C-V2X Use Cases and Service Level Requirements

Volume III

5GAA Automotive Association
Technical Report

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Contents

Foreword

This Technical Report has been produced by 5GAA.

The contents of the present document are subject to continuing work within the Working Groups (WG) and may change following formal WG approval. Should the WG modify the contents of the present document, it will be re-released by the WG with an identifying change of the consistent numbering that all WG meeting documents and files should follow (according to 5GAA Rules of Procedure):

x-nnzzzz

(1) This numbering system has six logical elements:

(a) x: a single letter corresponding to the working group:

where x =

T (Use cases and Technical Requirements)

A (System Architecture and Solution Development)

P (Evaluation, Testbed and Pilots)

S (Standards and Spectrum)

B (Business Models and Go-To-Market Strategies)

(b) nn: two digits to indicate the year. i.e. 16,17,18, etc

(c) zzzz: unique number of the document

(2) No provision is made for the use of revision numbers. Documents which are a revision of a previous version should indicate the document number of that previous version

(3) The file name of documents shall be the document number. For example, document S-160357 will be contained in file S-160357.doc

1 Scope

The present report contains the third volume (Volume III) of 5GAA WG1 agreed use case (UC) descriptions for Use Cases developed within the 5GAA, and consolidated in WG1.

The results and conclusions of this report, and of the future use case descriptions and related communication requirements, are intended to serve as input for the work of other WGs in 5GAA, as well as sources for input and feedback to standardization activities, e.g., in 3GPP.

2 References

The following documents contain provisions which, through reference in this text, constitute provisions of the present document.

- References are either specific (identified by date of publication, edition number, version number, etc.) or non-specific.
- For a specific reference, subsequent revisions do not apply.
- For a non-specific reference, the latest version applies.

[1] 5GAA T-180065, “Work Item Description: Use Case and Service Level requirements”, February 2018

[2] 5GAA T-200111, “TR C-V2X Use Cases and Service Level Requirements Vol I V3.0”, 2023

[3] 5GAA T-210021, “TR C-V2X Use Cases and Service Level Requirements Vol II V2.0”, 2023

[4] ISO 23374:2021, “Intelligent transport systems — Automated valet parking systems (AVPS) — System framework, requirements for automated driving, and communication interface”, not released as IS

3 Definitions and Abbreviations

3.1 Definitions

For the purposes of the present document, the following definitions apply:

Drop off area: Location where the driver leaves the HV and AVPS receives the authority

OB: Operator Backend, manages the system participants

P: Automated valet parking facility management, e.g. manages environmental conditions

Parking area: Area within the so called operation zone consisting of multiple parking spots

Parking Facility: Public or private car park capable of AVPS

Parking spot: Area within the parking facility where a single vehicle can be parked

Pick up area: Location where AVPS brings the HV back for the user to board the vehicle and regain the authority

R: Remote vehicle operation sub-system

Road environments: Road environments are the typical places where vehicle traffic and C-V2X use cases occur, such as intersections, urban and rural streets, high speed roads (Autobahn), parking lots, etc.

Service Level Requirement (SLR): SLRs describe solution agnostic requirements of a use case.

U: User frontend, may be integrated to e.g. mobile phones, vehicle HMI

UB: User Backend, user request processing – mainly closely linked to / part of VB

Use Cases: Use cases are the high level procedures of executing an application in a particular situation with a specific purpose.

User Stories: User stories are specific variations of one use case.

V: On-board vehicle operation sub-system

VB: (OEM) Vehicle Backend, e.g. remote engagement / disengagement, authorization of handover, engine start etc.

3.2 Abbreviations

For the purposes of the present document, the following symbols apply:

AVPS	Automated Valet Parking System
HV	Host Vehicle, equals SV (Subject Vehicle) in [3]
KPI	Key Performance Indicator
SLR	Service Level Requirement
UC	Use Case

4 Introduction

Following the first volume (Volume I) [2] and second volume (Volume II) [3] set of use case descriptions and the corresponding framework developed in WG1, this document presents the third volume (Volume III) of use case descriptions.

The use case descriptions are written from the vehicle perspective and strive to be solution agnostic and applicable to both driven and autonomous vehicles. The realization of use cases does not preclude applications performing various tasks supporting the use cases, such as collecting information, analyzing etc. Furthermore, radio symbols in figures indicate a connected vehicle. The templates for use case descriptions, the use case classification scheme and in general the methodology that WG1 has developed for the description of the use cases and the corresponding Service Level Requirement (SLRs) are presented in [2].

Note: It is also assumed that messages are exchanged in a secure way between authenticated parties.

The remainder of this document is structured as follows. Section 5 contains the use case descriptions and the service level requirements (SLRs). Section 6 concludes the document.

