



SURFACE VEHICLE STANDARD

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Application Protocol and Requirements for Maneuver Sharing and Coordinating Service

RATIONALE

This SAE Standard is the first edition of application protocol and requirements for maneuver sharing and coordinating service (MSCS). This is to improve road safety and traffic efficiency by sharing and coordinating vehicle maneuvers via V2X communications. Maneuver sharing and coordination are required for V2X entities to make safe and efficient driving decisions. To achieve these capabilities, the necessary V2X message structures, information elements, and their associated protocols are defined in this document.

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1. SCOPE

This SAE Standard provides requirements to support applications for the maneuver sharing and coordinating service (MSCS) beyond broadcast of basic safety messages (BSMs). This is to improve road safety and traffic efficiency by sharing and coordinating vehicle maneuvers via vehicle-to-everything (V2X) communications. This document lays out use case scenarios and defines vehicle-to-vehicle (V2V) application protocols, system requirements and message sets for MSCS. The defined message sets for MSCS will result in identifying new message types, data frames, and data elements for SAE J2735.

2. REFERENCES

2.1 Applicable Documents

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

2.1.1 SAE Publications

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

SAE J2735	V2X Communications Message Set Dictionary
SAE J2945/1	On-Board System Requirements for V2V Safety Communications
SAE J2945/5	Service Specific Permissions and Security Guidelines for Connected Vehicle Applications
SAE J3161/1	On-Board System Requirements for LTE-V2X V2V Safety Communications
SAE J3164	Ontology and Lexicon for Automated Driving System (ADS)-Operated Vehicle Behaviors and Maneuvers in Routine/Normal Operating Scenarios
SAE J3216	Taxonomy and Definitions for Terms Related to Cooperative Driving Automation for On-Road Motor Vehicles
SAE J3224	V2X Sensor-Sharing for Cooperative and Automated Driving

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.

IEEE Std 1609.2-2016 IEEE Standard for Wireless Access in Vehicular Environments - Security Services for Applications and Management Messages

IEEE Std 1609.12-2019 IEEE Standard for Wireless Access in Vehicular Environments (WAVE) - Identifier Allocations

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 accessed at <https://standards.ieee.org/about/sasb/patcom/patents/>.

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. DEFINITIONS

AFFECTED VEHICLE: A connected vehicle which is affected by a sub-maneuver.

CONNECTED VEHICLE: A vehicle which is capable of V2X¹ communication. Note that, in the present document, a connected vehicle is required to exchange the BSMs as specified in SAE J3161/1 or SAE J2945/1.

EMERGENCY MANEUVER RESERVATION: Maneuver sharing and coordinating message with the message type of 6 generated by an HV to announce an emergency maneuver.

EXECUTANT VEHICLE: A connected vehicle which is intended to perform a sub-maneuver.

HOST VEHICLE: A connected vehicle which transmits a maneuver intent or maneuver request. An MSCS session initiator.

HV MANEUVER CANCELLATION: Maneuver sharing and coordinating message with the message type of 4 generated by an HV to announce cancellation of the on-going maneuver negotiation.

MANEUVER EXECUTION STATUS: Maneuver sharing and coordinating message with the message type of 7 generated by an executant vehicle to share the status of maneuver execution.

MANEUVER INTENT: Maneuver sharing and coordinating message with the message type of 0 generated by an HV to share intended maneuver without initiating a maneuver negotiation state.

MANEUVER REQUEST: Maneuver sharing and coordinating message with the message type of 1 generated by an HV to share intended maneuver and initiate a maneuver negotiation state.

MANEUVER RESERVATION: Maneuver sharing and coordinating message with the message type of 3 generated by an HV to announce a granted maneuver request.

MANEUVER RESPONSE: Maneuver sharing and coordinating message with the message type of 2 generated by an RV to respond to a maneuver request.

MANEUVER: Goal-oriented vehicle movement undertaken by an ADS or human driver in order to achieve a specific result/outcome.

REMOTE VEHICLE: A connected vehicle which is intended to receive a maneuver intent or maneuver request. An MSCS session participant.

RV MANEUVER CANCELLATION REQUEST: Maneuver sharing and coordinating message with the message type of 5 generated by an RV to request cancellation of an on-going maneuver negotiation.

UNCONNECTED VEHICLE: A vehicle which is not capable of V2X communication, i.e., a vehicle which is not a connected vehicle.

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.

