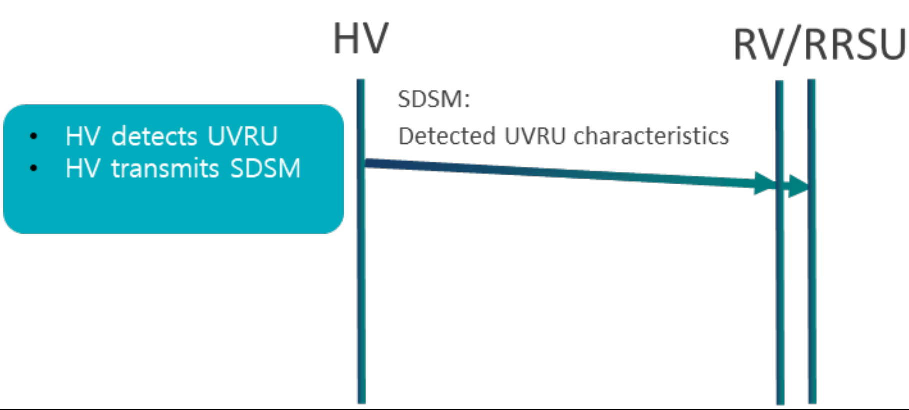
4.2.2.1 Detection of an Unequipped Vehicle by a Host Vehicle

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	
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

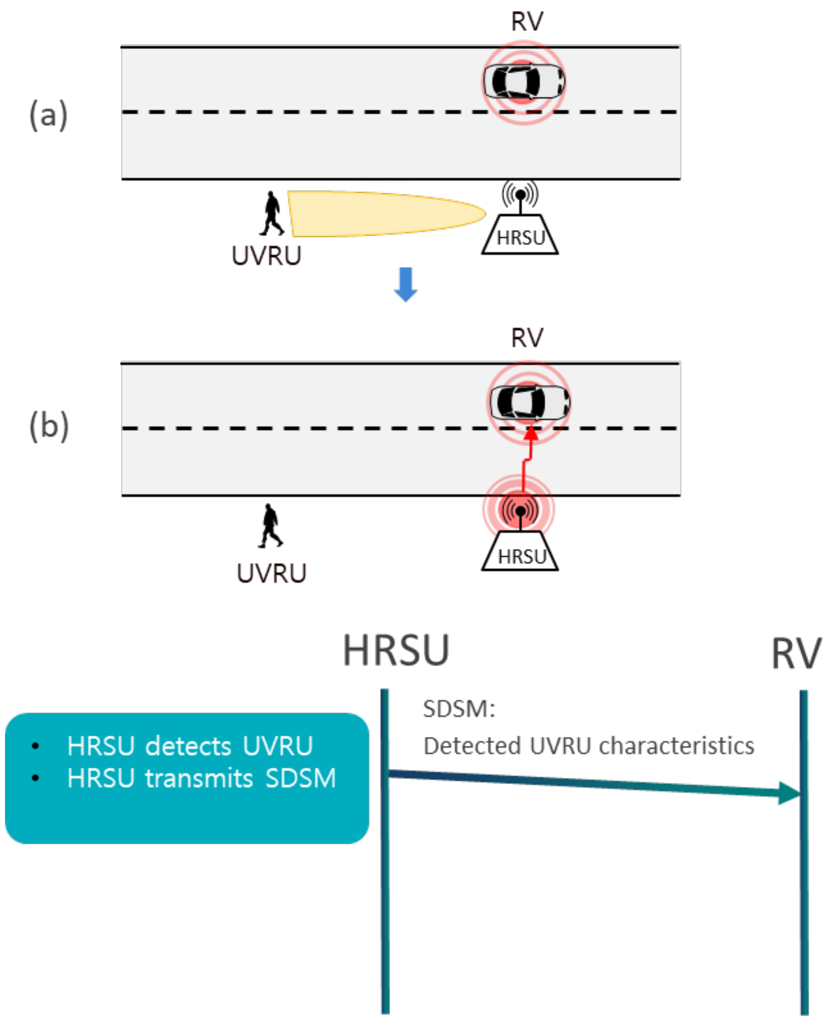
4.2.2.2 Detection of an Unequipped Vehicle by an HRSU

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	
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

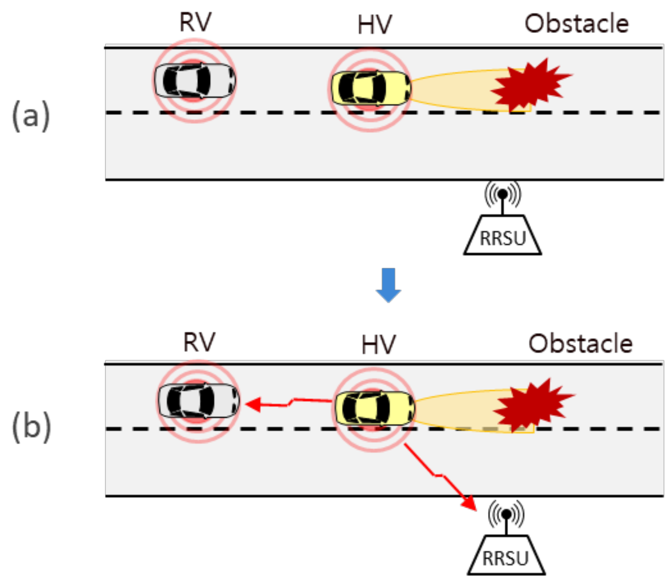
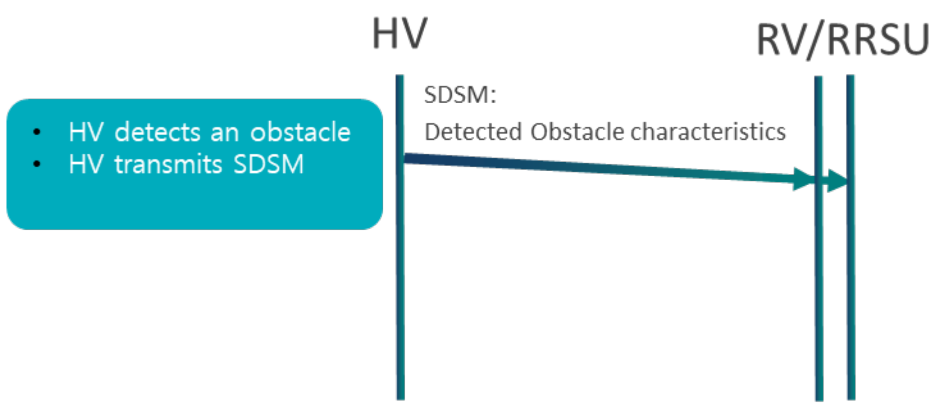
4.2.2.3 Detection of UVRU by a Host Vehicle

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	
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

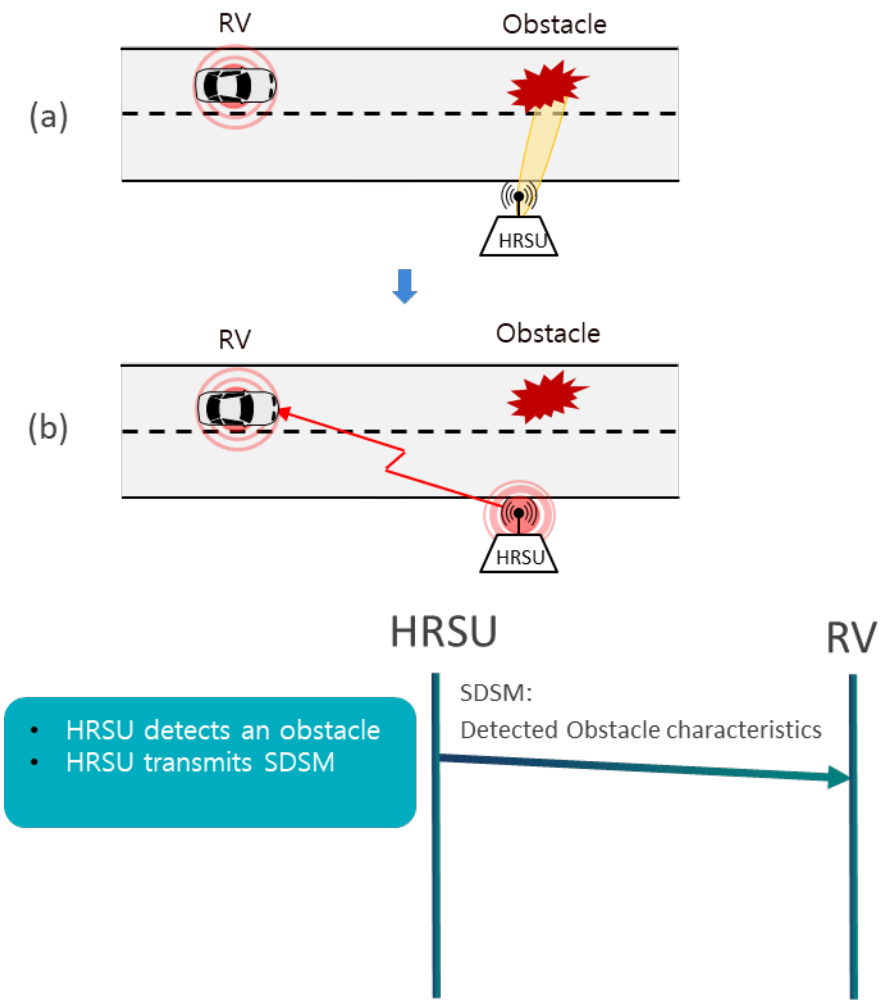
4.2.2.4 Detection of a UVRU by an RSU

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	
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	 
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	
Use case flow description	a. HRSU detects an obstacle, and determines its static and dynamic characteristics, and collects this information into a SDSM b. 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.

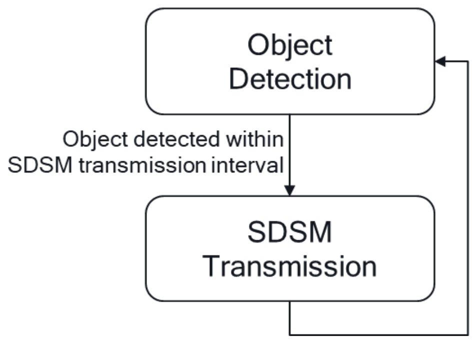


Figure 2 - Basic SDSM states

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.

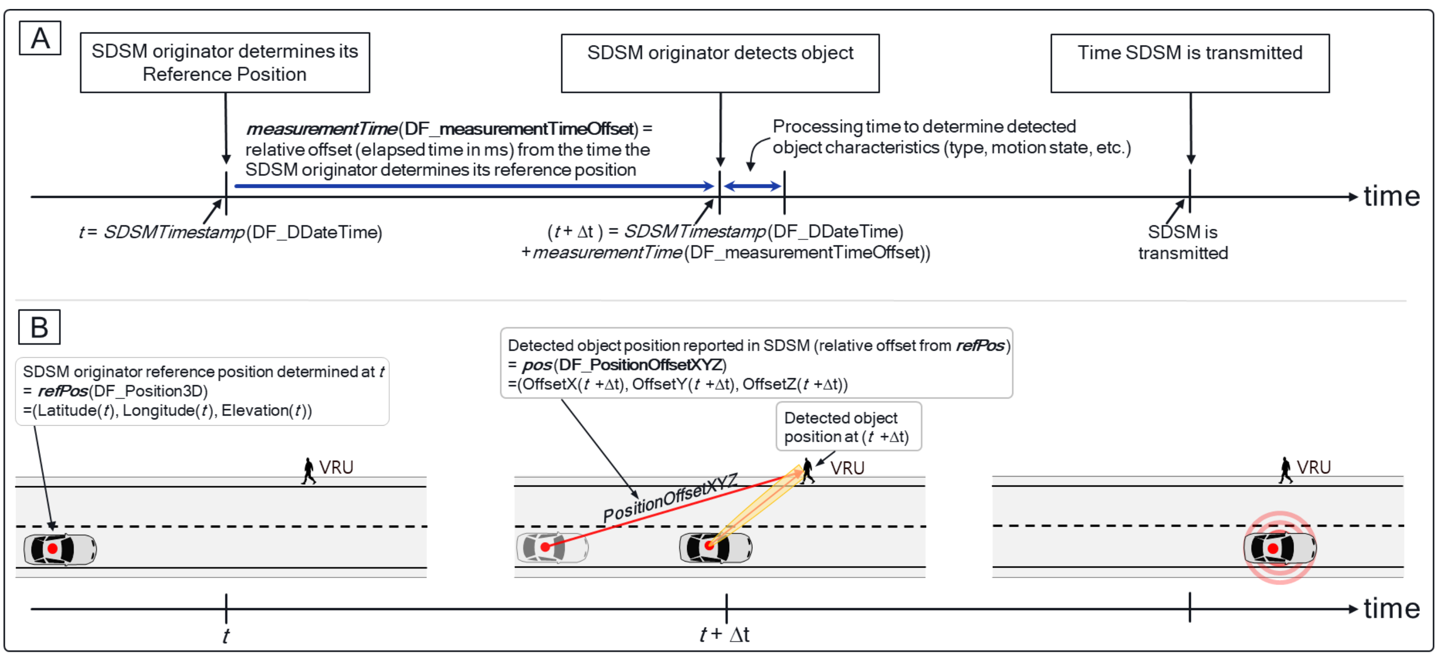


Figure 3 - SDSM reported timestamps and positions

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.

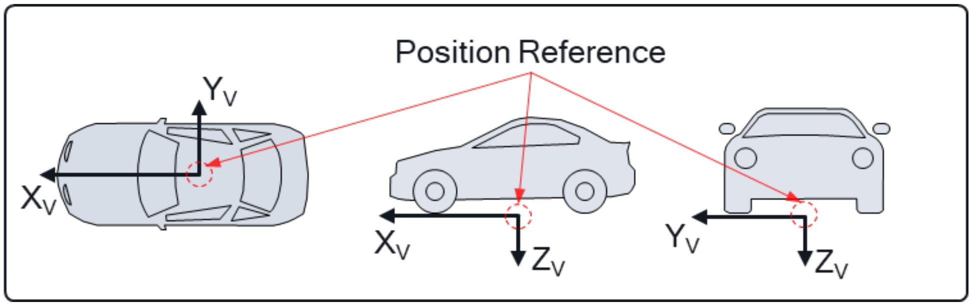


Figure 4 - Vehicle reference position

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.

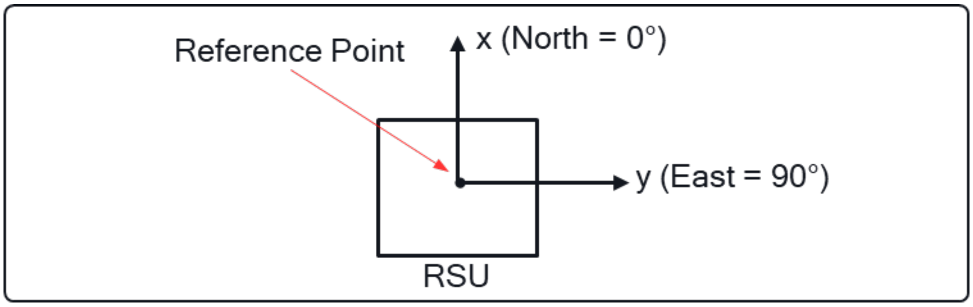


Figure 5 - RSU reference position

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.

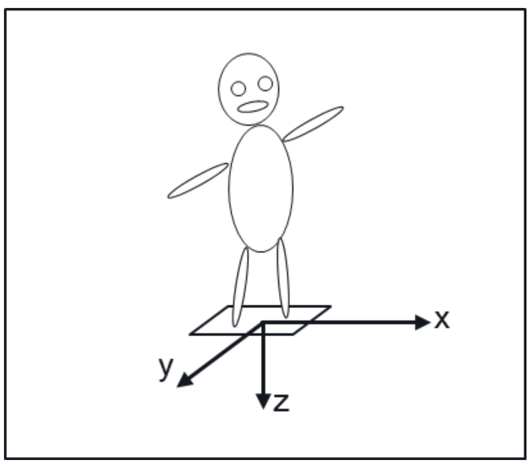


Figure 6 - VRU reference position

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 Xv-axis).