5 5G C-V2X Use Cases Descriptions

5.1 Safety

5.1.1 Cooperative Adaptive Cruise Control (CACC)

Use Case Name	Cooperative Adaptive Cruise Control
User Story	The host vehicle (HV) wants to reduce the gap to the leading vehicle (remote vehicle – RV) while keeping an adapted and safe distance to the RV. The goal is to achieve more fluid and controlled speed adaptation to the RV, which creates smoother manoeuvring of the vehicle but also enables safe reaction to currently not detectable behaviours such as acceleration and breaking from vehicles in the lane ahead.
Category	Convenience, safety.
Road Environment	Urban, Rural, Highway.
Short Description	HV tries to adjust its speed efficiently to achieve better reaction to the leading vehicles (RV) and to safely reduce the distance between itself and the leading vehicle. This function also works when not all vehicles ahead of the receiving vehicle can communicate status messages.
Actors	Host vehicle (HV): the vehicle that is following RV, adaption its velocity while keeping a certain distance. Remote vehicle (RV): the vehicle that is driving in front of HV.
Vehicle Roles	HV: follow RV while adapting speed and keeping a certain distance. RV: drive in front of HV.
Road/Roadside Infrastructure Roles	N/A.
Other Actors' Roles	N/A.
Goal	Improve safety and convenience compared to standard ACC.
Needs	Provision of kinematics and position information from RV to HV.
Constraints/ Presumptions	The use case needs to be called off by the HV once the safety of either HV or RV is in danger. This can be done by the use of other data than kinematics or position information, such as emergency messages or sensory detection. As the HV adapts its behaviour to the RV regularly, it can be assumed the function adapts to environmental changes, if however, these changes are not taken into account correctly, the use case must be cancelled by the affected vehicle. This does not affect the use case running in other vehicles.
Geographic Scope	Anywhere.
Illustrations	N/A.
Pre-Conditions HV	• The HV is receiving kinematics and position information from vehicles ahead in its lane.
Pre-Conditions RVs	• RV is providing kinematics, position, and vehicle state (e.g. indicator state) information to potential HVs.
Main Event Flow	• RV provides its basic status information including speed, heading and position

	• HV use this information and can identify it belonging to specific vehicles ahead of it. Based on the information the HV then adapts its speed. • HV repeats this step in a loop to continuously adapt speed and distance to RV.
Alternative Event Flow	Not applicable.
Post-Conditions	None.
Information Requirements	Basic vehicle status data.

User Story	Description
#1: ACC with status messages	In this user story, existing adaptive Cruise Control (ACC) is extended with the information received and evaluated from status messages of surrounding vehicles to enable even better adaptation to their behaviours.
#2: ACC with control information	In this user story, ACC is extended with specific messages from the leading vehicle's control system, providing early information on acceleration / deceleration to improve the ACC adaptation.

User Story #1			
Service Level Requirement	**SLR Unit**	**SLR Value**	**Explanations/Reasoning/Background**
Range	[m]	800	The range depends on vehicle speeds and therefore possible inter-vehicle-distances. Vehicles on high-speed roads will need adequate time to stop.
Information Requested/Generated	Quality of information/Information needs	300 bytes	Vehicles must provide kinematics and position information periodically (e.g. using BSM/CAM) to enable continuous speed and distance adaptation.
Service Level Latency	[ms]	100	Exchange of messages must happen quickly, but speed adaptation will only be initiated upon inspection of vehicle safety. Slower messaging will reflect on higher inter-vehicle distance
Service Level Reliability	%	99.9	Rationale for the SLR is the needed high availability of the function. Safety typically is assured by monitoring and, if outages are detected, getting into a safe state or degrade the function. This however should be avoided for the sake of the perceived quality by the users.
Velocity	[m/s]	60	Support up to approx. 210km/h, similar to current ACCs.
Vehicle Density	[vehicle/km^2]	10,000	Assumes functionality to be used in all kinds of traffic scenarios, ranging from stop-and-go in urban scenarios, to low density high speed autobahn driving.
Positioning	[m]	0.5 (Xσ)	As the function will also rely on vehicle sensors the longitudinal position accuracy is much more

			relevant than the lateral position accuracy that is less critical. Position within the lane is sufficient.
Interoperability/ Regulatory/ Standardisation Required	[yes/no]	Yes/Yes/Yes	Interoperability due to different OEMs. Regulation is needed to determine the inter-vehicle distances for the use case. A standardised protocol is needed.

User Story #2			
Service Level Requirement	**SLR Unit**	**SLR Value**	**Explanations/Reasoning/Background**
Range	[m]	800	The range depends on vehicle speeds and therefore possible inter-vehicle-distances. Vehicles on high-speed roads will need adequate time to stop.
Information Requested/Generated	Quality of information/Information needs	300 bytes (speed & position) 100 bytes (acceleration / deceleration)	Vehicles must provide kinematics and position information periodically (e.g. using BSM/CAM) to enable continuous speed and distance adaptation. Acceleration and deceleration are provided continuously or on demand.
Service Level Latency	[ms]	100 (speed & position) 10 (acceleration / deceleration)	Exchange of messages must happen quickly, but speed adaptation will only be initiated upon inspection of vehicle safety. Slower messaging will reflect on higher inter-vehicle distance. Acceleration and deceleration are tightly integrated with HV control and need low latency.
Service Level Reliability	%	99.9	Rationale for the SLR is the needed high availability of the function. Safety typically is assured by monitoring and, if outages are detected, getting into a safe state or degrade the function. This however should be avoided for the sake of the perceived quality by the users.
Velocity	[m/s]	60	Support up to approx. 210km/h, similar to current ACCs.
Vehicle Density	[vehicle/km^2]	10,000	Assumes functionality to be used in all kinds of traffic scenarios, ranging from stop-and-go in urban scenarios, to low density high speed autobahn driving.
Positioning	[m]	0.5 (Xσ)	As the function will also rely on vehicle sensors the longitudinal position accuracy is much more relevant than the lateral position accuracy that is less critical. Position within the lane is sufficient.
Interoperability/ Regulatory/ Standardisation Required	[yes/no]	Yes/Yes/Yes	Interoperability due to different OEMs. Regulation is needed to determine the inter-vehicle distances for the use case. A standardised protocol is needed.