4. ACRONYMS

ADS	Automated driving system
BSM	Basic safety message
CAN	Controller area network
CV	Connected vehicle
DVI	Driver-vehicle interface
ECU	Electronic control unit
GNSS	Global navigation satellite system
HV	Host vehicle
MSCM	Maneuver sharing and coordinating message
MSCS	Maneuver sharing and coordinating service
OBU	Onboard unit
RF	Radio frequency
RSU	Roadside unit
RV	Remote vehicle
SDSM	Sensor data sharing message
TRR	Target road resource
UPER	Unaligned packed encoding rules
UV	Unconnected vehicle
V2I	Vehicle-to-infrastructure
V2V	Vehicle-to-vehicle
V2X	Vehicle-to-everything, used as a general term for all communications based on SAE J2735
VRU	Vulnerable road user

5. CONCEPT OF OPERATION AND SYSTEM DESCRIPTION

5.1 MSCS System Overview

Maneuver sharing and coordinating service (MSCS) system supports applications for MSCS beyond broadcast of BSMS. MSCS and the applications enable V2X-capable road entities to share, negotiate, and coordinate their intended maneuvers, and share execution status so that road safety and traffic efficiency can be improved.

[Figure 1](#) illustrates the components of the MSCS system and its interfaces. The MSCS 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 maneuver sharing and coordinating messages (MSCMs). 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 CAN bus, dead reckoning sensors and optical/camera-based systems.
- **OBU Control Processor Electronic Control Unit (ECU):** Executes software that generates MSCMs for transmission according to the requirements in this standard and controls the OBU as maneuver coordination.

NOTE: This standard defines the MSCS application protocol and requirements for only V2V use cases. The use cases including RSU will be standardized in subsequent versions of this standard.

- **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 for device authentication and 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.

Systems communicate amongst themselves using the V2X radio subsystem as an interface. The 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, audio, and/or haptic alerts. The system can also interface with the vehicle controller area network (CAN) bus to obtain vehicle status information. The safety application ECU, CAN bus, and DVI are outside the scope of this standard.