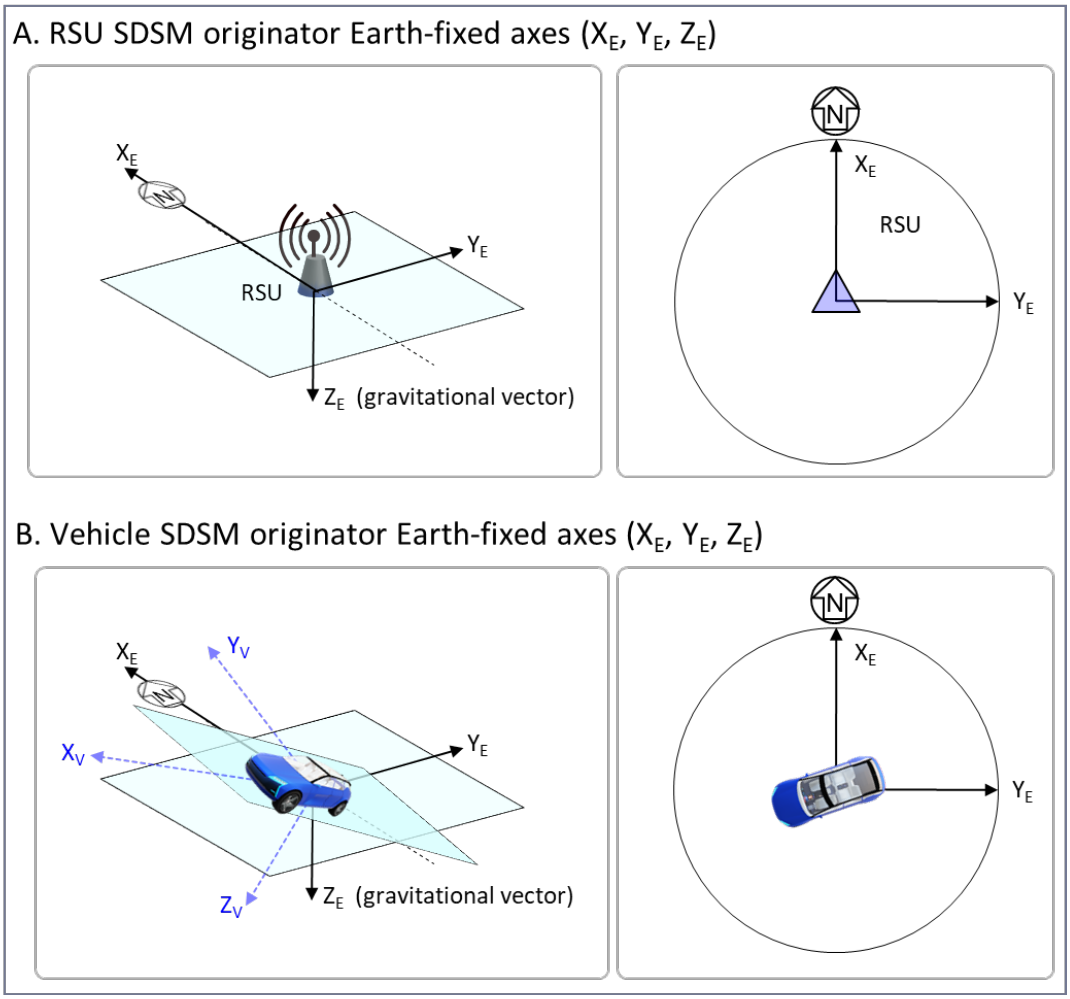


Figure 7 - HV Earth-fixed axes

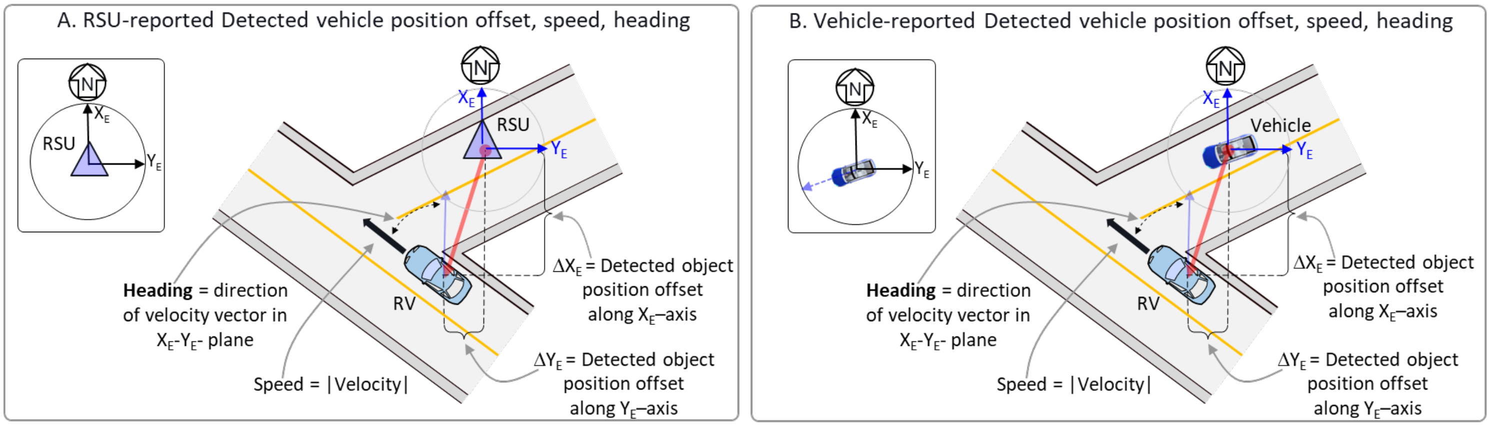


Figure 8 - Detected object position offset

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

a. 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.

b. Detected vehicle pitch, given by the angle between the detected vehicle x_V-axis and the (x_E-y_E) plane.

c. Detected vehicle roll, given by the angle between the detected vehicle y_V-axis and the (x_E-y_E) plane.

d. 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.

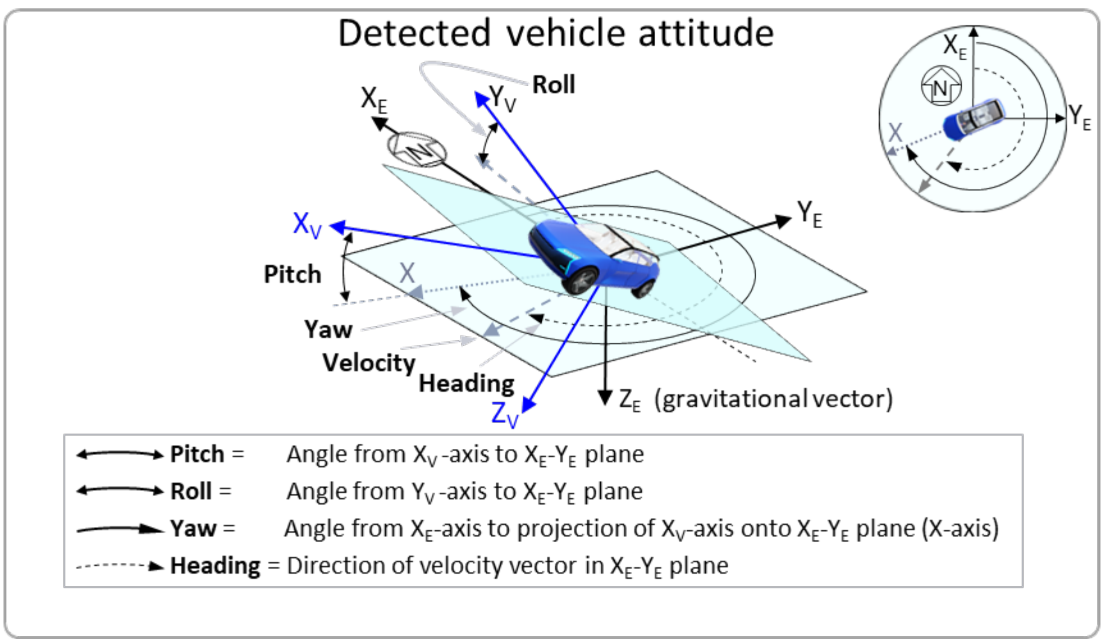


Figure 9 - Detected vehicle

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.

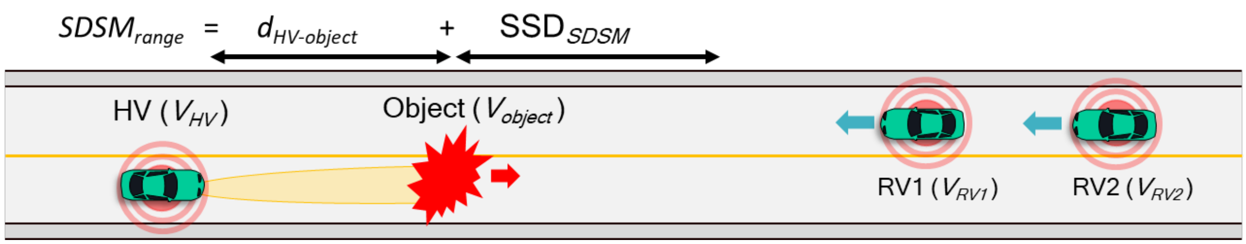


Figure 10 - Detection of obstacle by host vehicle

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.

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

where:

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

$V_{BSM,MAX}$ = 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

$V_{Object,MAX}$ = 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/s^2

6. SSS MESSAGE SETS

6.1 Message: MSG_SensorDataSharingMessage (SDSM)

6.1.1 SDSM ASN.1

```
SensorDataSharingMessage
{joint-iso-itu-t (2) country (16) us (840) organization (1) sae (114566)
v2x-communications (1) technical-committees (1) advanced-applications (3) technical-
reports (1) j3224 (3224) part-0 (0) asn1-module (1) sensorDataSharingMessage (1) version-
1 (1)}

DEFINITIONS AUTOMATIC TAGS ::=
BEGIN

IMPORTS
        Acceleration,
        AccelerationSet4Way,
        BasicVehicleClass,
        DDateTime,
        Elevation,
        ElevationConfidence,
        ExteriorLights,
        Heading,
        HeadingConfidence,
        Latitude,
        Longitude,
        MsgCount,
        Position3D,
        PositionalAccuracy,
        PositionConfidenceSet,
        SemiMajorAxisAccuracy,
        SemiMinorAxisAccuracy,
        SemiMajorAxisOrientation,
        Speed,
        SpeedConfidence,
        TemporaryID,
        TimeConfidence,
        VehicleHeight,
        VehicleLength,
        VehicleSize,
        VehicleWidth,
        VerticalAcceleration,
        YawRate
              FROM Common {joint-iso-itu-t (2) country (16) us (840) organization (1)
              sae (114566) v2x-communications (1) technical-committees (1) v2x-core
              (5) technical-reports (1) j2735 (2735) part-0 (0) asn1-module (1)
              common (38) version-1 (1)}
        Attachment,
        AttachmentRadius,
        PersonalDeviceUserType,
        PropelledInformation
              FROM PersonalSafetyMessage {joint-iso-itu-t (2) country (16) us (840)
              organization (1) sae (114566) v2x-communications (1) technical-
              committees (1) v2x-core (5) technical-reports (1) j2735 (2735) part-0
              (0) asn1-module (1) personalSafetyMessage (21) version-1 (1)}
        AccelerationConfidence,
        YawRateConfidence
              FROM ProbeVehicleData {joint-iso-itu-t (2) country (16) us (840)
              organization (1) sae (114566) v2x-communications (1) technical-
```

```
                  committees (1) v2x-core (5) technical-reports (1) j2735 (2735) part-0
                  (0) asn1-module (1) probeVehicleData (15) version-1 (1)};


SensorDataSharingMessage ::= SEQUENCE {
      msgCnt MsgCount,
      -- Sequence number
      sourceID TemporaryID,
      -- temporary vehicle ID / RSU ID. SDSM source.
      equipmentType EquipmentType,
      -- Sender type
       sDSMTimeStamp DDateTime,
      -- SDSM transmission time
      refPos Position3D,
      -- Sender reference position
      refPosXYConf PositionalAccuracy,
      refPosElConf ElevationConfidence OPTIONAL,
      objects DetectedObjectList
      -- detected objects

}

EquipmentType ::= ENUMERATED{
      unknown (0),
      rsu (1),
      obu (2),
      vru (3),
      ...
}



DetectedObjectList::= SEQUENCE (SIZE(1..256)) OF DetectedObjectData

DetectedObjectData::= SEQUENCE {
      detObjCommon DetectedObjectCommonData,
      -- Common data for detected object
      detObjOptData DetectedObjectOptionalData OPTIONAL
      -- Type specific optional data
}
DetectedObjectOptionalData ::= CHOICE {
      detVeh DetectedVehicleData,
      -- Detected vehicle data
      detVRU DetectedVRUData,
      -- Detected VRU data
      detObst DetectedObstacleData
      -- Detected obstacle data
}

DetectedObjectCommonData::= SEQUENCE {
      objType ObjectType,
      objTypeCfd ClassificationConfidence,
      objectID ObjectID,
      -- temporary ID assigned by source
      measurementTime MeasurementTimeOffset,
      -- Detection time
      timeConfidence TimeConfidence,
      pos PositionOffsetXYZ,
      posConfidence PositionConfidenceSet,
      speed Speed,
      speedConfidence SpeedConfidence,
```

```
      speedZ Speed OPTIONAL,
      speedConfidenceZ SpeedConfidence OPTIONAL,
      heading Heading,
      headingConf HeadingConfidence,
      accel4way AccelerationSet4Way OPTIONAL,
      accCfdX AccelerationConfidence OPTIONAL,
      accCfdY AccelerationConfidence OPTIONAL,
      accCfdZ AccelerationConfidence OPTIONAL,
      accCfdYaw YawRateConfidence OPTIONAL,
      ...
}
DetectedVehicleData::= SEQUENCE {
      lights ExteriorLights OPTIONAL,
      vehAttitude Attitude OPTIONAL,
      vehAttitudeConfidence AttitudeConfidence OPTIONAL,
      vehAngVel AngularVelocity OPTIONAL,
      vehAngVelConfidence AngularVelocityConfidence OPTIONAL,
      size VehicleSize OPTIONAL,
      height VehicleHeight OPTIONAL,
      vehicleSizeConfidence VehicleSizeConfidence OPTIONAL,
      vehicleClass BasicVehicleClass OPTIONAL,
      classConf ClassificationConfidence OPTIONAL,
      ...
}

DetectedVRUData::= SEQUENCE {
      basicType PersonalDeviceUserType OPTIONAL,
      propulsion PropelledInformation OPTIONAL,
      attachment Attachment OPTIONAL,
      radius AttachmentRadius OPTIONAL

}

DetectedObstacleData::= SEQUENCE {
      obstSize ObstacleSize,
      obstSizeConfidence ObstacleSizeConfidence

}

ObjectType::= ENUMERATED{
      unknown (0),
      vehicle (1),
      vru (2),
      animal (3),
      ...
}

ObjectID ::= INTEGER (0..65535)

ClassificationConfidence ::= INTEGER (0..101)

MeasurementTimeOffset ::= INTEGER (-1500..1500) -- LSB units of 1ms

PositionOffsetXYZ ::= SEQUENCE {
      offsetX ObjectDistance,
      offsetY ObjectDistance,
      offsetZ ObjectDistance OPTIONAL
      }

ObjectDistance ::=INTEGER(-32767..32767)  --LSB units of 0.1 meters
```

```
Attitude ::= SEQUENCE {
      pitch PitchDetected,
      roll RollDetected,
      yaw YawDetected
      }

PitchDetected ::= INTEGER (-7200..7200)
      -- LSB units of 0.0125 degrees (signed)
      -- range of -90 to 90 degrees

RollDetected ::= INTEGER  (-14400..14400)
      -- LSB units of 0.0125 degrees (signed)
      -- range of -180 to 180 degrees

YawDetected ::= INTEGER (-14400..14400)
      -- LSB units of 0.0125 degrees (signed)
      -- range of -180 to 180 degrees

AttitudeConfidence ::= SEQUENCE {
      pitchConfidence HeadingConfidence,
      rollConfidence HeadingConfidence,
      yawConfidence HeadingConfidence
      }

AngularVelocity ::= SEQUENCE {
      pitchRate PitchRate,
      rollRate RollRate

      }

PitchRate ::= INTEGER (-32767..32767)
      -- LSB units of 0.01 degrees per second (signed)
      -- unavailable (32767)


RollRate ::= INTEGER (-32767..32767)
      -- LSB units of 0.01 degrees per second (signed)
      -- unavailable (32767)

AngularVelocityConfidence ::= SEQUENCE {
      pitchRateConfidence     PitchRateConfidenceOPTIONAL,
      rollRateConfidence    RollRateConfidence OPTIONAL

      }

PitchRateConfidence ::= ENUMERATED {
      unavailable    (0), -- B'000  Not Equipped with angular velocity status
      -- or angular velocity status is unavailable
      degSec-100-00  (1), -- B'001  100  deg/sec
      degSec-010-00  (2), -- B'010  10   deg/sec
      degSec-005-00  (3), -- B'011  5    deg/sec
      degSec-001-00  (4), -- B'100  1    deg/sec
      degSec-000-10  (5), -- B'101  0.1  deg/sec
      degSec-000-05  (6), -- B'110  0.05 deg/sec
      degSec-000-01  (7)  -- B'111  0.01 deg/sec
      }

RollRateConfidence ::= ENUMERATED {
      unavailable    (0), -- B'000  Not Equipped with angular velocity status
      -- or angular velocity status is unavailable
      degSec-100-00  (1), -- B'001  100  deg/sec
```

```
      degSec-010-00  (2), -- B'010  10   deg/sec
      degSec-005-00  (3), -- B'011  5    deg/sec
      degSec-001-00  (4), -- B'100  1    deg/sec
      degSec-000-10  (5), -- B'101  0.1  deg/sec
      degSec-000-05  (6), -- B'110  0.05 deg/sec
      degSec-000-01  (7)  -- B'111  0.01 deg/sec
      }

VehicleSizeConfidence ::= SEQUENCE {
      vehicleWidthConfidence     SizeValueConfidence,
      vehicleLengthConfidence    SizeValueConfidence,
      vehicleHeightConfidence    SizeValueConfidence OPTIONAL
      }

ObstacleSize ::= SEQUENCE {
      width SizeValue,
      length SizeValue,
      height SizeValue OPTIONAL
      }

ObstacleSizeConfidence ::= SEQUENCE {
      widthConfidence     SizeValueConfidence,
      lengthConfidence    SizeValueConfidence,
      heightConfidence    SizeValueConfidence OPTIONAL
      }

SizeValue ::= INTEGER (0..1023) -- LSB units are 10 cm with a range of >100 meters

SizeValueConfidence ::= ENUMERATED {
      unavailable (0),
      size-100-00 (1), -- (100 m)
      size-050-00 (2), -- (50 m)
      size-020-00 (3), -- (20 m)
      size-010-00 (4), -- (10 m)
      size-005-00 (5), -- (5 m)
      size-002-00 (6), -- (2 m)
      size-001-00 (7), -- (1 m)
      size-000-50 (8), -- (50 cm)
      size-000-20 (9), -- (20 cm)
      size-000-10 (10), -- (10 cm)
      size-000-05 (11), -- (5 cm)
      size-000-02 (12), -- (2 cm)
      size-000-01 (13) -- (1 cm)
      }

END
```