5.2 Vehicle Operations Management

No new use cases were added in this category in the current version of this document.

5.3 Convenience

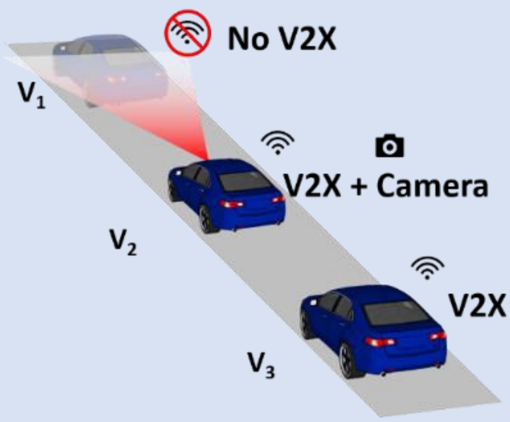
No new use cases were added in this category in the current version of this document.

5.4 Automated Driving

5.4.1 Data sharing of dynamic objects

Use Case Name	Data sharing of dynamic objects
User Story	Vehicles collect information on dynamic objects in the road and other traffic participants based on vehicle sensor data. They share the relevant information as processed data.
Category	Safety.
Road Environment	Intersection, urban, rural, highway.
Short Description	Vehicles collect information on dynamic objects on the road and other traffic participants based on vehicle sensor data. They share the relevant information as processed data. The corresponding information will be collected together with the geographic location of the vehicle for the purpose of sharing with other vehicles, especially AVs and V2X AS (Application Server). The receiving vehicles analyse the objects received and classifies them and creates and overlay with its own sensor data (environmental perception). The receiving vehicle analyses the shared data and performs analysis and verdict generation in conjunctions with its own sensors.
Actors	Host vehicle, remote vehicle.
Vehicle roles	HV represents the vehicle that detects relevant information based on its own sensor data during the driving; the RV receives information collected by the HV.
Road/Roadside Infrastructure Roles	Optionally, a roadside infrastructure role can provide processed information derived from sensor data to RVs. Alternatively, roadside equipment may relay information from the HV to RVs.
Other Actors' Roles	Optionally, a V2X application server role may be involved in the use case for receiving information from HV and forwarding it to the RV.
Goal	Share dynamic objects and road-participant information detected by vehicles, so that the environmental perception of the other vehicles is extended.
Needs	To provide safe and optimal route selection for semi- and fully automated driving by exploiting the available data gathered from sensor information shared by other road users and road infrastructure. To enhance visibility of non-connected road users by incorporating them into V2X network of connected vehicles.
Constraints/ Presumptions	Assumptions will be required for the following information: • The HV is able to detect dynamic objects and road-participants based on its sensor data. • The HV is able to associate the detections with a certain confidence. • The HV is able to communicate the detected dynamic objects. Note: same applies if a RSU is detecting and sharing detected objects.

<table>
<tr><td>Geographic Scope</td><td>Global.</td></tr>
<tr><td>Illustrations</td><td>
Basic use case

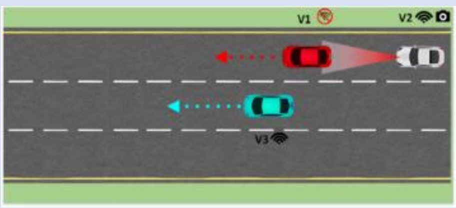


On-board vehicle sensors on Host Vehicle (V_2)such as camera, RADAR etc. infers information about surrounding vehicles (V_1).
On Board Unit (OBU) on HV transmits object data of the detected object (V_1).
All other V2X vehicles (V_3) understand information such as position, direction and speed of vehicle (V_1).

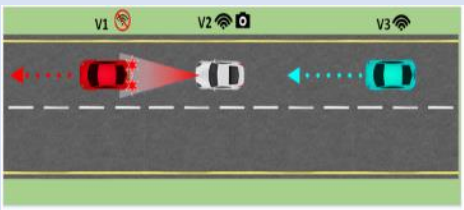
Examples of safety applications based on shared sensor data