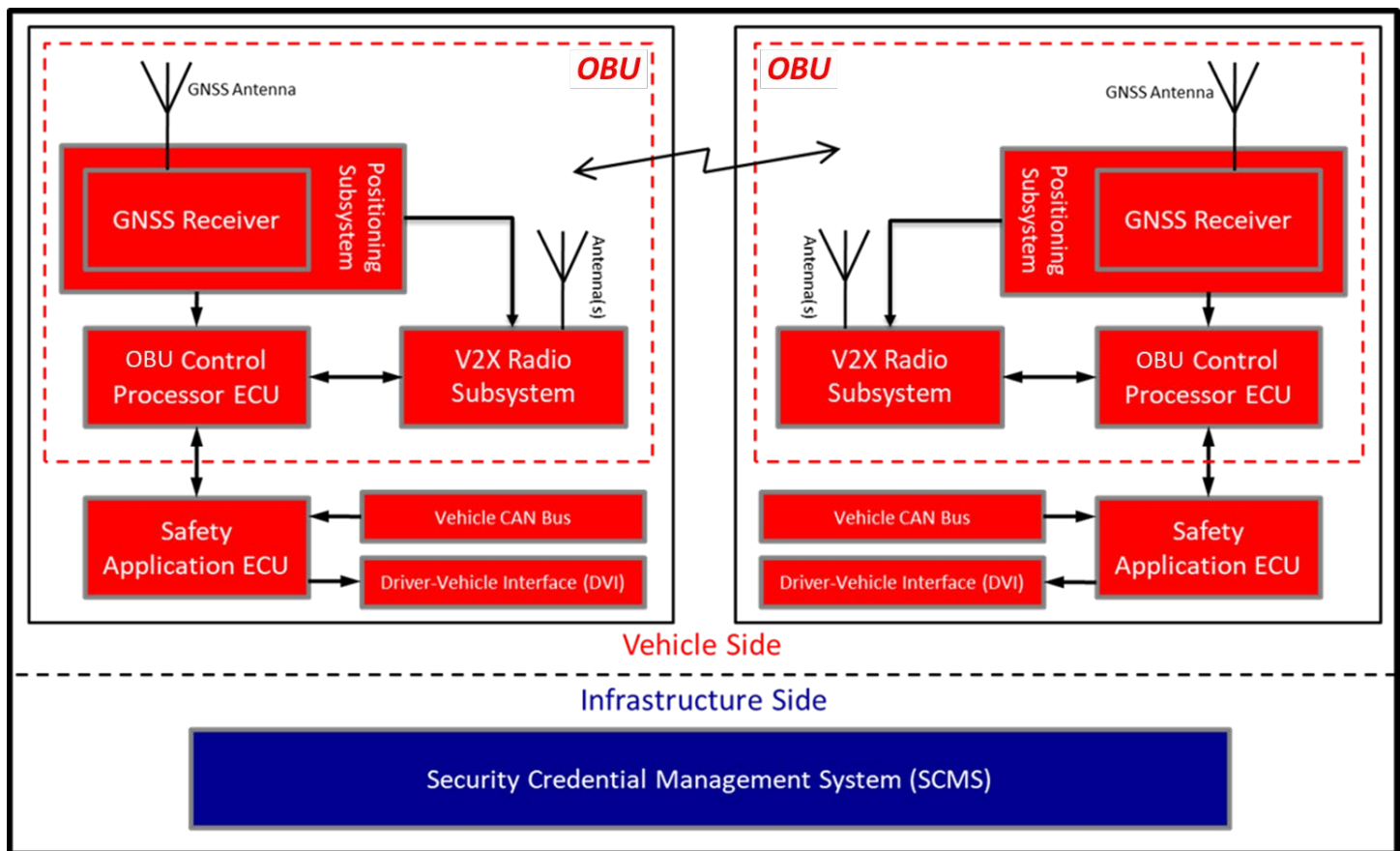


Figure 1 - MSCS system

5.2 MSCS Use Cases

5.2.1 Overview

This clause introduces use cases of MSCS. Two categories of application scenario are defined:

- Cooperative lane change
- Cooperative lane merge

NOTE: Additional use cases will be addressed in future revisions of this standard. They may include the centralized cooperative lane change and merge, the automated intersection crossing for intersection management, and the group start and traffic flow speed optimization for traffic flow management.

A template for use case description is defined with items as following items:

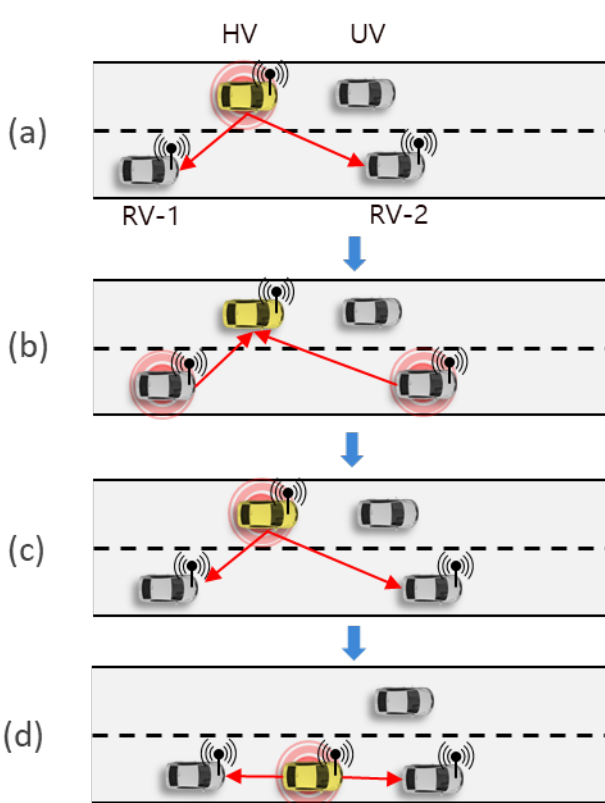
- Use case name
- V2X type (V2V, V2I, V2N, or V2P)
- Overview
- Brief description
- Road environment
- Participants

- Participants’ roles
- Assumptions and preconditions
- Use case flow illustrations
- Use case flow description

NOTE: More information can be found in the 5GAA White Paper “C-V2X Use Cases Volume II: Examples and Service Level Requirements.”