7. OTHER REQUIREMENTS

7.1 Positioning and Timing Requirements

7.1.1 Position Determination

Refer to SAE J2945/1, Section 6.2.

7.2 SDSM Transmission Requirements

7.2.1 SDSM Transmission Contents

When transmitting a SDSM, the system shall generate the corresponding MSG_MessageFrame containing MSG_SensorDataSharingMessage and the data frames and data elements as specifed in this standard and SAE J2735.

7.2.2 Minimum Transmission Criteria

The system shall transmit an SDSM only if the SDSM meets the minimum criteria for SDSM transmission specified in Table 1. If at any time the system cannot formulate an SDSM that meets the minimum transmission criteria, the system ceases transmitting SDSMs until the criteria are met.

Table 1 - Minimum criteria for SDSM transmission

Data Element/Field	Can be set to unavailable, or represent an unknown value?	Section Reference (this standard)
DE_MsgCount	No	See Appendix B
DE_EquipmentType	No	See A.2.2
DE_TemporaryID	No	See Appendix B
DF_DDateTime	No	See Appendix B
DF_Position3D		
DE_Latitude	No	See Appendix B
DE_Longitude	No	See Appendix B
DE_Elevation	Yes	See Appendix B
DF_PositionalAccuracy		
DE_SemiMajorAxisAccuracy	Yes	See Appendix B
DE_SemiMinorAxisAccuracy	Yes	See Appendix B
DE_SemiMajorAxisOrientation	Yes	See Appendix B
DE_ElevationConfidence	Yes	See Appendix B
DF_DetectedObjectList		

Table 2 - Minimum criteria for SDSM transmission, detected object common data

Data Element/Field	Can be set to unavailable, or represent an unknown value?	Requirements
DF_DetectedObjectCommonData		
DE_ObjectType	No	See A.2.7
DE_ClassificationConfidence	Yes	See A.2.1
DE_ObjectID	No	See A.2.6
DE_MeasurementTimeOffset	No	See A.2.4
DE_TimeConfidence	No	See Appendix B
DF_PositionOffsetXYZ		
DE_offsetX	No	See A.2.5
DE_offsetY	No	See A.2.5
DE_offsetZ	No	See A.2.5
DF_PositionConfidenceSet		
DE_PositionConfidence	Yes	See Appendix B
DE_ElevationConfidence	Yes	See Appendix B
DE_Speed	Yes	See Appendix B
DE_SpeedConfidence	Yes	See Appendix B
DE_SpeedZ	Yes	See A.2.17
DE_SpeedConfidenceZ	Yes	See A.2.18
DE_Heading	Yes	See Appendix B
DE_HeadingConfidence	Yes	See Appendix B
DF_AccelerationSet4Way		
DE_Acceleration	Yes	See Appendix B
DE_VerticalAcceleration	Yes	See Appendix B
DE_YawRate	No	See Appendix B
DE_AccelerationConfidence (accCfdX)	Yes	See Appendix B
DE_AccelerationConfidence (accCfdY)	Yes	See Appendix B
DE_AccelerationConfidence (accCfdZ)	Yes	See Appendix B
DE_YawRateConfidence	Yes	See Appendix B

Table 3 - Minimum criteria for SDSM transmission, detected vehicle data

Data Element/Field	Can be set to unavailable, or represent an unknown value?	Requirements
DF_DetectedVehicleData	No	See A.1.9
DE_ExteriorLights	No	See Appendix B
DF_Attitude	No	See A.1.3
DE_PitchDetected	Yes	See A.2.8
DE_RollDetected	Yes	See A.2.11
DE_YawDetected	Yes	See A.2.16
DF_AttitudeConfidence	No	See A.1.4
DE_HeadingConfidence (pitchConfidence)	Yes	See A.1.4
DE_ HeadingConfidence (rollConfidence)	Yes	See A.1.4
DE_ HeadingConfidence (yawConfidence)	Yes	See A.1.4
DF_AngularVelocity	Yes	See A.1.1
DE_PitchRate	Yes	See A.2.9
DE_RollRate	Yes	See A.2.12
DF_AngularVelocityConfidence	No	See A.1.2
DE_PitchRateConfidence	Yes	See A.2.10
DE_RollRateConfidence	Yes	See A.2.13
DF_VehicleSize	No	See Appendix B
DE_VehicleWidth	No	See Appendix B
DE_VehicleLength	No	See Appendix B
DE_VehicleHeight	No	See Appendix B
DF_VehicleSizeConfidence	No	See A.1.12
DE_SizeValueConfidence (vehicleWidthConfidence)	Yes	See A.1.12
DE_SizeValueConfidence (vehicleLengthConfidence)	Yes	See A.1.12
DE_SizeValueConfidence (vehicleHeightConfidence)	Yes	See A.1.12
DE_BasicVehicleClass	Yes	See Appendix B
DE_ClassificationConfidence	Yes	See A.2.1

Table 4 - Minimum criteria for SDSM transmission, detected VRU data

Data Element/Field	Can be set to unavailable, or represent an unknown value?	Requirements
DF_DetectedVRUData	Yes	See A.1.10
DE_PersonalDeviceUserType	Yes	See Appendix B
DF_PropelledInformation	No	See Appendix B
DE_HumanPropelledType	Yes	See Appendix B
DE_AnimalPropelledType	Yes	See Appendix B
DE_MotorizedPropelledType	Yes	See Appendix B
DE_Attachment	Yes	See Appendix B
DE_AttachmentRadius	No	See Appendix B

Table 5 - Minimum criteria for SDSM transmission, detected obstacle data

Data Element/Field	Can be set to unavailable, or represent an unknown value?	Requirements
DF_DetectedObstacleData		
DF_ObstacleSize	No	See A.1.5
DE_SizeValue (width)	No	See A.1.5
DE_SizeValue (length)	No	See A.1.5
DE_SizeValue (height)	No	See A.1.5
DF_ObstacleSizeConfidence		
DE_SizeValueConfidence (widthConfidence)	Yes	See A.1.6
DE_SizeValueConfidence (lengthConfidence)	Yes	See A.1.6
DE_SizeValueConfidence (heightConfidence)	Yes	See A.1.6

7.3 Security and Privacy Requirements

7.3.1 Data Integrity and Data Source Authenticity and Authorization

7.3.1.1 On-Board Units

The OBU shall sign the messages it disseminates to other OBUs or RSUs using IEEE 1609.2 certificates that include the provider service identification (PSID) assigned for the SSS application, according to the IEEE 1609.2 security profile in Appendix C.

The OBU shall ensure that the received messages are validly signed with an IEEE 1609.2 certificate that include the PSID for Sensor Sharing Service as specified in Appendix B and the appropriate SSP as specified in Appendix C, if any, indicating the sender was authorized to send such a message.

NOTE: The certificate issuance policy may address the question of whether an OBU whose Basic Safety Service has been blocked from receving certificates may still be able to obtain certificates for SDSMs.

7.3.1.2 Roadside Units

The RSU shall sign the messages it disseminates to OBUs using IEEE 1609.2 certificates that include the PSID assigned for the SSS application, according to the IEEE 1609.2 security profile in Appendix C.

The RSU shall ensure that the messages received from OBUs are validly signed with an IEEE 1609.2 certificate that includes the PSID for SSS as specified in Appendix B and the appropriate SSP as specified in Appendix C, if any, indicating the sender was authorized to send such a message.

7.3.2 User Privacy

For all OBUs and other device types, and any other users of the system, participation in the system shall be optional.

All vehicle and device types, and any other users of the system, shall be able to participate in the system without being identified (no use of personally identifiable information).

If the sending OBU requires pseudonymity (which is determined by criteria outside the scope of this standard), it is recommended that the pseudonymity techniques of SAE J3161/1, Sections 6.5.1 and 6.5.3 (SAE J2945/1, sections 6.5.1 and 6.5.2) are used. These techniques include changing the signing certificate from time to time. This change should be synchronized with changing the signing certificate that the OBU uses to sign other broadcast messages, if that certificate is different. An OBU architecture that supports this synchronization is described in ETSI TS 102 723-8. OBUs shall use IEEE 1609.2 pseudonym certificates, i.e., certificates where the `id` field in the ToBeSignedCertificate is of type `none` or `linkageData`. RSUs shall use IEEE 1609.2 application certificates, i.e., certificates where the `id` field in the `ToBeSignedCertificate` is of type `name` or `binaryId`.

If the certificate used to sign SDSMs is different from that used to sign BSMs, then both certificates shall be changed at the same time.

7.4 Security Management (SECMGNT)

The security management principles outlined in SAE J2945/1, Section 6.6 apply to this application and the OBUs and RSUs hosting it.

8. VARIABLES AND PARAMETER SETTINGS

The following is a list of variables and suggested parameters used in the SSS protocol.

Table 6 - SSS parameters

Section Reference(s)	Parameter	Value	Rationale(s)
7.2	vSDSMrate	10 Hz	1

1. The setting is based on the need to provide accurate and timely safety alerts for the use cases described in 4.2.

9. NOTES

9.1 Revision Indicator

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

PREPARED BY SAE ADVANCED APPLICATIONS TECHNICAL COMMITTEE

APPENDIX A - DESCRIPTION OF INFORMATION ELEMENTS

A.1 DATA FRAMES

A.1.1 Data Frame: DF_AngularVelocity

Use:	This data frame is a set of angular velocity values in three orthogonal directions of the vehicle. The positive longitudinal axis is to the front of the vehicle. The positive lateral axis is to the right side of the vehicle (facing forward). Positive yaw is to the right (clockwise). A positive vertical z axis is downward with the zero point at the bottom of the vehicle's tires.

ASN.1 representation:	`AngularVelocity ::= SEQUENCE {`
	`     pitchRate PitchRate,`
	`     rollRate RollRate,`
	`}`

Used by:	This entry is directly used by the following data structure in this standard: DF DetectedVehicleData <ASN>

A.1.2 Data Frame: DF_AngularVelocityConfidence

Use:	This data frame is a set of confidence values for angular velocity in three orthogonal directions of the vehicle. The positive longitudinal axis is to the front of the vehicle. The positive lateral axis is to the right side of the vehicle (facing forward). Positive yaw is to the right (clockwise). A positive vertical "z" axis is downward with the zero point at the bottom of the vehicle's tires. This data frame shall always be present when DF_AngularVelocity is present.

ASN.1 representation:	`AngularVelocityConfidence ::= SEQUENCE {`
	`     pitchRateConfidence     PitchRateConfidence,`
	`     rollRateConfidence    RollRateConfidence,`
	`}`

Used by:	This entry is directly used by the following data structure in this standard: DF DetectedVehicleData <ASN>

A.1.3 Data Frame: DF_Attitude

Use:	This data frame is a set of attitude values for a detected vehicle consisting of pitch, roll and yaw, where pitch, roll and yaw are expressed in the three orthogonal directions of the vehicle, as defined in clause 5.3.2.

ASN.1 representation:	`Attitude ::= SEQUENCE {`
	`     pitch PitchDetected,`
	`     roll RollDetected,`
	`     yaw YawDetected,`
	`}`

Used by:	This entry is directly used by the following data structure in this standard: DF DetectedVehicleData <ASN>

A.1.4 Data Frame: DF_AttitudeConfidence

Use:	This data frame is a set of attitude confidence values in three orthogonal directions of the vehicle, as defined in clause 5.3.2. The positive longitudinal axis is to the front of the vehicle. The positive lateral axis is to the right side of the vehicle (facing forward). Positive yaw is to the right (clockwise). A positive vertical "z" axis is downward with the zero point at the bottom of the vehicle's tires. This data frame shall always be present when DF_Attitude is present.

ASN.1 representation:	`AttitudeConfidence ::= SEQUENCE {`
	`     pitchConfidence HeadingConfidence,`
	`     rollConfidence HeadingConfidence,`
	`     yawConfidence HeadingConfidence,`
	`}`

Used by:	This entry is directly used by the following data structure in this standard: DF DetectedVehicleData <ASN>

A.1.5 Data Frame: DF_ObstacleSize

Use:	The DF_ObstacleSize data frame defines the size in length, witdth and height of a detected obstacle.

ASN.1 representation:	`ObstacleSize ::= SEQUENCE {`
	`     width  SizeValue,`
	`     length SizeValue,`
	`     height SizeValue OPTIONAL`
	`}`

Used by:	This entry is directly used by the following data structure in this standard: DF DetectedObstacleData <ASN>

A.1.6 Data Frame: DF_ObstacleSizeConfidence

Use:	The DF_ ObstacleSizeConfidence is a data frame representing the accuracies associated with a detected object length, detected object width detected object vehicle height in a single data concept.

ASN.1 representation:	`ObstacleSizeConfidence ::= SEQUENCE {`
	`     widthConfidence     SizeValueConfidence,`
	`     lengthConfidence    SizeValueConfidence`
	`     heightConfidence    SizeValueConfidence OPTIONAL`
	`}`

Used by:	This entry is directly used by the following data structure in this standard: DF DetectedObstacleData <ASN>

A.1.7 Data Frame: DF_PositionOffsetXYZ

Use:	The DF_ PositionOffsetXYZ data element is used to convey an XYZ offset from a known point.