1. Intersection Collision Warning (ICW)

2. Blind Spot Warning (BSW)

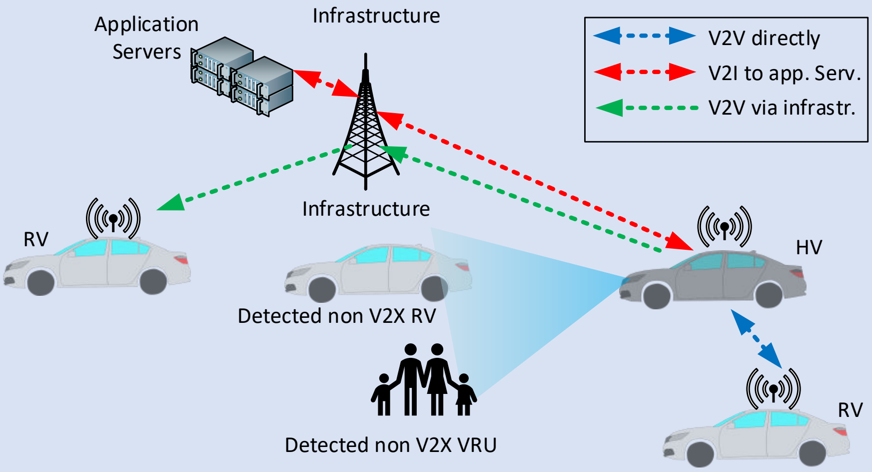


3. Electronic Emergency Brake Lights(EEBL)

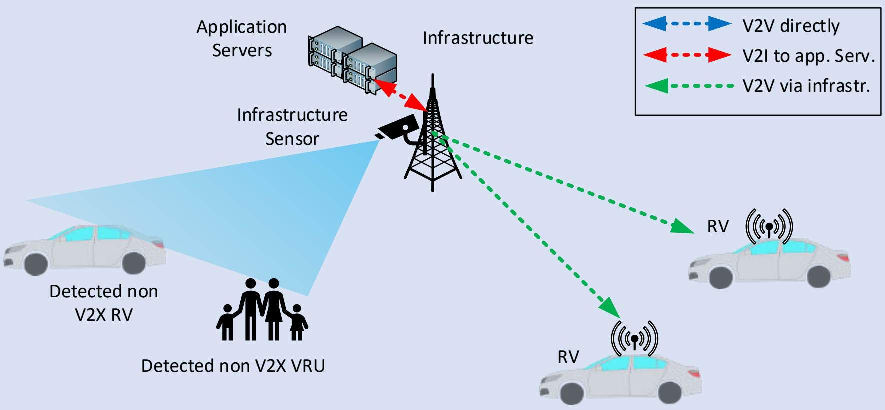


4. Left turn Assist (LTA)
</td></tr>
</table>

V2V vs V2I Vehicle sensor sharing



Infrastructure sensor sharing



Pre-Conditions	• The HVs/RSUs are equipped with sensors and they can share processed information. The vehicles e.g. AVs that receive the information can make optimal and safe driving decisions based on a real-time, and reliable representation of the environment.
Main Event Flow	• The HV/RSU detects a dynamic objects or road-participants. • The HV/RSU sends out processed information from its sensors. • The RV is approaching the scenario application zone and receives the information directly from the HV/RSU.
Alternate Event Flow	• The HV detects a dynamic objects or road-participants. • The HV sends out processed information from its sensors to the V2X application server. • The application server gathers and redistributes the object information to the concerned RVs.

	• The RV is approaching the scenario application zone and receives the information from the V2X application server.
Post-Conditions	Information on the detected dynamic objects and road-participants are available and considered by the RV for driving decisions.
Information Requirements	• HV's sensor data used for dynamic objects. • Road participants. • Car status (e.g. location, dynamics, etc.).

User Story #1			
Service Level Requirement	**SLR Unit**	**SLR Value**	**Explanations/Reasoning/Background**
Range	[m]	300 m	Minimum range assuming the maximum speed in a highway and 4 seconds response time for AVs.
Information Requested/Generated	Quality of information/ Information needs	300 - 1400 bytes/per message	The message sent from HVs to RVs or AS contains detected event types (barriers, road work, bad weather, etc.), location, priority, etc. And the message is sent by an event trigger. This size depends on the number of objects detected placed into the message by the sending vehicle
Service Level Latency	[ms]	100	Same latency as for similar awareness creating services such as BSMs or CAMs.
Service Level Reliability	%	99.9	High reliability is needed for AVs to take action based on the hazard and road event message for other vehicles.
Velocity	[m/s]	69.4	Maximum speed on highways is assumed to be 250 km/h. The maximum speed will match the traffic levels in different regions.
Vehicle Density	[vehicle/km^2]	12,000	The maximum assumed density in urban situations.
Positioning	[m]	1.5 (3σ)	AVs need pinpoint accuracy to estimate event locations and avoid collisions. Typical positioning accuracy is needed to confirm the traffic lane.
Interoperability/ Regulatory/ Standardisation Required	[yes/no]	Yes/Yes/Yes	Interoperability between different OEMs' vehicles is needed (Scenario 1), as well as between the HD map provider and different vehicles (Scenario 2). Standardisation is required in the sense that the format for sensor data exchange should be commonly understood by all involved vehicles.