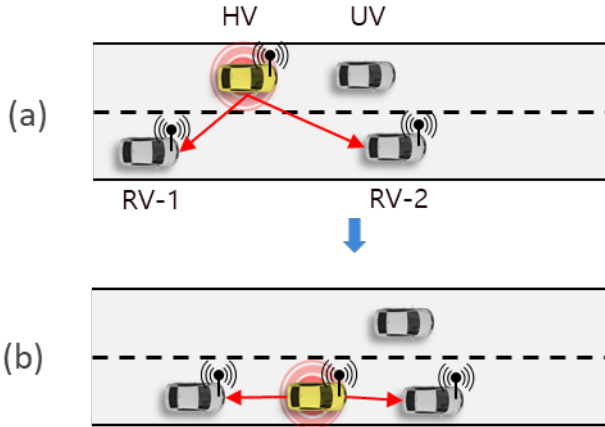
5.2.2 Cooperative Lane Change

5.2.2.1 Cooperative Lane Change (V2V)

Use case name	Cooperative lane change
V2X type	V2V
Overview	Vehicle changing to an adjacent lane after negotiation with surrounding vehicles
Brief description	Vehicle intends to change to an adjacent lane because of traffic conditions, an obstacle in its driving trajectory, or as part of its planned route. Inter-vehicle negotiation and cooperation are performed to propose, accept, and execute the lane change in a manner safe to all participating vehicles.
Road environment	Urban, rural, highway
Participants	CVs (HV and RVs)
Participants’ roles	• Host vehicle (HV): Lane change maneuver initiator • Remote vehicles (RVs): Lane change maneuver collaborators
Assumptions and preconditions	For below diagrams, both CVs (HV and RVs) and UVs are considered
Use case flow illustrations	 Figure 2 - Illustration for use case of cooperative lane change (V2V)

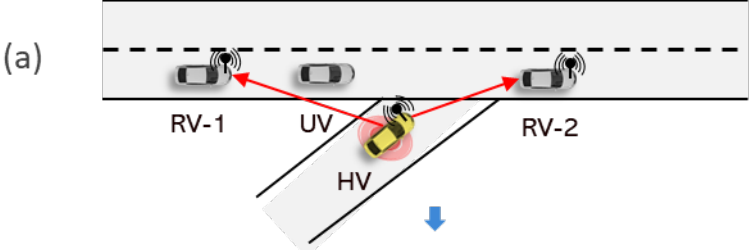
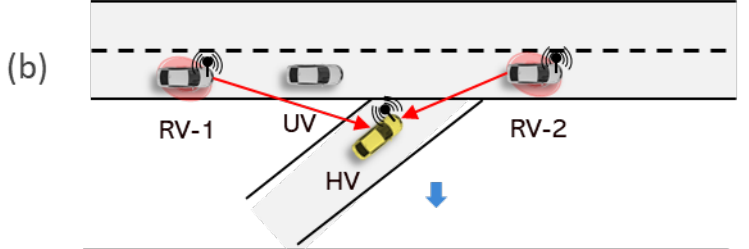
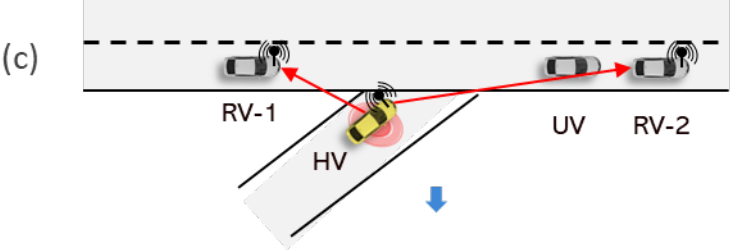
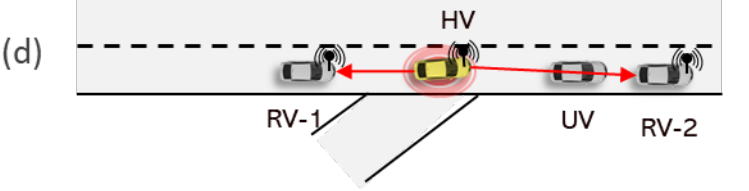
Use case flow description	- a. ○ HV decides to change to an adjacent lane ○ Based on current position, speed, and intent of HV and surrounding vehicles, HV determines that coordination with other vehicles is desirable ○ HV sends a lane change request with relevant information such as current motion state, target lane, time window, planned trajectory, etc., to affected vehicles - b. ○ RV-1 and RV-2 determine they can accommodate HV's lane change request ○ RV-1 transmits an acceptance ○ RV-2 transmits an acceptance - c. ○ HV sends a maneuver reservation to affected vehicles (RV-1, RV-2) to inform that the lane change request is granted - d. ○ HV keeps monitoring motion state of RVs and UVs via BSMs from RVs, HV sensors or sensor data sharing from other vehicles to make sure HV's maneuver will not create any danger of collision with them ○ HV executes lane change with sending the execution status messages to RVs until the execution is completed
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5.2.2.2 Cooperative Lane Change of an Emergency Vehicle (V2V)