ASN.1 representation:	`PositionOffsetXYZ ::= SEQUENCE {`
	`     offsetX ObjectDistance`
	`     offsetY ObjectDistance`
	`     offsetZ ObjectDistance OPTIONAL`
	`     …`
	`}`

Used by:	This entry is directly used by the following data structure in this standard: DF DetectedObjectCommonData <ASN>

A.1.8 Data Frame: DF_DetectedObjectCommonData

Use:	The DF_DetectedObjectCommonData data frame defines the minimum set of detected characteristics an HV or HRSU provides for a detected object.

ASN.1 representation:	`DetectedObjectCommonData::= SEQUENCE {`
	`objType ObjectType,`
	`objTypeCfd ClassificationConfidence,`
	`objectID ObjectID INTEGER (0..65535),`
	`measurementTime MeasurementTimeOffset,`
	`timeConfidence TimeConfidence,`
	`pos PositionOffsetXYZ,`
	`posConfidence PositionConfidenceSet,`
	`speed Speed,`
	`speedConfidence SpeedConfidence,`
	`speedZ SpeedZ OPTIONAL,`
	`speedConfidenceZ SpeedConfidenceZ OPTIONAL,`
	`heading Heading,`
	`headingConf HeadingConfidence,`
	`accel4way AccelerationSet4Way OPTIONAL,`
	`accCfdX AccelerationConfidence OPTIONAL,`
	`accCfdY AccelerationConfidence OPTIONAL,`
	`accCfdZ AccelerationConfidence OPTIONAL,`
	`accCfdYaw YawRateConfidence OPTIONAL,`
	`}`

Used by:	This entry is directly used by the following data structure in this standard: MSG SensorDataSharingMessage (SDSM) <ASN>

A.1.9 Data Frame: DF_DetectedVehicleData

Use:	The DF_DetectedVehicleData data frame defines the set of detected characteristics an HV or HRSU provides for a detected vehicle.

ASN.1 representation:	`DetectedVehicleData::= SEQUENCE {`
	`lights ExteriorLights OPTIONAL,`
	`vehAttitude Attitude OPTIONAL,`
	`vehAttitudeConfidence AttitudeConfidence OPTIONAL,`
	`vehAngVel AngularVelocity OPTIONAL,`
	`vehAngVelConfidence AngularVelocityConfidence OPTIONAL,`
	`size VehicleSize OPTIONAL,`
	`height VehicleHeight OPTIONAL,`
	`vehicleSizeConfidence VehicleSizeConfidence OPTIONAL,`
	`vehicleClass BasicVehicleClass OPTIONAL,`
	`classConf ClassificationConfidence OPTIONAL,`
	`}`

Used by:	This entry is directly used by the following data structure in this standard: MSG SensorDataSharingMessage (SDSM) <ASN>

A.1.10 Data Frame: DF_DetectedVRUData

Use:	The DF_DetectedVRUData data frame defines the set of detected characteristics an HV or HRSU provides for a detected VRU.

ASN.1 representation:	`DetectedVRUData::= SEQUENCE {`
	`basicType PersonalDeviceUserType OPTIONAL,`
	`propulsion PropelledInformation OPTIONAL,`
	`attachment Attachment OPTIONAL,`
	`radius AttachmentRadius OPTIONAL`

Used by:	This entry is directly used by the following data structure in this standard: MSG MSG_SensorDataSharingMessage (SDSM) <ASN>

A.1.11 Data Frame: DF_DetectedObstacleData

Use:	The DF_DetectedObstacleData data frame defines the set of detected characteristics an HV or HRSU provides for a detected obstacle.

ASN.1 representation:	`DetectedObstacleData::= SEQUENCE {`
	`obstSize ObstacleSize,`
	`obstSizeConfidence ObstacleSizeConfidence`
	`}`

Used by:	This entry is directly used by the following data structure in this standard: MSG SensorDataSharingMessage (SDSM) <ASN>

A.1.12 Data Frame: DF_VehicleSizeConfidence

Use:	The DF_VehicleSizeConfidence is a data frame representing the accuracies associated with vehicle length, vehicle width and vehicle height in a single data concept. This data frame shall always be present when DF_VehicleSize is present. VehicleHeightConfidence shall always be present when DE_VehicleHeight is present.

ASN.1 representation:	`VehicleSizeConfidence ::= SEQUENCE {`
	`VehicleWidthConfidence SizeValueConfidence,`
	`VehicleLengthConfidence SizeValueConfidence`
	`VehicleHeightConfidence SizeValueConfidence OPTIONAL`
	`}`

Used by:	This entry is directly used by the following data structure in this standard: DF DetectedVehicleData <ASN>

A.1.13 Data Frame: DF_DetectedObjectOptionalData

Use:	The DF DetectedObjectOptionalData data element is used to type-specific detected characteristics an HV or HRSU provides for a detected object.

ASN.1 representation:	`DetectedObjectOptionalData ::= CHOICE {`
	`detVeh DetectedVehicleData OPTIONAL,`
	`-- Detected vehicle data`
	`detVRU DetectedVRUData OPTIONAL,`
	`-- Detected VRU data`
	`detObst DetectedObstacleData OPTIONAL`
	`-- Detected obstacle data`
	`}`

Used by:	This entry is directly used by the following data structure in this standard: MSG SensorDataSharingMessage (SDSM) <ASN>

A.1.14 Data Element: DF_DetectedObjectList

Use:	
ASN.1 representation:	`DetectedObjectList ::= SEQUENCE (SIZE(1..256)) OF DetectedObjectData`
Used by:	This entry is directly used by the following data structure in this standard: MSG SensorDataSharingMessage (SDSM) <ASN>

A.2 DATA ELEMENTS

A.2.1 Data Element: DE_ClassificationConfidence

Use:	Describes the confidence value for the type of detected object. The value should be set to: ▪ Unknown (0): in case the confidence value is unknown but the reported classification is still valid. ▪ A value between 1 and 100 representing the confidence that the provided class applies for the object. ▪ Unavailable (101): in case the class confidence value computation is not available for this object. Indicates that the class assignment is invalid. This data element shall always be present when DE_BasicVehicleClass is present.
ASN.1 representation:	`ASN.1 ::= INTEGER (0..101)`
Used by:	This entry is directly used by the following two data structures in this standard: DF DetectedObjectCommonData <ASN> DF DetectedVehicleData <ASN>

A.2.2 Data Element: DE_EquipmentType

Use:	This DE defines the originating device type.

ASN.1 representation:	`EquipmentType ::= ENUMERATED{`
	`unknown (0),`
	`rsu (1),`
	`obu (2),`
	`vru (3),`
	`...`
	`}`

Used by:	This entry is directly used by the following data structure in this standard: MSG SensorDataSharingMessage (SDSM) <ASN>

A.2.3 Data Element: DE_MeasurementTimeOffset

Use:	The DE_MeasurementTimeOffset data element, a signed value, is used to convey an offset in time relative to the sDSMTimeStamp associated with the reference position. Negative values indicate the provided detected object characteristics refer to a point in time after the sDSMTimeStamp (i.e., after the reference position has been determined), as described in 5.3. The DE_Measurement TimeOffset shall comply with the requirements in SAE J2735, Section 11.3.
ASN.1 representation:	`MeasurementTimeOffset ::= INTEGER (-1500..1500)) -LSB units of 1ms (signed)`
Used by:	This entry is directly used by the following data structure in this standard: DF DetectedObjectCommonData <ASN>

A.2.4 Data Element: DE_ObjectDistance

Use:	The DE_ObjectDistance, a signed value, provides a scalar distance in units of 0.1 m.
ASN.1 representation:	`ObjectDistance ::= INTEGER(-32767..32767) -LSB units of 0.1m (signed)`
Used by:	This entry is directly used by the following data structure in this standard: DF PositionOffsetXYZ <ASN>

A.2.5 Data Element: DE_ObjectID

Use:	The DE is ObjectID provides an identifier that is assigned to each detected object from a range of monotonically increasing numbers. The assigned ObjectID is maintained for a detected object a long as the object is detected. ObjectID is re-initialized once the signing certificate of the HV changes.
ASN.1 representation:	`ObjectID ::= INTEGER (0..65535)`
Used by:	This entry is directly used by the following data structure in this standard: DF DetectedObjectCommonData <ASN>

A.2.6 Data Element: DE_ObjectType

Use:	Describes the classification of a detected object. The object can be classified into one of four categories: unknown, vehicle, VRU, animal.

ASN.1 representation:	`ASN.1 ::= ENUMERATED{`
	`unknown (0),`
	`vehicle (1),`
	`vru (2),`
	`animal (3),`
	`...`
	`}`

Used by:	This entry is directly used by the following data structure in this standard: DF DetectedObjectCommonData <ASN>

A.2.7 Data Element: DE_PitchDetected

Use:	The DE_PitchDetected defines angle between the ground plane (the plane normal to the gravitational vector) and the vehicle body X-axis in 0.0125 degree resolution, as described in 5.3.3. Clockwise rotation about the Y-axis is positive and counterclockwise rotation about the Y-axis is negative.

ASN.1 representation:	`PitchDetected ::= INTEGER (-7200..7201)`
	`-- LSB units of 0.0125 degrees (signed)`
	`-- range of -90 to 90 degrees`
	`-- The value 7201 indicates that pitch is unavailable`

Used by:	This entry is directly used by the following data structure in this standard: DF Attitude <ASN>

A.2.8 Data Element: DE_PitchRate

Use:	The DE_PitchRate data element provides the Pitch Rate of a detected object about its lateral axis (Y-axis). DE_PitchRate is, a signed value, positive indicating clockwise rotation expressed in 0.01 degree per second. A value of 32767 indicates the value is unavailable.

ASN.1 representation:	`PitchRate ::= INTEGER (-32767..32767)`
	`-- LSB units of 0.01 degrees per second (signed)`
	`-- unavailable (32767)`

Used by:	This entry is directly used by the following data structure in this standard: DF AngularVelocity <ASN>

A.2.9 Data Element: DE_PitchRateConfidence

Use:	The DE_PitchRateConfidence is a set of confidence values for pitch rate of a detected object about its lateral axis (Y-axis). The positive longitudinal axis is to the front of the vehicle. The positive lateral axis is to the right side of the vehicle (facing forward). Clockwise rotation about the Y-axis is positive and counterclockwise rotation about the Y-axis is negative.

ASN.1 representation:	`PitchRateConfidence ::= ENUMERATED {`
	`unavailable (0), -' B'000 Not Equipped with angular velocity status`
	`-- or angular velocity status is unavailable`
	`degSec-100-00 (1), -' B'001 100 deg/sec`
	`degSec-010-00 (2), -' B'010 10 deg/sec`
	`degSec-005-00 (3), -' B'011 5 deg/sec`
	`degSec-001-00 (4), -' B'100 1 deg/sec`
	`degSec-000-10 (5), -' B'101 0.1 deg/sec`
	`degSec-000-05 (6), -' B'110 0.05 deg/sec`
	`degSec-000-01 (7) -' B'111 0.01 deg/sec`
	`--- Encoded as a 3 bit value`

Used by:	This entry is directly used by the following data structure in this standard: DF AngularVelocityConfidence <ASN>

A.2.10 Data Element: DE_RollDetected

Use:	The DE_RollDetected defines angle between the ground plane (the plane normal to the gravitational vector) and the vehicle body Y-axis in 0.0125 degree resolution, as described in 5.3.3. Clockwise rotation about the X-axis is positive and counterclockwise rotation about the X-axis is negative.

ASN.1 representation:	`RollDetected ::= INTEGER (-14400..14400)`
	`-- LSB units of 0.0125 degrees (signed)`
	`-- range of -180 to 180 degrees`
	`-- The value 14400 indicates that roll is unavailable`

Used by:	This entry is directly used by the following data structure in this standard: DF Attitude <ASN>

A.2.11 Data Element: DE_RollRate

Use:	The DE_RollRate data element provides the Roll Rate of a detected object about its longitidinal axis (X-axis). DE_RollRate is a signed value, positive indicating clockwise rotation (to the right) expressed in 0.01 degree per second. A value of 32767 indicates the value is unavailable.

ASN.1 representation:	`RollRate ::= INTEGER (-32767..32767)`
	`-- LSB units of 0.01 degrees per second (signed)`
	`-- unavailable (32767)`

Used by:	This entry is directly used by the following data structure in this standard: DF AngularVelocity <ASN>

A.2.12 Data Element: DE_RollRateConfidence

Use:	The DE_RollRateConfidence is a set of confidence values for roll rate of a detected object about its longitudinal axis (X-axis). The positive longitudinal axis is to the front of the vehicle. Clockwise rotation about the X-axis is positive and counterclockwise rotation about the X-axis is negative.

ASN.1 representation:	`RollRateConfidence ::= ENUMERATED {`
	`unavailable (0), -’ B'000 Not Equipped with angular velocity status`
	`-- or angular velocity status is unavailable`
	`degSec-100-00 (1), -’ B'001 100 deg/sec`
	`degSec-010-00 (2), -’ B'010 10 deg/sec`
	`degSec-005-00 (3), -’ B'011 5 deg/sec`
	`degSec-001-00 (4), -’ B'100 1 deg/sec`
	`degSec-000-10 (5), -’ B'101 0.1 deg/sec`
	`degSec-000-05 (6), -’ B'110 0.05 deg/sec`
	`degSec-000-01 (7) -’ B'111 0.01 deg/sec`
	`--- Encoded as a 3 bit value`

Used by:	This entry is directly used by the following data structure in this standard: DF AngularVelocityConfidence <ASN>

A.2.13 Data Element: DE_SizeValue

Use:	The DE_SizeValue provides a measure of size along a dimension of a detected object.

ASN.1 representation:	`SizeValue ::= INTEGER (0..1023)`
	`-- LSB units are 10 cm with a range of >100 meters`
	`-- The value 0 indicates that size is unavailable`

Used by:	This entry is directly used by the following data structure in this standard: DF ObstacleSize <ASN>

A.2.14 Data Element: DE_SizeValueConfidence

Use:	The DE_SizeValueConfidence is a set of confidence values for the size of a detected object. The value zero shall be sent when data is unavailable.

ASN.1 representation:	`SizeValueConfidence ::= ENUMERATED {`
	`unavailable (0),`
	`size-100-00 (1), -- (100 m)`
	`size-050-00 (2), -- (50 m)`
	`size-020-00 (3), -- (20 m)`
	`size-010-00 (4), -- (10 m)`
	`size-005-00 (5), -- (5 m)`
	`size-002-00 (6), -- (2 m)`
	`size-001-00 (7), -- (1 m)`
	`size-000-50 (8), -- (50 cm)`
	`size-000-20 (9), -- (20 cm)`
	`size-000-10 (10), -- (10 cm)`
	`size-000-05 (11), -- (5 cm)`
	`size-000-02 (12), -- (2 cm)`
	`size-000-01 (13) -- (1 cm)`
	`}`

Used by:	This entry is directly used by the following two data structurea in this standard: DF VehicleSizeConfidence <ASN> DF ObstacleSizeConfidence <ASN>

A.2.15 Data Element: DE_YawDetected

Use:	The DE_YawDetected defines yaw angle in 0.0125 degree resolution, as described in 5.3.3. Clockwise rotation about the Z-axis is positive and counterclockwise rotation about the Z-axis is negative.

ASN.1 representation:	`YawDetected ::= INTEGER (-14400..14400)`
	`-- LSB units of 0.0125 degrees (signed)`
	`-- range of -180 to 180 degrees`
	`-- The value 14400 indicates that yaw is unavailable`

Used by:	This entry is directly used by the following data structure in this standard: DF Attitude <ASN>

A.2.16 Data Element: DE_SpeedZ

Use:	This data element represents the detected object speed along the detected object's Z-axis expressed in unsigned units of 0.02 m/s. A value of 8191 shall be used when the speed is unavailable.