5.4.2 Non-analyzed Sensor Signal Sharing

Use Case Name	Non-analyzed Sensor Signal Sharing (previously named Unclassified Sensor Data Sharing for AVs)
User Story	Non-analyzed sensor data perceived by other road users (e.g. other vehicles, VRU) in the road and/or infrastructure is provided/transmitted to HV. The relevant sensor data is

	shared as data stream that could be used for HVs sensor fusion. In general, non-analyzed sensor data provided by other road entities (that) contain not analysed dynamic and/or static objects on the road are used to increase the trust level of the car's own sensor observations and extends its viewing range. Note: Instead of pre-analysing the sensor data stream at the providing entity, resulting in shared dynamic and/or static objects on the road, the sensor data stream is used to increase the trust level by the HV sensor fusion.
Category	Autonomous driving.
Road Environment	Intersection, school zone, rural, highway.
Short Description	The host vehicle (HV) is provided/receives non-analyzed sensor data on request e.g. when faced with an obstructed view or when it enters a section of the road covered by sensors of other road users. HV will request also meta-data that qualify the specific sensor data shared (location of the camera, codec, …). An automated HV can subscribe to the non-analyzed sensor sharing service that provides specific sensor meta-data and an encoded data stream. The vehicle is then authenticated and enabled to receive authorised data from the remote road user and infrastructure. The authorised host vehicle receives the provided non-analyzed sensor data, analyses the data and makes a decision based on the outcome. This fulfils two purposes: 1) The trust level of the car's own sensor observations will be increased by adding an enhanced source. 2.) The car's view of the road is enhanced at the front and back, enabling a smoother and more far-sighted driving experience.
Actors	Host Vehicle (HV), Remote Vehicle (RV), roadside infrastructure.
Vehicle Roles	HV represents the vehicle consuming the non-analyzed sensor data when it is provided by other road users (RV, roadside infrastructure) to HV. Remote vehicles represent other neighbouring vehicles that are represented as mainly moving (or static) objects in the non-analyzed sensor data.
Road/Roadside Infrastructure Roles	(Optional) different types of sensors (RADAR, LIDAR, cameras) provide a complete picture of the dynamic and static road conditions
Other Actors' Roles	-
Goal	Increases trust in the HV's sensor perception data and enhances the viewing range which can be limited or obstructed by other vehicles, road bends or dips, intersections or limited sensor range.
Needs	To provide safety and optimal route selection for semi- and fully automated driving by exploiting the availability data provided from other road users (vehicles, infrastructure, and others). The HV can combine received perception data with its own sensor data to gain the trust and improve the reliability of the situation awareness.
Constraints/ Presumptions	• The vehicles and road infrastructure provide the sensor data stream. The receiving vehicle has processing capabilities to manage unclassified sensor data. • The HV can subscribe to the non-analyzed sensor data sharing service. • HV has implemented an automated driving SW stack enabling the sensor data fusion on perceived data from external sources.
Geographic Scope	Global.
Illustrations	N/A.
Pre-Conditions	• The vehicle, road infrastructure can provide non-analyzed sensor data and announce this as a service. • The HV is equipped with devices receive and process non-analyzed sensor data streams from other vehicles, road infrastructure.
Main Event Flow	• Entering the area covered by sensors incl. non-analyzed sensor sharing service provided by other road users (e.g. other vehicles, VRU) on the road and/or infrastructure (e.g. RSU), the HV and the former mentioned road users or road

	infrastructure perform an initial handshake to establish an non-analyzed sensor sharing service communication link. • During the service establishment the basic specific meta-data (e.g. technical capabilities: location of the camera, codec, …) that are provided are exchanged and agreed on. • In case of infrastructure involvement: As basic functionality, the infrastructure's sensors track all moving vehicles including the HV so its location is known. • Optionally: infrastructure or other road user and the HV agree on an ID for the HV that will be used as identification inside the uni-casted environment data. • The HV is authenticated and enabled to receive authorised data from the remote road user or infrastructure. • The authorised HV receives the provided non-analyzed sensor data stream, analyses the data and makes decisions for the dynamic driving task based on the outcome.
Alternate Event Flow	Not applicable.
Post-Conditions	• The HV has left the area covered by sensors incl. non-analyzed sensor sharing service provided by other road users and road infrastructure. • The HV finished the manoeuver it had requested for the non-analyzed sensor data stream. • After sign-off is performed the HV continues using its own sensors only.
Information Requirements	• Road user sensor data (RADAR, LIDAR, camera, etc,.) including video streams, meta-data describing the technical capabilities, service announce information, and information ensuring the trustworthiness of sensor data (if possible). • HV's status (e.g. precise geo location, dynamics, etc.). • RV's status (e.g. precise geo location, dynamics, etc.). • Road infrastructure precise and exact geo location.

User Story #1			
Service Level Requirement	**SLR Unit**	**SLR Value**	**Explanations/Reasoning/Background**
Range	[m]	300 m	Minimum range assuming the maximum speed in a highway and 4 seconds response time for AVs.
Information Requested/Generated	Quality of information/ Information needs	Video streaming: 8 Mbps LIDAR streaming: 35 Mbps	Video Streaming.: 8 Mbps are needed to transmit a progressive high- definition video signal with resolution 1280x720, frame rate 30 Hz, colour depth 8 bit, 24 bit resolution (e.g. with H.264). LIDAR Streaming: assumes 35 Mbps.
Service Level Latency	[ms]	50	The latency requirement for a video frame depends on the vehicle speed and heading as well as pitch angle changes. Latency of 50 ms should be kept, lower values would increase the experience of this function. Additional delays would lead to additional buffering in the rear vehicle. 50 ms is the considered e2e communication layer latency, without including application layer processing times e.g. coding, de-coding. Additional latency requirements: • The duration of service discovery phase should be in maximum 500 ms (i.e. time duration for HV to identify if RV supports the see-through service). Service discovery includes the communication