Use case name	Cooperative lane change of an emergency vehicle
V2X type	V2V
Overview	Eligible emergency vehicle changing to an adjacent lane after announcement to surrounding vehicles
Brief description	Eligible emergency vehicle intends to change to an adjacent lane because of emergency. Inter-vehicle cooperation is performed to announce and execute the lane change in a manner safe to all participating vehicles.
Road environment	Urban, rural, highway
Participants	CVs (HV and RVs)
Participants' roles	- Host vehicle (HV): Lane change maneuver initiator - Remote vehicles (RVs): Lane change maneuver collaborators
Assumptions and preconditions	For below diagrams, both CVs (HV and RVs) and UVs are considered
Use case flow illustrations	 Figure 3 - Illustration for use case of cooperative lane change for an emergency vehicle (V2V)
Use case flow description	a. ○ HV decides to change to an adjacent lane ○ Based on current position, speed, and intent of HV and surrounding vehicles, HV determines that coordination with other vehicles is desirable ○ HV sends an emergency lane change reservation with relevant information such as current motion state, target lane, time window, planned trajectory, etc., to affected vehicles b. ○ HV keeps monitoring motion state of RVs and UVs via BSMs from RVs, HV sensors, or sensor data sharing from other vehicles to make sure HV's maneuver will not create any danger of collision with them ○ HV executes lane change with sending the execution status messages to RVs until the execution is completed

5.2.3 Cooperative Lane Merge

5.2.3.1 Cooperative Lane Merge (V2V)

Use case name	Cooperative lane merge
V2X type	V2V
Overview	Vehicle entering a roadway through merging cooperation between vehicles
Brief description	Vehicle intends to merge into a roadway via an on-ramp. Inter-vehicle negotiation and cooperation are performed to propose, accept and execute the lane merge in a manner safe to all participating vehicles.
Road environment	On-ramp
Participants	CVs (HV and RVs)
Participants' roles	- Host vehicle (HV): Lane merge maneuver initiator - Remote vehicles (RVs): Lane merge maneuver collaborators
Assumptions and preconditions	For below diagrams, both CVs (HV and RVs) and UVs are considered
Use case flow illustrations	(a)  (b)  (c)  (d)  Figure 4 - Illustration for use case of cooperative lane merge (V2V)

Use case flow description	- a. ○ HV decides to merge into a main roadway via on-ramp ○ Based on current position, speed, and intent of HV and surrounding vehicles, HV determines that coordination with other vehicles is desirable ○ HV sends a lane merge request with relevant information such as current motion state, target lane, time window, planned trajectory, etc., to vehicles near the entrance, RV-1, RV-2 - b. ○ RV-1 and RV-2 determine they can accommodate HV's lane merge request ○ RV-1 transmits an acceptance ○ RV-2 transmits an acceptance - c. ○ HV sends a maneuver reservation to affected vehicles (RV-1, RV-2) to inform that the lane merge request is granted - d. ○ HV keeps monitoring motion state of RVs and UVs via BSMs from RVs, HV sensors or sensor data sharing from other vehicles to make sure HV's maneuver will not create any danger of collision with them ○ HV executes lane merging with sending the execution status messages to RVs until the execution is completed
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5.2.3.2 Cooperative Lane Merge of an Emergency Vehicle (V2V)

Use case name	Cooperative lane merge of an emergency vehicle
V2X type	V2V
Overview	Eligible emergency vehicle entering a roadway through merging cooperation between vehicles
Brief description	Eligible emergency vehicle intends to merge into a roadway via an on-ramp. Inter-vehicle cooperation is performed to announce and execute the lane merge in a manner safe to all participating vehicles.
Road environment	On-ramp
Participants	CVs (HV and RVs)
Participants' roles	- Host vehicle (HV): Lane merge maneuver initiator - Remote vehicles (RVs): Lane merge maneuver collaborators
Assumptions and preconditions	For below diagrams, both CVs (HV and RVs) and UVs are considered
Use case flow illustrations	Figure 5 - Illustration for use case of cooperative lane merge for an emergency vehicle (V2V)
Use case flow description	- HV decides to merge into a main roadway via on-ramp - Based on current position, speed, and intent of HV and surrounding vehicles, HV determines that coordination with other vehicles is desirable - HV sends an emergency lane merge reservation with relevant information such as current motion state, target lane, time window, planned trajectory, etc., to vehicles near the entrance, RV-1, RV-2 - HV keeps monitoring motion state of RVs and UVs via BSMs from RVs, HV sensors or sensor data sharing from other vehicles to make sure HV's maneuver will not create any danger of collision with them - HV executes lane merging with sending the execution status messages to RVs until the execution is completed

5.3 Security

The security needs for these use cases are described in this clause. These security constraints reflect the sensitive nature of certain data, which is necessary to protect (e.g., maneuver data, or personally identifiable information) from attacks.

5.3.1 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.

5.3.2 Data Integrity and Availability

The system needs to provide a mechanism to verify that data has not been changed or significantly delayed between the entity that produced the data and the entity that consumes the data.

5.3.3 User Privacy

Participation in the system needs to be optional, with personally identifiable information not being transmitted or stored. For emergency vehicles using MSCS, privacy is not a requirement.