ASN.1 representation:	`Speed ::= INTEGER (0..8191) - Units of 0.02 m/s`
	`-- The value 8191 indicates that`
	`-- speed is unavailable`

Used by:	This entry is directly used by the following data structure in this standard: DF DetectedObjectCommonData <ASN>

A.2.17 Data Element: DE_SpeedConfidenceZ

Use:	The DE_SpeedConfidence data element is used to provide the 95% confidence level for the currently reported value of DE_SpeedZ, taking into account the current calibration and precision of the sensor(s) used to measure and/or calculate the value. This data element is only to provide the listener with information on the limitations of the sensing system, not to support any type of automatic error correction or to imply a guaranteed maximum error. This data element should not be used for fault detection or diagnosis, but if a vehicle is able to detect a fault, the confidence interval should be increased accordingly. This data element shall always be present when DE_SpeedZ is present.

ASN.1 representation:	`SpeedConfidence ::= ENUMERATED {`
	`unavailable (0), -- Not Equipped or unavailable`
	`prec100ms (1), -- 100 meters / sec`
	`prec10ms (2), -- 10 meters / sec`
	`prec5ms (3), -- 5 meters / sec`
	`prec1ms (4), -- 1 meters / sec`
	`prec0-1ms (5), -- 0.1 meters / sec`
	`prec0-05ms (6), -- 0.05 meters / sec`
	`prec0-01ms (- -- 0.01 meters / sec`
	`}`

Used by:	This entry is directly used by the following data structure in this standard: DF DetectedObjectCommonData <ASN>

APPENDIX B - STANDARDS PROFILES

B.1 IEEE 1609.2 (1609.2)

See security profile in Appendix C.

B.2 IEEE 1609.12

This specifies the requirements from IEEE 1609.12 to support SDSM operation.

Table B1 - IEEE 1609.12 requirements

IEEE 1609.12 Clause	Title (IEEE 1609.12 Clause)	Required for	Requirement
4.1.x	Provider service identifier (PSID)	SSS	The system shall set the PSID value to the value assigned to "Sensor Sharing Service" (0x90), as listed by IEEE-RA website (https://standards.ieee.org/products-services/regauth/psid/public.html).

B.3 SAE J2735

All Data Frames (DFs) and Data Elements (DEs) imported from SAE J2735 comply with the requirements defined in SAE J2735 and the requirements in Table B2.

Table B2 - SAE J2735 data field, data element requirements

DF, DE Name	Requirement	Note
DE_Acceleration	Refer to SAE J2735, Section 7.1 .	2
DF_AccelerationSet4Way	Refer to SAE J2735, Section 6.1.	2
DE_BasicVehicleClass	Refer to SAE J2735, Section 7.15.	2
DF_DDateTime	Refer to SAE J2735, Sections 6.19, 11.3.	1
DE_Elevation	Refer to SAE J2945/1, Section 6.3.6.	1
DE_ElevationConfidence	Refer to SAE J2735, Section 7.43. This data element shall always be present when DE_Elevation is present.	1
DF_ExteriorLights	Refer to SAE J2735, Section 7.46.	2
DE_Heading	Refer to SAE J2735, Section 7.53.	2
DE_HeadingConfidence	Refer to SAE J2735, Section 7.52.	2
DE_Latitude	Refer to SAE J2945/1, Section 6.3.5.	1
DE_Longitude	Refer to SAE J2945/1, Section 6.3.5.	1
DE_MeasurementTimeOffset	Refer to SAE J2735, Section 11.3.	2
DE_MsgCount	Refer to SAE J2735, Section 7.104. The system shall initialize the DE_MsgCount to a random value within the range defined by SAE J2735 when sending the first SDSM after system device startup. If the certificate used to sign the SDSM has changed since transmitting the most recent SDSM, the system shall re-initialize the DE_MsgCount field to a new random value within the range defined by SAE J2735 before transmitting the next SDSM. The system shall set DE_MsgCount equal to one greater than the value used in the previously transmitted SDSM, if the certificate used to sign the SDSM has not changed since sending the most recent SDSM. For this element, the value after 127 is zero per SAE J2735.	1
DE_PositionConfidence	Refer to SAE J2735, Section 7.139.	2
DE_SemiMajorAxisAccuracy	Refer to SAE J2945/1, Section 6.3.6.7.	1
DE_SemiMinorAxisAccuracy	Refer to SAE J2945/1, Section 6.3.6.7.	1
DE_SemiMajorAxisOrientation	Refer to SAE J2945/1, Section 6.3.6.7.	1
DE_Speed	Refer to SAE J2735, Section 7.179.	2
DE_SpeedConfidence	Refer to SAE J2735, Section 7.176.	2

DF, DE Name	Requirement	Note
DE_TemporaryID	Refer to SAE J2945/1, Section 6.3.6.3. An OBU shall set the DE_TemporaryID to the same value as used for the BSM. When the TemporaryID for a BSM is changed, the SDSM TemporaryID shall also change, including (per 7.3.2) a change in the certificate used to sign the SDSM. An RSU shall use as its TemporaryID the HashedId4 of its current application certificate. Should this value collide with that used by another RSU in communications range of each other, the RSU needing a TemporaryID shall use a 4B random value for its TemporaryID. Note: The TemporaryID may be used to correlate the originator of an SDSM and BSM.	1
DE_TimeConfidence	Refer to SAE J2735, Section 7.192.	2
DF_VehicleSize	Refer to SAE J2735, Section 6.149.	2
DE_VehicleHeight	Refer to SAE J2735, Section 7.209.	2
DE_VehicleLength	Refer to SAE J2735, Section 7.210.	2
DE_VehicleWidth	Refer to SAE J2735, Section 7.214.	2
DE_VerticalAcceleration	Refer to SAE J2735, Section 7.217.	2
DE_YawRate	Refer to SAE J2735, Section 7.229.	2
DE_Attachment	Refer to SAE J2735, Section 7.12.	2
DE_AttachmentRadius	Refer to SAE J2735, Section 7.13.	2
DE_PersonalDeviceUserType	Refer to SAE J2735, Section 7.137.	2
DF_PropelledInformation	Refer to SAE J2735, Section 6.92.	2
DE_AccelerationConfidence	Refer to SAE J2735, Section 7.2. This data element shall always be present when DF_AccelerationSet4Way is present.	2
DE_YawRateConfidence	Refer to SAE J2735, Section 7.228. This data element shall always be present when DF_AccelerationSet4Way is present.	2

NOTES:
1. Data Field or Data Element is used to describe characteristics of the SDSM originator.
2. Data Field or Data Element is used to describe characteristics of SDSM detected objects (vehicle, VRU, obstacle).

APPENDIX C - SECURITY PROFILE

The security profile provided in this section shall be used for SDSMs. This profile uses IEEE 1609.2.

C.1 SECURITY PROFILE IDENTIFICATION

The system shall use the security profile identified in Table C1.

Table C1 - Security profile identification

Field	Value	Notes
Security Profile Identification	IEEE Std 1609.2a-2017	Version used for this profile
Name	"Sensor_Sharing_Security_Profile"	
PSIDs	0x90	
Other Considerations	This security profile is used for broadcasting sensor sharing information from OBUs or RSUs.	

C.2 SENDING

The system shall comply with the security profile for sending defined in Table C2.

Table C2 - Security profile for sending SDSMs

Field	Value	Notes
Sign Data	True	Sign all SDSM messages for data origin authentication and non-repudiation
Signed Data in Payload	True	SSS data is encapsulated in the signed data
External Data	False	No additional data is signed
External Data Source	N/A	
External Data Hash Algorithm	N/A	
Set Generation Time in Security Headers	False	Not necessary as it is included in SDSM payload
Set Generation Location in Security Headers	False	Not necessary as it is already included in SDSM payload
Set Expiry Time in Security Headers	False	Not necessary as old messages can be discarded at the application layer just like for BSMs.
Signed SPDU Lifetime	N/A	
Signer Type Self	Prohibited	Certificates must be issued by an approved SCMS CA
Signer Identifier Policy Type	Simple	
Simple Signer Identifier Policy: Minimum Inter Cert Time	450 ms	vMaxCertDigestInterval in BSM is 450 ms; similarly, SDSMs need not attach full cert more often than once per 0.5 second
Simple Signer Identifier Policy: Exceptions	True	Implementations may attach a cert more often if they consider that local conditions warrant it; local authorities may impose constraints on V2X traffic volume, which may result in limits on how many times a second a certificate is attached, and implementations need to be aware of these local regulations.

Field	Value	Notes
Simple Signer Identifier Policy: Signer Identifier Cert Chain Length	1	Use only the RSU or OBU application certificate in the SDSM
Text Signer Identifier Policy	N/A	
Sign With Fast Verification	Compressed	As customary, no advantage to other choices
EC Point Format	Compressed	Reduces packet size, as for BSMs
p2pcd_flavor	Out of band	As for BSMs
p2pcd_maxResponseBackoff	vP2pcd_maxResponseBackoff	Wait no more than *vP2pcd_maxResponseBackoffseconds* before deciding to send a response
p2pcd_responseActiveTimeout	vP2pcd_responseActiveTimeout	Send a response no more than *1/vP2pcd_responseActiveTimeout* per second
p2pcd_requestActiveTimeout	vP2pcd_requestActiveTimeout	*vP2pcd_requestActiveTimeout*
p2pcd_observedRequestTimeout	vP2pcd_observedRequestTimeout	*vP2pcd_observedRequestTimeout*
p2pcd_currentlyUsedTriggerCertificateTime	vP2pcd_currentlyUsedTriggerCertificateTime	Respond only to requests for certificates that have been used within the *vP2pcd_currentlyUsedTriggerCertificateTime*
p2pcd_responseCountThreshold	vP2pcd_responseCountThreshold	Respond only if fewer than *vP2pcd_responseCountThreshold* responses were seen during the backoff time
Repeat Signed SPDUs	False	Each SDSM is independently signed before transmission. SDSMs are not rebroadcasted
Time Between Signing	N/A	
Encrypt Data	False	Encryption is not used for SDSMs
pduFunctionalTypes	Application PDU	

C.3 RECEIVING

The system shall comply with the security profile for receiving defined in Table C3.

Table C3 - Security Profile for receiving SDSMs

Field	Value	Notes
Use Preprocessing	True	Store certificates to use to verify digests
Verify Data	True	A receiver may choose to verify all SDSMs, or to filter before verification to avoid verifying SDSMs from too far away
Relevance: Replay	False	Application detects duplication within the validity period, so no need for crypto-level detection
Relevance: Generation Time in Past	False	Set to false since Generation Time is not set in Security Headers
Validity Period	N/A	
Relevance: Generation Time in Future	False	Application detects future messages, so no need for crypto-level detection
Acceptable Future Data Period	N/A	
Generation Time Source	Payload	Since "*Set Generation Time in Security Headers*" is set to False
Relevance: Expiry Time	False	Since "*Set Expiry Time in Security - Headers*" is set to False

Field	Value	Notes
Expiry Time Source	N/A	
Consistency: Generation Location	True	Use the position data from the SDSM to compare to validity region of cert
Relevance: Generation Location Distance	False	Do not reject SDSM messages that are too far from the receiver; just like for BSMs. This can be done at the application layer if needed
Validity Distance	N/A	
Generation Location Source	Payload	Since "*Set Generation Location in Security Headers*" is set to False
Additional Geographic Consistency Conditions	False	
Identified Region Representation Accuracy	N/A	As in BSMs, generation location consistency check is implementation specific
Overdue CRL Tolerance	1 month	The period will be determined by the ecosystem governance body; very short for safety-critical applications versus ones that result in driver alerts only
Relevance: Certificate Expiry	True	Default recommended in IEEE 1609.2
Encrypted Data (accepted)	False	Encryption is not used for SDSM

C.4 SECURITY MANAGEMENT

The system shall comply with the security management profile defined in Table C4.

NOTE: The certificate with the SDSM PSID may be the same as the certificate for the BSM PSID.

Table C4 - Security management profile

Field	Value	Notes
Signing Key Algorithm	ecdsaNistP256withSha256	
Encryption Algorithm	N/A	
Implicit or Explicit Certificates	Implicit	As supported by SCMS
EC Point Format	Compressed	Packet size can be minimized; performance (verification speed) not a concern
Supported Geographic Regions	Rectangular, Polygonal, Identified: Country and Subregions	Type of geographic region of validity of certificates (example: a region could be the USA, and a subregion could be state or county); smaller regions can be described by polygons or rectangles
Maximum Full Certificate Chain Length	8	As in IEEE 1609.2
Use Individual Linkage ID	True	True as for BSMs
Use Group Linkage ID	False	No group linkage revocation
Signature Algorithms in Chain or CRL	ecdsaNistP256withSha256	Brainpool curves not needed in USA

C.5 OTHER

Table C5 identifies security fields that may be subject to future policy updates.

Table C5 - Fields subject to policy updates

Field	Value	Notes
Fields that may be subject to policy update	Overdue CRL tolerance, p2pcd_flavor, Signing key algorithm, Signature algorithms in chain or CRL	These fields may be updated by a SCMS in the future

C.6 ACTIVITY GROUPS AND SSP DESIGN

The SSP design used in this document consists of variable length string that contains an 8-bit version number with no other bits specified. Activity bits may be added to the table below once other use cases are fully specified.

The SSP may be omitted, i.e., the OPTIONAL ssp field may be omitted from the PsidSsp field in the certificate that contains the PSID for Sensor Sharing. An omitted SSP is to be interpreted as having the same semantics as an SSP with version number 1 and no other bits present.

The SSP sender is the entity providing the information.

This SSP role has the security impact identified in the analysis in Appendix E. As a result of this analysis, no special permissions are deemed to be needed since it was determined that sending SDSMs does not constitute a “privilege” that needs to be restricted, even when done by RSUs; that is, no special privilege is afforded to an HV or even RSU as either of them can send an SDSM, and the receiver behavior is expected to be the same.

Table C6 - Entity activity groups: SDSM

Entity Activity Group	Entity Activities	SSP Activity Bit
Sensor sharing: Equipped vehicle or RSU reporting UV	HV sends to RVs as in SAE J3224, Section 5	SSP is omitted from the certificate (default)
Sensor sharing: Equipped vehicle or RSU reporting VRU	HV sends to RVs as in SAE J3224, Section 5	SSP is omitted from the certificate (default)
Sensor sharing: Equipped vehicle or RSU reporting object	HV sends to RVs as in SAE J3224, Section 5	SSP is omitted from the certificate (default)

The SSP design used for SSS applications conformant with this document is:

- First 8 bits: version number = 1 (=0b0000 0001).
- No other bits are defined, as there are no roles defined within the application.
- Future versions of this standard may define semantics associated with additional bits in the SSP. Per SAE J2945/5, if an implementation of this version of this standard receives a message signed by a certificate with an SSP with additional bits beyond the first eight, it shall ignore those bits. If an implementation of a later version of the standard receives a certificate with an omitted SSP or an SSP with no bits beyond the version number, it will be expected to treat it as an SSP in which all bits beyond the version number are 0.

NOTE: Future versions of this standard are expected to design SSP bit semantics so that the assumption above leads to correct security outcomes, i.e., so that treating omitted bits as having the value 0 does not grant elevated privileges to the certificate holder.

NOTE: The version number in the SSP is expected to change only if EITHER the version number of the message structure changes, OR it proves necessary to change the semantics associated with particular assigned SSP bits.

APPENDIX D - MISBEHAVIOR CONSIDERATIONS (INFORMATIVE)

D.1 SCOPE

This appendix outlines principles for misbehavior detection and reporting for SDSMs.

According to SAE J2945/1, misbehavior detection "allows devices to (1) locally detect incorrect messages, whether malicious or harmful or not, and avoid acting based on them, and (2) if appropriate, determine that incorrect messages should be reported to a central misbehavior authority for additional enforcement if necessary to preserve the integrity of the application ecosystem."

For the Sensor Sharing Service/application, the determination of misleading or erroneous messages can be done in many cases via cross-checking SDSM content with the receiver's knowledge of the environment. The determination of misbehaving senders is based on the following criteria.

D.2 CRITERIA FOR SSS MISBEHAVIOR

- An SDSM sender sends an SDSM containing an object when no object is present.
- An SDSM sender sends an SDSM containing an object it did detect, but with incorrect characteristic(s) (including time offset).
- An SDSM sender sends SDSMs more frequently than allowed.
- An SDSM sender sends SDSMs with incorrect sender-vehicle fields (transmission time, position, etc.).