			establishment phase (i.e. receive resources) as well as the discovery request and discovery response messages that HV and RV send, respectively. • The HD sensor sharing establishment phase (i.e. a) HV asks for sensor sharing and b) RV provides the first video frame) should complete within maximum within 500 ms. • Service discovery and see-through establishment within 1000 ms will help the driver of the HV to activate the requested HD sensor sharing service quickly and take a fast decision whether to proceed within the overtake action. This also affects the engagement of the driver with the see-through application. • The sensor sharing release phase should be complete within maximum 500 ms
Service Level Reliability	%	99	Reliability of 99 % at the communication layer for video frames is needed to avoid massive artefacts that may lead to degradation of video quality for assisted driving.
Velocity	[m/s]	69.4	Maximum speed on highways is assumed to be 250 km/h. The maximum speed will match the traffic levels in different regions.
Vehicle Density	[vehicle/km ^2]	1,500	This type of service is most likely to be used in rural road environments. Two vehicles are involved in this Use Case.
Positioning	[m]	1.5 (3σ)	AVs need pinpoint accuracy to estimate event locations and avoid collisions. Typical positioning accuracy is needed to confirm the traffic lane.
Interoperability/ Regulatory/ Standardisation Required	[yes/no]	Yes/Yes/Yes	Interoperability between different OEMs' vehicles is needed. Standardisation is required in the sense that the format for sensor data exchange should be commonly understood by all involved vehicles.

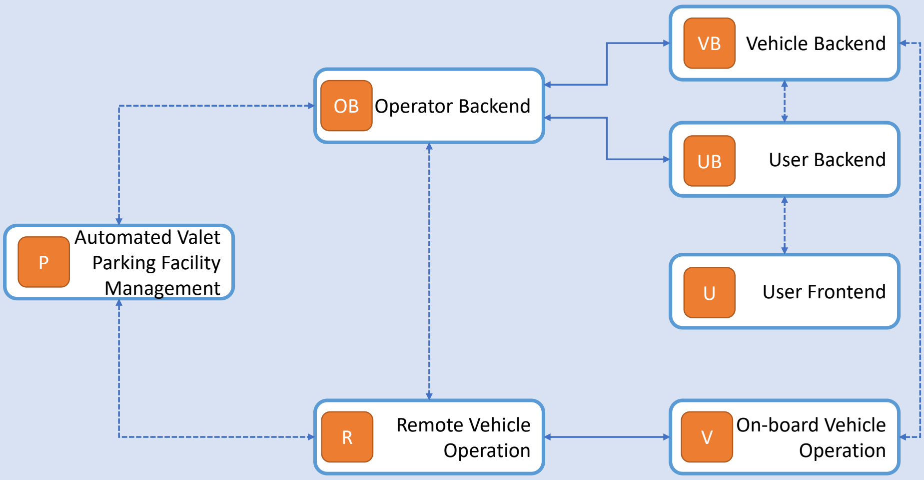
5.4.3 Automated Valet Parking (AVP)

Use Case Scenario	Automated Valet Parking
User story	When a vehicle arrives at the designated hand-over zone [4], the driver leaves the vehicle, and the vehicle is parked being operated by an Automated Valet Parking System (AVPS) after being authorized by the driver.
Category	Vehicle Operations Management, Convenience, Autonomous Driving, Traffic Efficiency and Environmental friendliness
Road Environment	Urban | Rural | Parking area (indoor or outdoor)

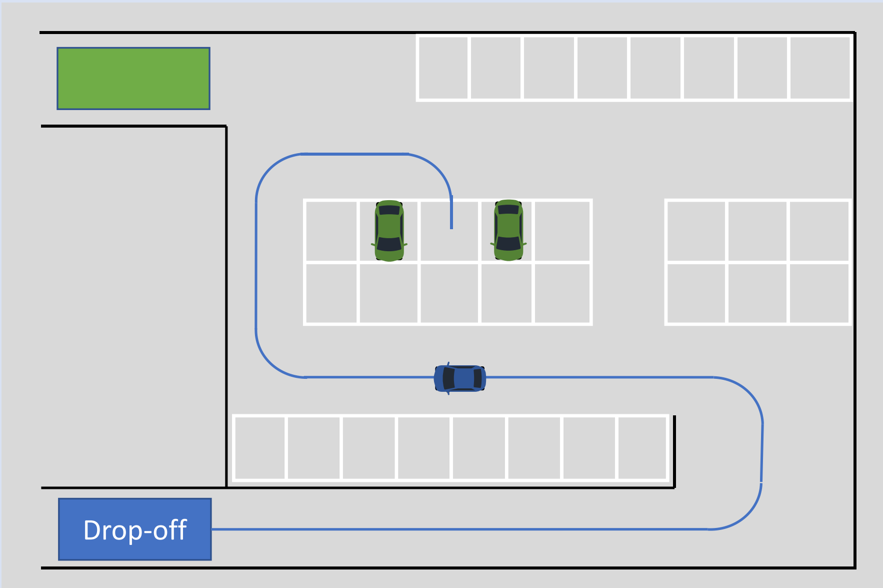
Short Description	• A vehicle arrives at the hand-over zone. • The driver hands the vehicle over to the AVPS. • The vehicle is parked in an automated manner into the destination parking spot operated by the AVPS. • The user may request a Pick-Up request to receive its vehicle in the same manner manged by the AVPS back.
Actors	Vehicle, Driver (User), AVPS (of Type 1, 2 or 3).
Vehicle Roles	Host Vehicle (HV) represents the parking vehicle.
Road & Roadside Infrastructure Roles	Connectivity to HV is provided via wireless communication enabling the Use Case Preparation (Wake-up) and Valet Parking operation. Depending on the AVP type, see below, infrastructure object sensing and computing capabilities are provided.