6. MSCS APPLICATION PROTOCOL

6.1 Introduction

This clause defines the MSCS application protocol and requirements for the use cases described in [5.2](#).

NOTE: Other use cases will be addressed in future revisions of this standard. Requirements in the present document can be modified in the future revisions.

6.2 Roles for MSCS and Maneuver Description

- HV and RVs: HV and RVs are roles on an MSCS session, i.e., an MSCS session initiator and MSCS session participants. An HV transmits its intended maneuver via a maneuver intent or maneuver request.

When an HV does not need to open an MSCS session, i.e., negotiation is not needed, it transmits a maneuver intent with or without specifying RVs.

NOTE 1: It is considered as “intent-sharing cooperation” as defined in SAE J3216.

Otherwise, i.e., if negotiation is needed because the intended maneuver needs any vehicle motion control or extra caution of any other CVs, it transmits a maneuver request to specified RVs. When RVs receive a maneuver request in which their identifications are indicated, the RVs shall respond to it. The maximum number of RVs shall be *vMaxNumRVs*.

NOTE 2: It is considered as “agreement-seeking cooperation” as defined in SAE J3216.

NOTE 3: Once an HV initiates an MSCS session, it shall not initiate a new MSCS session until the on-going MSCS session is closed. See [6.3.2](#) and [6.4.2](#).

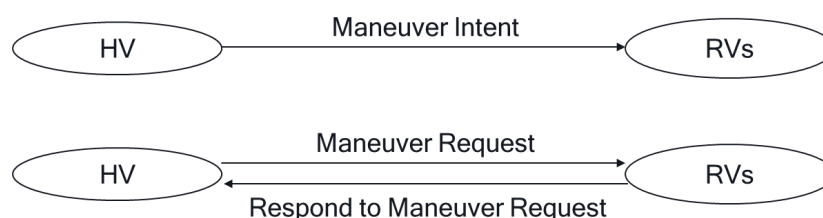


Figure 6 - Roles for MSCS: HV and RVs

- Executant Vehicle and Affected Vehicles: Executant vehicle and affected vehicles are roles on a sub-maneuver. A maneuver is described with a set of sub-maneuvers in the present document. Each sub-maneuver is intended to be performed by a CV, i.e., the executant vehicle, and agreed by nearby CVs to be affected, i.e., affected vehicles.

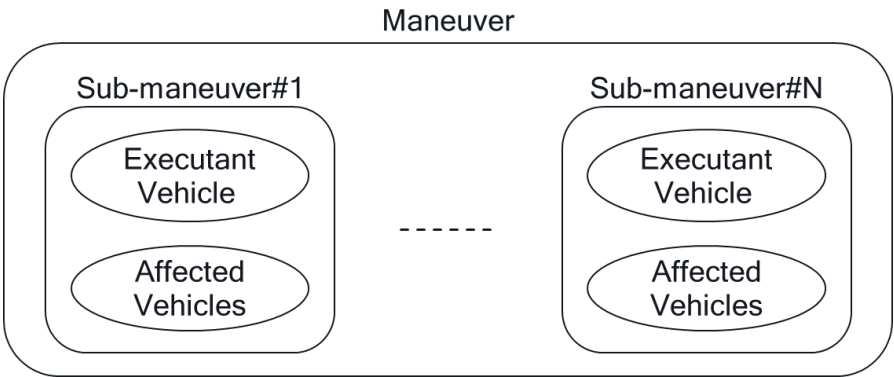


Figure 7 - Roles for MSCS: Executant vehicle and affected vehicles

- NOTE 1: The executant vehicle can be the HV or other CV (i.e., non-HV).
- NOTE 2: The union set of the executant vehicles and the affected vehicles of all sub-manuevers of a maneuver, exclusive of the HV, comprise the RVs of the maneuver.

A maneuver for MSCS is described is shown in [Figure 8](#). See Section [7](#) and [Appendix A](#) for details.