APPENDIX E - SECURITY ANALYSIS AND SSP DESIGN (INFORMATIVE)

E.1 APPLICATION SCENARIO

SAE J3224 Version 1.0 (2021) lists the following application scenario: Detection and notification of non-V2X capable entities (vehicles, VRUs, objects).

This scenario is analyzed in Tables A1 and A2. Next, in Table A3, the entity activity groups (SSP roles) are presented.

These activities are associated with one PSID for SDSMs. PSID [0x90] is used to identify Sensor Sharing Service related activities.

E.2 ANALYSIS

The risk analysis for the use case: Detection of an unequipped vehicle (UV) by an equipped vehicle follows.

Table E1 - Risk analysis: Detection of an unequipped vehicle by an equipped vehicle

<table>
<tr><td colspan="4">Use Case: Detection of an unequipped vehicle (UV) by an equipped vehicle</td></tr>
<tr><td colspan="4">Purpose: To increase other vehicles’ awareness, detecting and sharing the presence of an UV</td></tr>
<tr><td colspan="4">Actors:
▪ Host Vehicle (HV): Vehicle detecting UV and sharing UV characteristics via SDSM
▪ Unequipped Vehicle (UV): Vehicle detected
▪ Remote Vehicle (RV): Recipient of the SDSM
▪ Roadside Unit (RSU): Recipient of the SDSM
▪ Remote VRU (RVRU): Recipient of the SDSM</td></tr>
<tr><td>Information flow</td><td>Entity Activities</td><td>Description</td><td>Impact (Low/Med/High)</td></tr>
<tr><td>I1.1 SDSM: Detected UV characteristics</td><td>E1.1.1 UV characteristics sent to other RVs/RVRUs</td><td>HV detects a UV, determines its static and dynamic characteristics, and constructs an object representation, then transmits to others (RVs, RSUs, RVRUs)</td><td>C: Low
I: Medium
A: Low</td></tr>
<tr><td colspan="4">Notes, Assumptions and Extensibility Management:
NOTE 1: Confidentiality level is rated Low for this data, which is available/obtainable for any nearby vehicle.
NOTE 2: Integrity is rated Medium because spoofed data in this type of message may determine vehicle actions that may result in threats to life and/or property.
NOTE 3: Availability is rated Low because this functionality is for awareness/driver alerts (rather than full automation).</td></tr>
</table>

The risk analysis for the use case: Detection of a VRU by an equipped vehicle is identical to the risk analysis for a UV, as in Table E1. Thus, if the instances of “UV” are replaced by “VRU” in that table, the analysis holds.

The risk analysis for the use case: Detection of an object by an equipped vehicle is identical to the risk analysis for a UV, as in Table E1. Thus, if the instances of “UV” are replaced by “object” in that table, the analysis holds.

The risk analyses for the three use cases above when the reporting entity is an RSU are very similar. As an example, the risk analysis for the use case: Detection of an unequipped vehicle (UV) by an RSU follows, and the other two are similar.

Table E2 - Risk analysis: Detection of an unequipped vehicle by an RSU

Use Case: Detection of an unequipped vehicle (UV) by an RSU			
Purpose: To increase other vehicles' awareness, detecting and sharing the presence of an UV			
Actors: ▪ Host RSU (HRSU): RSU detecting UV and shares UV characteristics via SDSM ▪ Unequipped Vehicle (UV): Vehicle detected ▪ Remote Vehicle (RV): Recipient of the SDSM ▪ Roadside Unit (RSU): Recipient of the SDSM ▪ Remote VRU (RVRU): Recipient of the SDSM			
Information flow	**Entity Activities**	**Description**	**Impact** (Low/Med/High)
I1.1 SDSM: Detected UV characteristics	E1.1.1 UV characteristics sent to other RVs/RVRUs	RSU detects a UV, determines its static and dynamic characteristics, and constructs an object representation, then transmits to others (RVs, RSUs, RVRUs)	C: Low I: Medium A: Low
Notes, Assumptions and Extensibility Management: NOTE 1: Confidentiality level is rated Low for this data, which is available/obtainable for any nearby vehicle. NOTE 2: Integrity is rated Medium because spoofed data in this type of message may determine vehicle actions that may result in threats to life and/or property. NOTE 3: Availability is rated Low because this functionality is for awareness/driver alerts (rather than full automation).			

APPENDIX F - HIGH DEFINITION DATA SHARING (INFORMATIVE)

This appendix provides an informational description of sensors sharing of high definition data, consisting of data streaming over a separate communication channel. The HDD aspect of sensor sharing is under development and subject to further change. In this standard, the description of HDD is informational only.

F.1 SCOPE

This appendix describes the concept of operation, use cases, and message flows to create a High Definition Data Sharing Service (HDDSSS). This service enable RSUs and V2X vehicles to share information about their localized driving environment. This work defines message structure, originating V2X entity (OBU or RSU) requirements, information elements to describe detected objects, and facilitate sensor sharing.

F.2 TERMS AND DEFINITIONS

F.2.1 Definitions

HIGH-DEFINITION DATA (HDD): Detailed data generated by local perception sensors that can be made available to HV, RV, or RSU via subscription. The data can be specific to the sensor type (e.g., reflections, time of flight, point clouds, camera image, etc.) or not specific to any particular sensor type (e.g., occupancy grid map).

REGION OF INTEREST: Positional information indicating a region for which HDD is requested.

F.2.2 Abbreviations and Acronyms

HDD High-Definition Data

HDSM High-Definition Subscription Message

HDSS High-Definition Sensor Sharing

F.3 CONCEPT OF OPERATIONS AND SYSTEM DESCRIPTION

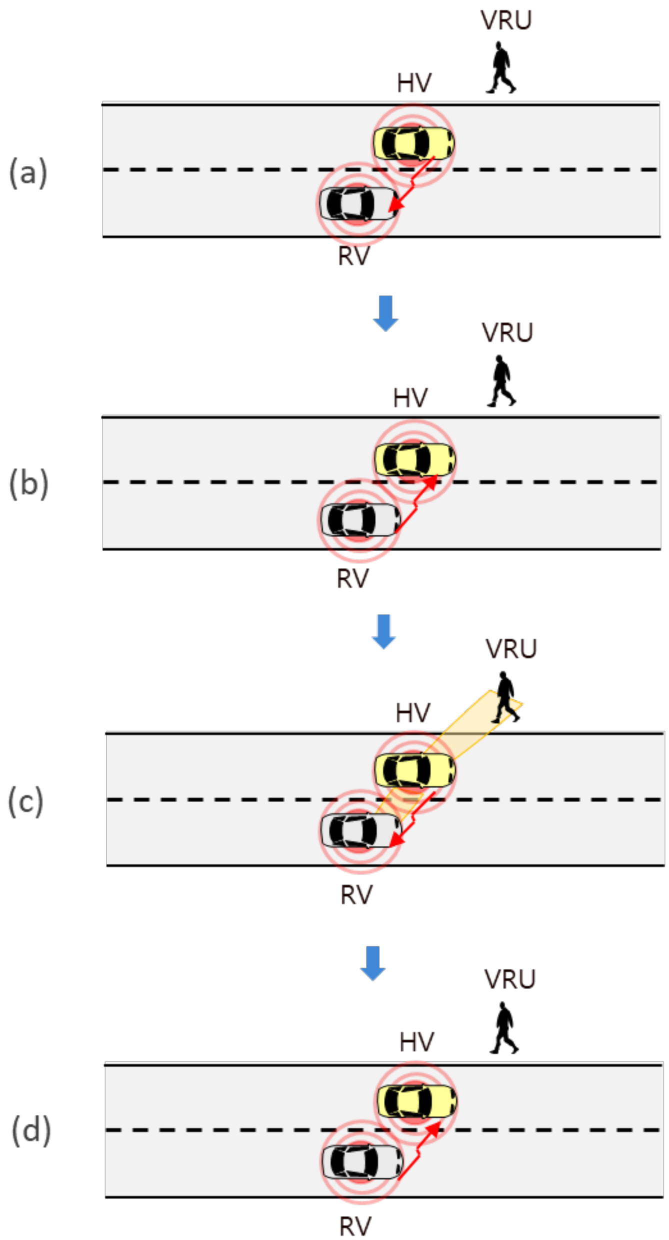
F.3.1 HDSS System Overview

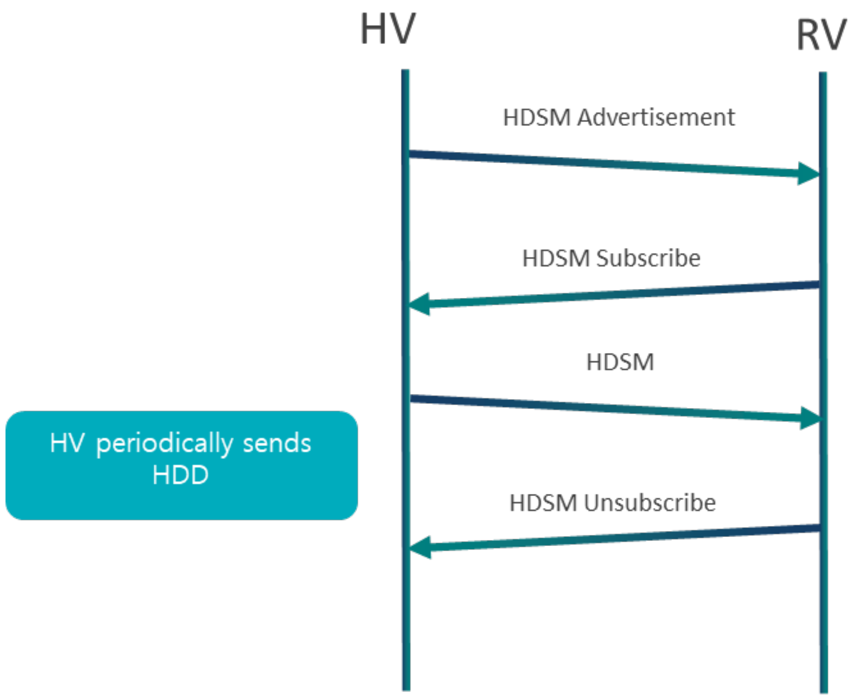
Vehicles and RSUs can use the high-definition subscription message (HDSM) to initiate access to high-definition data (HDD) streams which are available over a separate communication channel. When an RSU or vehicle advertises the availability of HDD from its sensor(s), RVs and RRSUs can subscribe and unsubscribe to available HDD streams.

F.3.2 HDSS Use Cases

F.3.2.1 HDD Stream Availability and Subscription

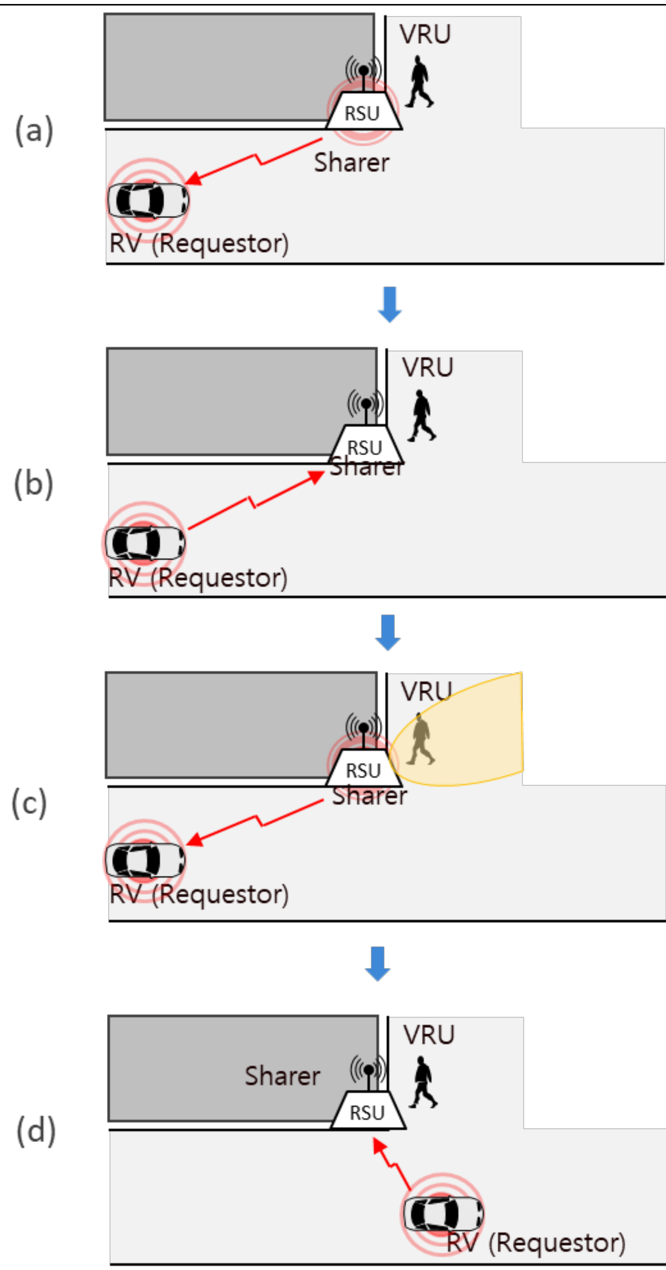
F.3.2.1.1 Transparent Vehicle

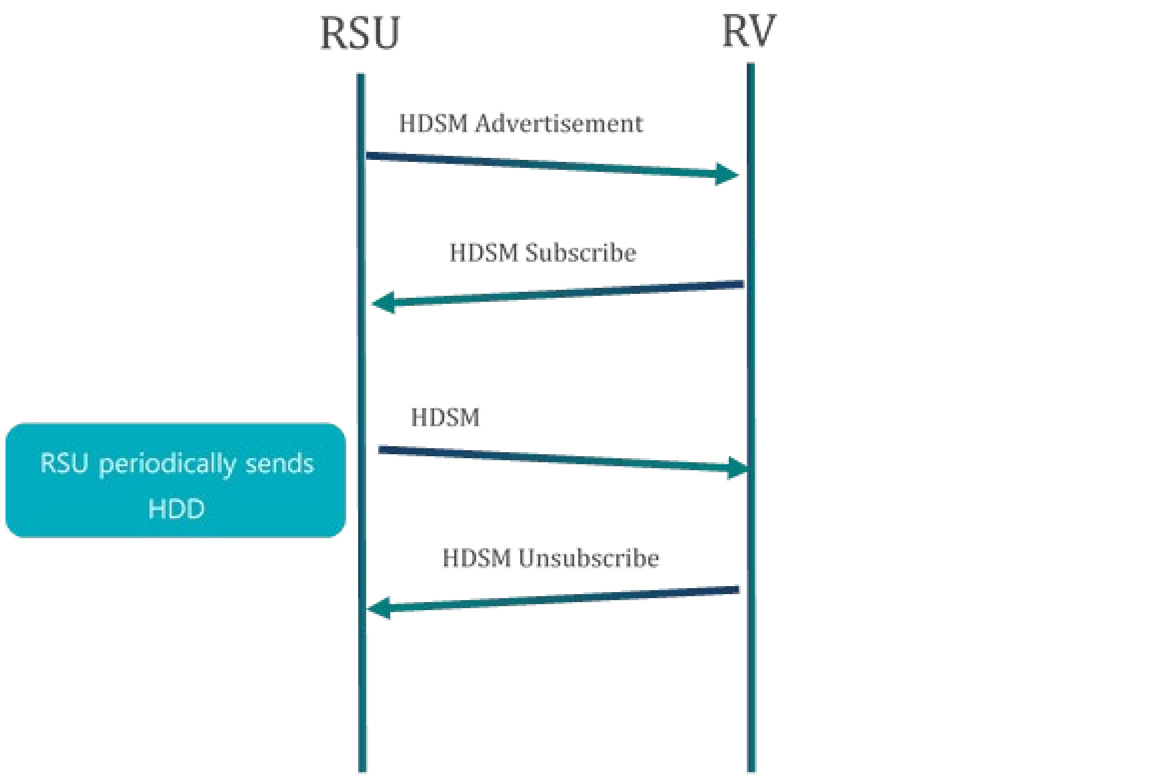
Use case name	Transparent Vehicle
Overview	HV shares HDD with an RV, effectively rendering itself transparent.
Brief description	An HV advertises its ability to share HDD about a VRU with vehicles that may be blocked from view of the VRU. An RV requests access to that data. The HV shares HDD and optionally only in the region of RV interest.
Road environment	Urban | Rural | Highway
Participants	Vehicles
Participants roles	There are two participant roles of involved in this use case: ▪ Sharer (HV): Host Vehicle which can share HDD. ▪ Requestor (RV): Remote Vehicle which would like to receive HDD from HV.
Assumptions and preconditions	The RV can receive and interpret the HDD in the manner provided by the HV.
Use case flow illustrations	