Other Actors' Roles	• AVPS of either
	  ○ Type 1 - Remote destination assignment: AVPS provides MAP and destination to the vehicle in order to drive in an autonomous manner (L4) to the available/reserved parking spot.
	  ○ Type 2 - Remote motion guidance: AVPS provides Safe Time sync and motion guidance to the vehicle in order to steer the automated vehicle remotely to the designated parking spot.
	  ○ Type 3 - Remote route guidance: AVPS provides the route/proposed path and destination to the vehicle in order to drive in an autonomous manner (L4) to the available/reserved parking spot.
	• Remote vehicle operation sub-system constructs an accurate surroundings environment model (of the HV) through the information received from sensors, control units and communication units, and provide the driving paths and/or manoeuvre instructions for the HV.
	• The AVP Management Sub-System provides e.g. high definition map inside the parking area, and sensor information inside the parking area. It is connected to the Parking Facility Management System.
	• The OEM backend system is connected to the HV and validates AVP requests and collects driving data directly from the vehicle. The OEM Backend is connected to the Automated Valet Parking Management System to authorize all actions that take over vehicle control (Handover, Motor start, etc.).
	• The AVP Management System is connected to the Valet parking Sub-Systems to monitor them. The Parking Facility Management System manages access to the parking garage and manages parking slot reservations and assignments. It incorporates also information from the AVPS Sub-System for parking spot availability for AVP.

Goal	Enable the parking of the HV through AVP without presence of driver and passengers.
Needs	The HV shall enable automated valet parking driving functionality and communication with Automated Valet Parking Management Sub-Systems. The parking area shall provide accurate and timely surrounding environment information inside the parking area by inside equipment, e.g. high resolution camera, LIDAR etc. to operate and supervise the AVP mission.
Constraints / Presumptions	The HV provides the capability (either Type 1 or 2 or 3) to enable AVP driving functionality. The Parking Facility Management System provides the data to identify free parking spots and their location. It is connected to AVP Sub-System to coordinate parking reservations and AVP parking reservations, as well as ad-hoc parking of AVP.
Geographic Scope	Anywhere.

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


Logical AVP System Architecture (according [4]); Key 1 Operator Interface, key 2 Management interfaces



AVPS Operation
</td></tr>
<tr><td>Pre-Conditions</td><td>
AVP Type 1&3 only:

- HV enables high accuracy positioning.
- HV vehicle must be able to autonomously drive based on the provided path.
</td></tr>
<tr><td>Main Event Flow</td><td>

- The HV arrives in the “Pick-up/Drop-off” area. The user requests to handover the driving authority to the AVP System.

AVP Type 2:

- Destination assignment, route planning, object and event detection, pose estimation, trajectory calculation is done by the AVPS’s Remote Vehicle Operation Sub-System.
- Path or trajectory information, i.e. motion guidance (like “forward 10m”), as well as pose estimation are transferred to the HV. In case of path “command mode”, the path can also be sent for the whole parking manoeuver and just the velocity is adapted continuously trough cyclic commands. Steering is done in the vehicle based on the location sensed by the infrastructure and the target path.
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	• Vehicle motion control according the motion guidance received is performed by the HV's Onboard Vehicle Operation Sub-System. All AVP types: • The AVP System provides the current state and position to the user. • The owner/user may request a Pick-Up request.
Alternative Event Flow	• The HV arrives in the "Pick up/Drop off" area. The user requests to handover the driving authority to the AVP System. AVP Type 1: • A high definition map of the AVP parking facility is provided to the HV's Onboard vehicle operation subsystem, as well as the driving destination (parking spot). • Route planning, object and event detection, localization, trajectory calculation as well as vehicle motion control is performed by the HV's Onboard Vehicle Operation Sub-System. • The AVP System provides the current state and position to the user. • The owner/user may request a Pick-Up request.
Alternative Event Flow	• The HV arrives in the "Pick up/Drop off" area. The user requests to handover the driving authority to the AVP System. AVP Type 3: • Destination assignment and route planning is done by the AVPS' Remote Vehicle Operation Sub-System. • Object and event detection is a shared task between HV's Onboard and AVPS' Remote Vehicle Operation Sub-System. • Localization, trajectory calculation and vehicle motion control is performed by the HV's Onboard Vehicle Operation Sub-System. • The AVP System provides the current state and position to the user. • The owner/user may request a Pick-Up request.
Post-Conditions	The HV has reached its destination and it is successfully parked at the destination parking place or has returned to the hand-over zone.
Service Level Requirements	• Service Level Latency • Service Level Reliability • Information requested/ generated • Vehicle Velocity • Vehicle Density • Positioning Accuracy
Information Requirements	• Type 1 only: High definition map inside the parking area. • Estimation of position. • Time Synchronization, Heartbeat • HV information (e.g., type, size, height, turn radius?). • HV's state information