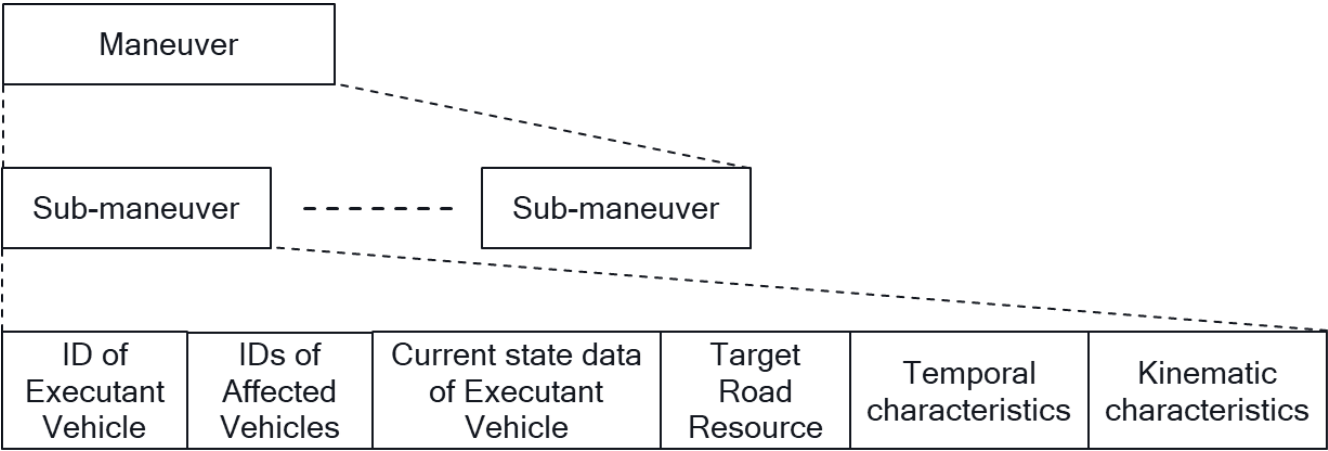


Figure 8 - Maneuver for MSCS

6.2.1 Sub-Maneuver

The minimum number of sub-maneuvers of a maneuver shall be one, and the maximum number of sub-maneuvers of a maneuver shall be $vMaxNumSubmaneuvers$.

Each sub-maneuver consists of the ID of the executant vehicle, IDs of the affected vehicles, current state data of the executant vehicle, target road resource, and associated temporal and kinematic characteristics.

Each sub-maneuver is intended to be performed by the HV or suggested to be performed by a CV other than the HV, i.e., the executant vehicle of each sub-maneuver can be either of the HV or another CV.

NOTE 1: There is no restriction such that at least one sub-maneuver's executant vehicle shall be the HV, i.e., it is allowed that the HV of a maneuver is not an executant vehicle of any sub-maneuver of a maneuver.

NOTE 2: There is no restriction such that one vehicle can be the executant vehicle of only one sub-maneuver, i.e., it is allowed that a same vehicle can be the executant vehicles of multiple sub-maneuvers of a maneuver.

6.2.1.1 ID of Executant Vehicle and IDs of Affected Vehicles

The TemporaryIDs in BSMs of the executant vehicle and affected vehicles are used as their identifiers for an MSCS session. See [8.3.3](#) for details.

6.2.1.2 Current State Data of Executant Vehicle

The current state data of executant vehicle of a sub-maneuver consists of the current geographical position, speed, heading, acceleration, and vehicle size of the executant vehicle.

6.2.1.3 Target Road Resource (TRR)

The TRR of a sub-maneuver consists of the TRR type and descriptions of the road resource which is intended to be occupied by the executant vehicle.

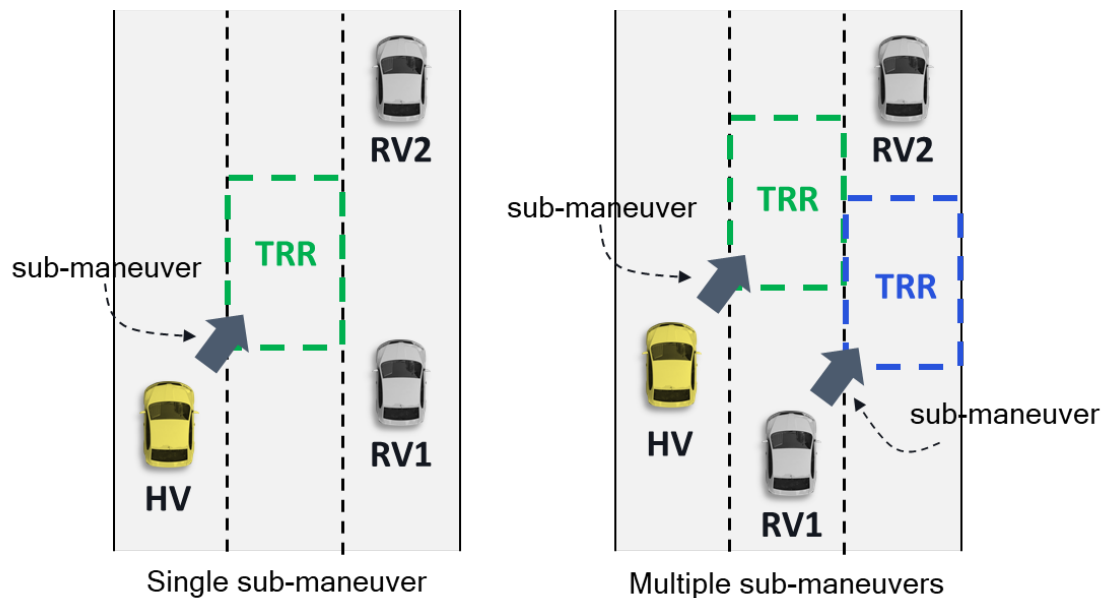


Figure 9 - Examples of target road resource for maneuvers with single sub-maneuver and multiple sub-maneuvers