<table>
<tr>
<td></td>
<td>


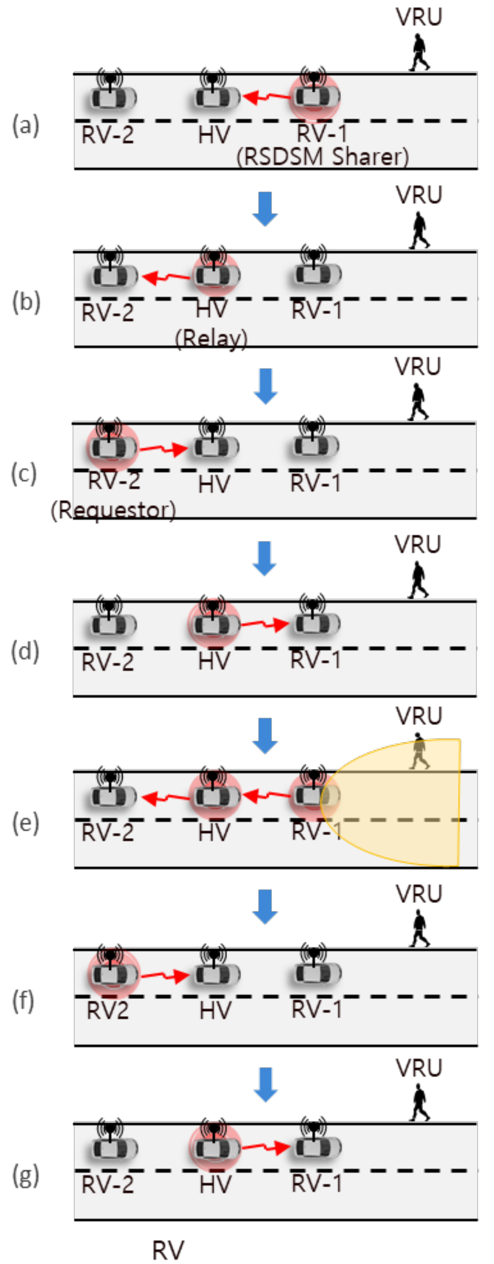
</td>
</tr>
<tr>
<td>Use case flow description</td>
<td>a. HV advertises its ability to share HDD and the field of view of its sensors.
b. RV sends a request to HV to subscribe to its HDD stream and, optionally, its Region of Interest.
c. HV periodically transmits its HDD that covers that RV’s Region of Interest to RV. If no Region of Interest was indicated, the HV transmits HDD that includes its sensors’ entire field of view.
d. After some time, RV notifies HV that it wishes to unsubscribe to the HDD stream. HV stops HDD transmission to RV.</td>
</tr>
</table>

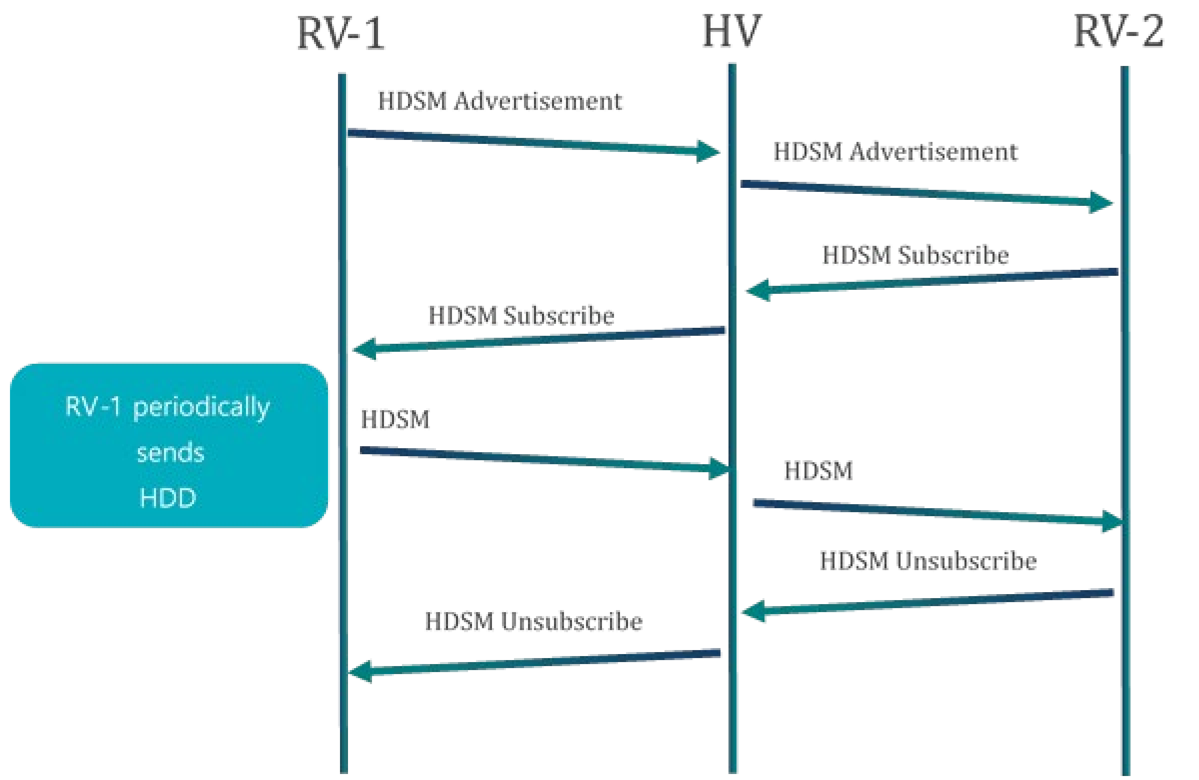
F.3.2.1.2 Blind Spot View by an RSU

Use case name	Blind spot view by an RSU
Overview	RSU shares HDD with an approaching vehicle, effectively eliminating blind spots.
Brief description	An RSU advertises its ability to share HDD streams. A Remote Vehicle requests access to that data, and optionally its region of interest. The source shares HDD for the requested region.
Road environment	Urban | Rural | Highway
Participants	Vehicles, RSUs
Participants roles	There are two participant roles involved in this use case: ▪ Sharer (RSU): RSU which can share HDD. ▪ Requestor (RV): Vehicle which would like to receive HDD from an RSU.
Assumptions and preconditions	The RV can receive and interpret the HDD in the manner provided by the RSU.
Use case flow illustrations	

	
Use case flow description	a. RSU advertises its ability to share HDD and the field of view of its sensors. b. RV sends a request to RSU to subscribe to its HDD stream and optionally indicates its Region of Interest. c. RSU periodically transmits its HDD that covers that RV's Region of Interest to RV. If no Region of Interest was indicated, the RSU transmits HDD that includes its sensors' entire field of view. d. After some time, RV notifies RSU that it wishes to unsubscribe from the HDD stream. RSU stops HDD transmission to RV.

F.3.2.1.3 Relaying for Transparent Vehicle

Use case name	Relaying for Transparent Vehicle
Overview	An entity relays HDD received from a nearby entity, to a third entity.
Brief description	An entity (the relay) advertises its ability to relay HDD from a separate entity (the source) to another entity (the requestor). The requestor requests access to that data. The relay retransmits HDD received from the source, to the requestor.
Road environment	Urban | Rural | Highway
Participants	Vehicles
Participants roles	There are three participant roles of vehicles involved in this use case: ▪ Sharer (RV-1): entity which can share HDD. ▪ Relay (HV): entity which can retransmit received HDD. ▪ Requestor (RV-2): entity which would like to receive HDD from RV-1.
Assumptions and preconditions	The RV-2 can receive and interpret the HDD in the manner provided by RV-1. The HV can relay the HDD between RV-1 and RV-2.
Use case flow illustrations	

<table>
<tr>
<td></td>
<td>


</td>
</tr>
<tr>
<td>Use case flow description</td>
<td>
a. RV-1 advertises its ability to share HDD and the field of view of its sensors.
b. HV advertises its ability to relay RV-1’s HDD and the field of view of RV-1’s sensors.
c. RV-2 sends a request to HV to subscribe to RV-1’s HDD stream and, optionally, its Region of Interest.
d. HV sends a request to RV-1 to subscribe to RV-1’s HDD stream using RV-2’s Region of Interest.
e. RV-1 periodically transmits its HDD that covers RV-2’s Region of Interest to HV. If no Region of Interest is indicated, RV-1 transmits HDD that includes the entire field of view.
f. HV retransmits RV-1’s HDD to RV-2.
g. After some time, RV-2 notifies HV that it wishes to unsubscribe from RV-1’s HDD stream.
h. HV notifies RV-1 that it wishes to unsubscribe from RV-1’s HDD stream. RV stops HDD transmission.
</td>
</tr>
</table>

F.4 HDSM PROTOCOL

F.4.1 HDSM Protocol states

The states of the HDSM protocol are illustrated in Figure F1.

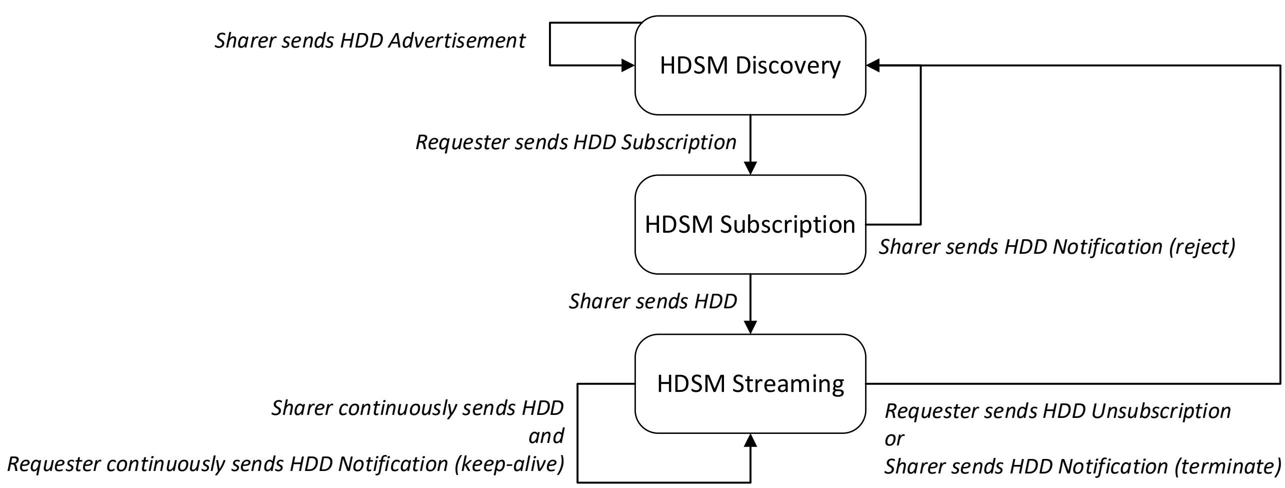


Figure F1 - Basic HDSM states between a sharer and requester

An HRSU or HV may take on the role of sharer or requester according to the basic HDSM states. The HRSU or HV may exercise multiple instances of the HDSM protocol concurrently with one or more corresponding requester or sharer, and may take on different roles.

F.4.2 HDSM Discovery state

In the HDSM Discovery state, the sharer advertises its ability to share HDD by transmitting the HDD Advertisement to the HV. The HDD Advertisement may indicate the availability of one or more sensors and their corresponding available formats. The HDD Advertisement may also specify a keep-alive interval for subscriptions. The requester receives the HDD Advertisement and may request to receive HDD by transmitting the HDD Subscription to the sharer.

F.4.3 HDSM Subscription state

In the HDSM Subscription state, the sharer receives the HDD Subscription and determines if the request can be supported. If able to be supported, the sharer begins transmission of HDD to the source of the HDD Subscription. If not able to be supported, the sharer shall transmit the HDD Notification with notificationType set to 0 (“rejection of subscription request”) to the requester. If the requester does not receive HDD Notification or HDD from the sharer, it may transmit another HDD Subsciption to the sharer.

F.4.4 HDSM Streaming state

In the HDSM Streaming state, the sharer continuously transmits HDD to the requester. The requester receives the HDD and periodically transmits the HDD Notification with notificationType set to 2 (“keep-alive”) and ReasonCode set to 0 (“none”) based on the keep-alive interval specified in the HDD Advertisement from the sharer. When the requester no longer requires the HDD, it may transmit a HDD Unsubscription to the sharer to cancel the subscription. When the sharer receives the HDD Unsubscription, it shall stop transmitting the HDD to the requester.

If the sharer intends to stop transmitting the HDD to the requester before receiving an HDD Unsubscription, for example after not receiving the keep-alive message for the specified keep-alive interval, it shall stop HDD transmission only after transmitting a HDD Notification with notificationType set to 1 (“termination of subscription request”) to the requester. If the HRSU determines the HV to have left the communication area, for example after encountering consecutive transmission failures for some duration, it may stop HDD transmission without transmitting the HDD Notification. The sharer may send the HDD Notification with a note: The temporary loss of communication for short durations may be expected due to the mobility environment and should be taken into account of when consecutive transmission failures are used to determine absence of the requester.

F.5 HDSS MESSAGE SETS

F.5.1 Message: MSG_HDDataAdvertisement (HDSM)

F.5.1.1 HDSM ASN.1

TBD.

F.5.2 Message: MSG_HDDataAdvertisement (HDDA)