Three types of TRR description and their characteristics are defined in [6.2.1.3.1](#) to [6.2.1.3.3](#).

NOTE: Sub-maneuvers in the same maneuver may use different TRR types.

6.2.1.3.1 TRR Type 1

A TRR of type 1 describes a straight or curved box shaped area with following characteristics.

The box shaped area shall be described with a geographical position of the middle of the front longitudinal side, lane offset, longitudinal length, and optional movement speed. The geographical position of the middle of the front longitudinal side shall be represented as a position offset with respect to the HV's reference position (hVP_{OS} of $DF_Position3D$), and the lane offset shall be with respect to the executant vehicle's current lane.

A TRR of type 1 can describe a non-moving area or a moving area with a constant speed. To describe a moving area, the movement speed shall be provided, and it means that the area moves with the constant speed from the time specified by the time stamp of the associated MSCM assuming that the movement direction follows the regional traffic regulation. To describe a non-moving area, the movement speed shall not be provided.

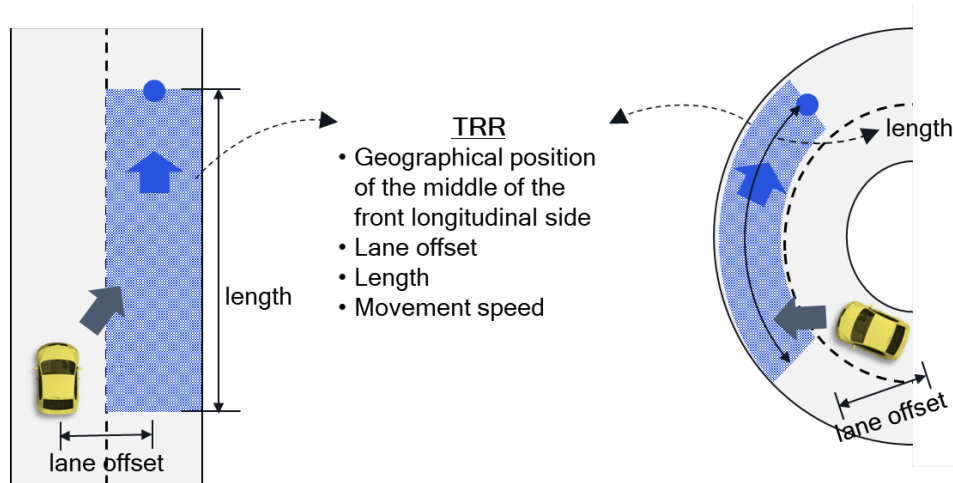


Figure 10 - TRR type 1 for straight and curved area

The TRR of type 1 is suitable for describing a non-moving area, e.g., lane merge. It can also be used for describing a moving area but the usage is limited for a moving area at a constant speed which might be aligned with the executant vehicle's speed.

6.2.1.3.2 TRR Type 2

A TRR of type 2 describes a straight or curved box shaped area with following characteristics.

The box shaped area shall be described with one or two surrounding vehicles, optional longitudinal length, lane offset, and safety gap. Two longitudinal sides of the box shape shall be described by descriptions of two surrounding vehicles on a same lane, or one surrounding vehicle and length. The description of a surrounding vehicle consists of its position, size, and identifier. The position of a surrounding vehicle shall be represented as a position offset with respect to the HV's reference position (hVP_{OS} of $DF_Position3D$), and the identifier of a surrounding vehicle is obtained from BSMs sent by the vehicle. The lane offset shall be with respect to the executant vehicle's current lane. The safety gap is the distance gap between the area and the surrounding vehicle(s).

Even if a surrounding vehicle of a TRR of type 2 changes its lane during the maneuver negotiation or execution states, the TRR description may be maintained validly with the assumption that a lane-maintaining virtual (or imaginary) vehicle replaces the surrounding vehicle where the virtual (or imaginary) vehicle is assumed to continuously have all identical information to the surrounding vehicle except only the lateral position.