F.5.2.1 HDSM ASN.1

```
HDDataAdvertisement ::= SEQUENCE {
      sourceID OCTET STRING (SIZE(1)),
      -- Temporary vehicle ID / RSU ID. HDDA source.
      equipmentType EquipmentType,
      -- Sender type
      HDDATimestampRSDATimestamp ::= SEQUENCE {
            dayOfMonth DDay,
            timeOfDay  DTime
            }
      -- HDDA time stamp
      refPos Position3D,
```

```
      -- Sender reference position
      refPosXYConf PositionalAccuracy,
      -- Sender position accuracy
      refPosElConf ElevationConfidence,
      -- Sender elevation confidence
      speed Speed,
      -- Sender speed
      speedConfidence SpeedConfidence,
      -- Sender speed confidence
      Sensors SensorList,
      -- List of sensors details,
      keepAliveInterval KeepAliveInterval,
      -- Maximum interval to keep subscription alive,
      relayedAdvertisements HDDataAdvertisementList OPTIONAL,
      -- List of relayed HDDAs
      …
}

SensorList ::= SEQUENCE (SIZE(1..128)) OF Sensor

Sensor ::= SEQUENCE {
      sensorID OCTET STRING (SIZE(1)), -- Sensor ID
      sensorType SensorType, -- Sensor type
      sensorDetectionArea SensorDetectionArea, -- Sensor detection Area
      monoVideoFormatList MonoVideoFormatList OPTIONAL,
      streamingDataFormat StreamingDataFormat, -- Format of streaming data
      …
}

MonoVideoFormatList ::= SEQUENCE (SIZE(1..32)) OF MonoVideoFormat

MonoVideoFormat ::= SEQUENCE {

      monoVideoFormatID OCTET STRING (SIZE(1)), -- Format ID

      monoVideoCodec MonoVideoCodec, -- Mono video sensor codec

      monoVideoResolution MonoVideoResolution, -- Mono video sensor resolution

      monoVideoFrameRate MonoVideoFrameRate, -- Mono video sensor frame rate

      …
}

MonoVideoCodec ::= ENUMERATED{
      undefined (0),
      h264 (1),
      mjpeg (2),
      …
}

MonoVideoResolution ::= ENUMERATED{
      undefined (0),
      720p (1),
      1080p (2),
      …
}

MonoVideoFrameRate ::= ENUMERATED{
      undefined (0),
```

```
      25 fps (1),
      30 fps (2),
      …
}

StreamingDataFormat ::= ENUMERATED{
      RTP (0),
      …
}

KeepAliveInterval::= INTEGER(0..255) -- LSB units of 1 second

EquipmentType ::= ENUMERATED{
      unknown (0),
      rsu (1),
      obu (2)
      …
}


Position3D ::= SEQUENCE {
      lat        Latitude,                -- in 1/10th micro degrees
      long      Longitude,                -- in 1/10th micro degrees
      elevation  Elevation  OPTIONAL,-- in 10 cm unit
      …
}

Latitude ::= INTEGER (-900000000..900000001)
      -- LSB = 1/10 microdegree
      -- Providing a range of plus-minus 90 degrees

Longitude ::= INTEGER (-1799999999..1800000001)
      -- LSB = 1/10 microdegree
      -- Providing a range of plus-minus 180 degrees

Elevation ::= INTEGER (-4096..61439)
      -- In units of 10 cm steps above or below the reference ellipsoid
      -- Providing a range of -409.5 to + 6143.9 meters
      -- The value -4096 shall be used when Unknown is to be sent

PositionalAccuracy ::= SEQUENCE {
      -- NMEA-183 values expressed in strict ASN form
      semiMajor     SemiMajorAxisAccuracy,
      semiMinor     SemiMinorAxisAccuracy,
      orientation     SemiMajorAxisOrientation
}

ElevationConfidence::= ENUMERATED {
      unavailable (0), -- B'0000 Not Equipped or unavailable
      elev-500-00 (1), -- B'0001 (500 m)
      elev-200-00 (2), -- B'0010 (200 m)
      elev-100-00 (3), -- B'0011 (100 m)
      elev-050-00 (4), -- B'0100 (50 m)
      elev-020-00 (5), -- B'0101 (20 m)
      elev-010-00 (6), -- B'0110 (10 m)
      elev-005-00 (7), -- B'0111 (5 m)
      elev-002-00 (8), -- B'1000 (2 m)
      elev-001-00 (9), -- B'1001 (1 m)
      elev-000-50 (10), -- B'1010 (50 cm)
      elev-000-20 (11), -- B'1011 (20 cm)
      elev-000-10 (12), -- B'1100 (10 cm)
```

```
      elev-000-05 (13), -- B'1101 (5 cm)
      elev-000-02 (14), -- B'1110 (2 cm)
      elev-000-01 (15) -- B'1111 (1 cm)
}


PitchDetected ::= INTEGER (-7200..7200)
      -- LSB units of 0.0125 degrees (signed)
      -- range of -90 to 90 degrees

RollDetected ::= INTEGER  (-14400..14400)
      -- LSB units of 0.0125 degrees (signed)
      -- range of -180 to 180 degrees

YawDetected ::= INTEGER (-14400..14400)
      -- LSB units of 0.0125 degrees (signed)
      -- range of -180 to 180 degrees

Speed ::= INTEGER (0..8191) -- Units of 0.02 m/s
      -- The value 8191 indicates that
      -- speed is unavailable

SensorList ::= SEQUENCE (SIZE(1..128)) OF Sensor

Sensor ::= SEQUENCE {
      sensorID SensorID, -- Sensor ID
      sensorType SensorType, -- Sensor type
      sensorDetectionAreasensorD SensorDetectionArea, -- Sensor detection Area
      …
}

SensorType ::= ENUMERATED{
      undefined (0),
      radar (1),
      lidar (2),
      mono video (3),
      stereo vision (4),
      night vision (5),
      pmd (6),
      spherical camera (7),
      occupancy grid (8),
      ...
      }

SensorDetectionArea ::= SEQUENCE {
      positionOffsetXSensorPositionOffset, -- Sensor’s X position offset from the reference
      position
      positionOffsetYSensorPositionOffset, -- Sensor’s Y position offset from the reference
      position
      positionOffsetZSensorPositionOffset, -- Sensor’s Z position offset from the reference
      positionrangeSensorRange, -- Sensor’s range
      horizontalOpeningAngleStartSensorAngle, -- Sensor’s horizontal opening angle (start)
      horizontalOpeningAngleEndSensorAngle, -- Sensor’s horizontal opening angle (end)
      verticalOpeningAngleStartSensorAngle OPTIONAL, -- Sensor’s vertical opening angle
      (start)
      verticalOpeningAngleEndSensorAngle OPTIONAL, -- Sensor’s vertical opening angle (end)
      ...
      }

SensorPositionOffset ::= INTEGER(-32767..32767) -- LSB units of 0.01 meters
```

```
SensorRange ::= INTEGER(1…10000) -- LSB units of 0.1 meters

SensorAngle ::== INTEGER(1…3601) -- LSB units of 0.1 degrees (3601 corresponds to
“unavailable”)

}

HDDataAdvertisementList ::= SEQUENCE (SIZE(1..32)) OF HDDataAdvertisement
```

F.5.3 Message: MSG_HDDataSubscription (HDDS)

F.5.3.1 HDDS ASN.1

```
HDDataSubscription ::= SEQUENCE {
      sourceID OCTET STRING (SIZE(1)),
      -- Temporary vehicle ID / RSU ID. HDDS source.
      subscriptionID OCTET STRING (SIZE(1)),
      -- ID to identify this request
      equipmentType EquipmentType,
      -- Sender type
      HDDSTimestamp RSDSTimestamp ::= SEQUENCE {
            dayOfMonth DDay,
            timeOfDay  DTime
            }
      -- HDDS time stamp
      refPos Position3D,
      -- Sender reference position
      refPosXYConf PositionalAccuracy,
      -- Sender position accuracy
      refPosElConf ElevationConfidence,
      -- Sender elevation confidence

      speed Speed,
      -- Sender speed
      speedConfidence SpeedConfidence,
      -- Sender speed confidence
      subscriptionRequests SubscriptionRequestList,
      -- List subscription requests
      relayedSubscriptionRequests HDDataSubscriptionList OPTIONAL,
      -- List of relayed HDDSs
      ...
}

SubscriptionRequestList::= SEQUENCE (SIZE(1..128)) OF SubscriptionRequest

SubscriptionRequest::= SEQUENCE {
      targetID OCTET STRING (SIZE(1)),
      -- Target temporary vehicle ID / RSU ID. HDDM source.
      targetSensorFormatIDList SEQUENCE (SIZE(1..128)) OF SensorFormat (SIZE(1)),
      -- List of target sensor and format IDs
      regionOfInterest SensorDetectionArea OPTIONAL, -- Region of interest
      …
}

SensorFormatID ::= SEQUENCE {
      sensorID OCTET STRING (SIZE(1)), -- sensor ID
      formatID OCTET STRING (SIZE(1)), -- format ID
}

HDDataSubscriptionList::= SEQUENCE (SIZE(1..32)) OF HDDataSubscription
```

F.5.4 Message: MSG_HDDataUnsubscription (HDDU)

F.5.4.1 HDDU ASN.1

```
HDDataUnsubscription ::= SEQUENCE {
      -- Temporary vehicle ID / RSU ID. HDDU source.
      subscriptionID OCTET STRING (SIZE(1)),
      -- ID of subscription request to be unsubscribed
      targetID OCTET STRING (SIZE(8)),
      -- Target temporary vehicle ID / RSU ID. HDDM source.
      targetSensorIDList SEQUENCE (SIZE(1..128)) OF OCTET STRING (SIZE(1)),
      -- List of target sensor IDs
}
```

F.5.5 Message: MSG_HDDataNotification (HDDN)

F.5.5.1 HDDN ASN.1

```
HDDataNotification ::= SEQUENCE {
      sourceID OCTET STRING (SIZE(1)),
      -- Temporary vehicle ID / RSU ID. HDDN source.
      targetID OCTET STRING (SIZE(8)),
      -- Target temporary vehicle ID / RSU ID. HDDS source.
      subscriptionID OCTET STRING (SIZE(1)),
      -- ID of subscription request from HDDS source
      notificationType NotificationType,
      -- Type of notification message
      reasonCode ReasonCode OPTIONAL,
      -- Reason for this notification
}

NotificationType ::= ENUMERATED{
      rejection of subscription request (0),
      termination of subscription request (1),
      keep-alive (2),…
}

ReasonCode ::= ENUMERATED{
      unspecified (0),
      request unsupported (1),
      unexpected or unsupported position of requester (2),

      …
}
```

F.6 DESCRIPTION OF INFORMATION ELEMENTS

F.6.1 Data Frames

F.6.1.1 Sensor

Description	The DF_Sensor describes the sensor ID, sensor type, and sensor detection area of a sensor.

ASN.1 representation	`Sensor ::= SEQUENCE {`
	`sensorIDOCTET STRING (SIZE(1)), -- Sensor ID`
	`sensorTypeSensorType, -- Sensor type`
	`sensorDetectionAreaSensorDetectionArea, -- Sensor detection Area`
	`monoVideoFormatList MonoVideoFormatList OPTIONAL,`
	`streamingDataFormat StreamingDataFormat, -- Format of streaming data`
	`…`
	`}`

Units	N/A

F.6.1.2 SensorList

Description	The DF_SensorList provides a list of sensors.
ASN.1 representation	`SensorList ::= SEQUENCE (SIZE(1..128)) OF Sensor`
Units	N/A

F.6.1.3 SensorDetectionArea

Description	The DF_SensorDetectionArea describes the detection area of the sensor. This consists of the sensor’s position offsets (x, y, z axes) from the reference position, detection range, horizontal opening angle, vertical opening angle.

ASN.1 representation	`SensorDetectionArea ::= SEQUENCE {`
	`positionOffsetXSensorPositionOffset, -- Sensor’s X position offset from the reference position`
	`positionOffsetYSensorPositionOffset, -- Sensor’s Y position offset from the reference position`
	`positionOffsetZSensorPositionOffset, -- Sensor’s Z position offset from the reference position`
	`rangeSensorRange, -- Sensor’s range`
	`horizontalOpeningAngleStartSensorAngle, -- Sensor’s horizontal opening angle (start)`
	`horizontalOpeningAngleEndSensorAngle, -- Sensor’s horizontal opening angle (end)`
	`verticalOpeningAngleStartSensorAngle OPTIONAL, -- Sensor’s vertical opening angle (start)`
	`verticalOpeningAngleEndSensorAngle OPTIONAL, -- Sensor’s vertical opening angle (end)`
	`...`
	`}`

Units	N/A

F.6.1.4 HDDataAdvertisementList

Description	The DF_HDDataAdvertisementList provides a list of HDDAs used for relaying other senders’ HDDAs.
ASN.1 representation	`HDDataAdvertisementList ::= SEQUENCE (SIZE(1..32)) OF HDDataAdvertisement`
Units	N/A

F.6.1.5 MonoVideoFormatList

Description	This data frame provides a list of formats for mono video sensor type.
ASN.1 representation	`MonoVideoFormatList ::= SEQUENCE (SIZE(1..32)) OF MonoVideoFormat`
Units	N/A

F.6.1.6 MonovideoFormat

Description	This data frame describes the format for mono video sensor type.

ASN.1 representation	`MonoVideoFormat ::= SEQUENCE {`
	`monoVideoFormatIDOCTET STRING (SIZE(1)), -- Format ID`
	`monoVideoCodec MonoVideoCodec, -- Mono video sensor codec`
	`monoVideoResolutionMonoVideoResolution, -- Mono video sensor resolution`
	`monoVideoFrameRate MonoVideoFrameRate, -- Mono video sensor frame rate`
	`…`
	`}`

Units	N/A

F.6.1.7 SubscriptionRequest

Description	The DE_SubscriptionRequest provides the subscription request for High-Definition data sharing.

ASN.1 representation	`SubscriptionRequest::= SEQUENCE {`
	`targetIDOCTET STRING (SIZE(1)), -- Target temporary vehicle ID / RSU ID. HDDM source.`
	`targetSensorIDListSEQUENCE (SIZE(1..128)) OF OCTET STRING (SIZE(1)), -- List of target sensor IDs`
	`regionOfInterestSensorDetectionArea OPTIONAL, -- Region of interest`
	`…`
	`}`

Units	N/A

F.6.1.8 SubscribeRequestList

Description	The DF_SubscribeRequestList provides a list of subscription requests.
ASN.1 representation	`SubscriptionRequestList::= SEQUENCE (SIZE(1..128)) OF SubscriptionRequest`
Units	N/A

F.6.2 Data Elements

F.6.2.1 SensorType

Description	The DE_SensorType describes the type of a sensor.

ASN.1 representation	`SensorType ::= ENUMERATED{`
	`undefined (0),`
	`radar (1),`
	`lidar (2),`
	`mono video (3),`
	`stereo vision (4),`
	`night vision (5),`
	`pmd (6),`
	`spherical camera (7),`
	`occupancy grid (8),`
	`...`
	`}`

Units	N/A

F.6.2.2 SensorPositionOffset

Description	The DE_SensorPositionOffset provides the relative position of the sensor from the reference position, expressed in a unit of 0.01 m. The sensor's position determined from the DE_SensorPositionOffset serves as the origin of a sensor-specific coordinate system.
ASN.1 representation	`SensorPositionOffset ::= INTEGER(-32767..32767) -- LSB units of 0.01 meters`
Units	0.01 meters (signed)

F.6.2.3 SensorRange

Description	The DE_SensorRange provides the detection range of the sensor, expressed in a unit of 0.1 m. The sensor's position determined from the DE_SensorPositionOffset serves as the origin of a sensor-specific coordinate system.
ASN.1 representation	`SensorRange ::= INTEGER(0…10000) -- LSB units of 0.1 meters`
Units	0.1 meters

F.6.2.4 SensorAngle

Description	The DE_SensorAngle provides the sensor's opening angle used to define the start or the end of the sensor's opening angle in the horizontal plane or the vertical plane. The sensor's position determined from the DE_SensorPositionOffset serves as the origin of a sensor-specific coordinate system. This is expressed in a unit of 0.1 degree. The value "3601" indicates that the angle information is unavailable.
ASN.1 representation	`SensorAngle ::== INTEGER(1…3601) -- LSB units of 0.1 degrees (3601 corresponds to "unavailable")`
Units	0.1 degrees

F.6.2.5 NotificationType

Description	The DE_NotificationType provides the type of notification in response to HDDS.

ASN.1 representation	`NotificationType ::= ENUMERATED{`
	`rejection of subscription request (0),`
	`termination of subscription request (1),`
	`keep-alive (2),`
	`…`
	`}`

Units	N/A

F.6.2.6 ReasonCode

Description	The DE_ReasonCode provides the reason for the notification.

ASN.1 representation	`ReasonCode ::= ENUMERATED{`
	`unspecified (0),`
	`request unsupported (1),`
	`unexpected or unsupported position of requester (2),`
	`…`
	`}`

Units	N/A

F.6.2.7 MonoVideoCodec

Description	The DE_MonoVideoCodec provides the video codec for mono video sensor type.

ASN.1 representation	`MonoVideoCodec ::= ENUMERATED{`
	`undefined (0),`
	`h264 (1),`
	`mjpeg (2),`
	`…`
	`}`

Units	N/A

F.6.2.8 MonoVideoResolution

Description	The DE_ MonoVideoResolution provides the video resolution for mono video sensor type.

ASN.1 representation	`MonoVideoResolution ::= ENUMERATED{`
	`undefined (0),`
	`720p (1),`
	`1080p (2),`
	`…`
	`}`

Units	N/A

F.6.2.9 MonoVideoFrameRate

Description	The DE_MonoVideoFrameRate provides the video frame rate for mono video sensor type.

ASN.1 representation	`MonoVideoFrameRate ::= ENUMERATED{`
	`undefined (0),`
	`25 fps (1),`
	`30 fps (2),`
	`…`
	`}`

Units	N/A

F.6.2.10 StreamingDataFormat

Description	The DE_ StreamingDataFormat provides the data format used during streaming of the sensor type.

ASN.1 representation	`StreamingDataFormat ::= ENUMERATED{`
	`RTP (0),`
	`…`
	`}`

Units	N/A

F.6.2.11 KeepAliveInterval

Description	The DE_KeepAliveInterval provides the maximum time interval between two consecutive keep-alive messages to keep the subscription alive. This is expressed in a unit of 100 ms.
ASN.1 representation	`KeepAliveInterval ::== INTEGER(0…255) -- LSB units of 100 ms`
Units	100 ms