User Story #1	Automated Valet Parking Type 2: Remote motion guidance
User Story	In this user story the AVP Remote Vehicle Operation Sub-System assumes full control of the HV's movement. Based, on the sensor information (e.g., cameras, LIDAR, RADARs) installed and operated by the AVPS service provider, as well as cyclic status delivery by the HV, the AVP Remote Operation Sub-System builds the environmental model and provides manoeuvre instructions (e.g., driving direction, speed, acceleration, distance, driving direction). This information is sent to the HV to steer it along the (by Remote Vehicle Operation) calculated path to the destination parking position.
Main Event Flow	• The HV arrives in the "Pick up/Drop off/Hand-over zone" area. The user requests to handover the driving authority to the AVP System. • The driver leaves the HV and handovers authority to the AVP system. • Destination assignment, route planning, object and event detection, pose estimation, trajectory calculation is done by the AVPS sub-system Remote vehicle operation. • Motion guidance commands (e.g., driving direction, speed, acceleration, distance…), as well as pose estimation are transferred to the HV. • The HV executes manoeuvers based on the commands received via its motion control. • Regular feedback is sent from the HV to the AVP Remote Vehicle Operation Sub-system by the execution of the manoeuvers. • The AVP System provides the current state and position to the user. • HV, operated by the AVP's Remote Vehicle Operation Sub-system, is parked at the destination parking spot. • The owner/user may request a Pick-Up request.

User Story #1: Automated Valet Parking Type 2: Remote motion guidance			
SLR Title	**SLR Unit**	**SLR Value**	**Explanations/Reasoning/Background**
Range	**[m]**	N/A	Range depends on the location and environment. Coverage is needed to allow operation in the confined area of the parking facility the motion control via AVPS.
Information requested/ generated	**Quality of information / Information needs**	From HV to AVPS: 0.2 Mbps (Cyclic status message from HV to AVPS) From AVPS to HV: Up to 0.2 Mbit/s (Cyclic status message from AVPS to HV), Up to 2 Mbit/s (Non cyclic messages, Manoeuver instructions sent from AVPS)	From HV to AVPS*:* Cyclic message regarding the motion control *(*incl. curvature, velocity, yaw rate, driving direction, shift position*)* of the HV to the Remote Vehicle Operation Sub-system. Repetition rate assumed to be 10Hz. From the experience of trials the data rate of 0.2 Mbps can be derived. From AVPS to HV: Small size cyclic status message (10Hz) to confirm availability of the AVPS/communication. Either separate or combined with information on driving motion instructions towards the available parking spot sent from Remote Vehicle Operation Sub-system. The data are several kBytes. Rate depends on path or trajectory related data elements are transmitted. Current data rates are based on existing trials, further details will evolve from current standardization activities.

Service Level Latency	**[ms]**	From HV to AVPS and from AVPS to HV: 40 (Driving Permission)	From AVPS to HV: Latency for emergency stop i.e. driving permission lost, obstacle discovered by AVPS via sensors. System round trip latency 80ms. Current latencies are based on existing trials, further details will evolve from current standardization activities.
Service Level Reliability		99.9%	Communication reliability only affects availability of the AVPS and not safety. The system is designed in a way that any disruption to the communication results in safe behaviour.
Velocity	**[m/s]**	8.3	<30 km/h is the maximum considered speed inside the parking area (according [4]).
Vehicle Density	**[vehicle/km^2]**	1 (Storage level) *100 (Driving vehicles per floor) =100	The number of vehicles that need to be parked in the same area. If we would assume a number of 5% - 10% of the parking spaces for the number of remote driving vehicles we would end up for a big parking area (1000 vehicles) with about 50 – 100.
Positioning Accuracy	**[m]**	N/A	Positioning accuracy is controlled by AVPS and depends on the targeted performance of the AVPS (e.g. how close to park vehicles to each other, or constraint paths of the parking structure)
Interoperability / Regulatory / Standardization Required	**[yes/no]**	Yes/Yes/Yes	Regulation is needed, since authorities may need to specify e.g., maximum speed etc. Inter-operability and Standardization is also needed since vehicles from different OEMs will be supported by the AVPS. Regional Regulation: If applicable to AVP Type 2 a black box link of the AVPS to regulatory bodies might be considered. AVPS shall record and store the following data at a minimum: - Video image of the surroundings of the SV while automated vehicle operation is being performed. (Note that this may be done by a vehicle on-board camera or camera installed in the facility, and these cameras may also serve different purposes.) Upload is expected in an asynchronous manner, i.e. not during parking operation. - Data log of the following events - Change in system states

			- Communication within the system - Suspend condition codes

5.5 Platooning

No new use cases were added in this category in the current version of this document.

5.6 Traffic Efficiency and Environmental friendliness

No new use cases were added in this category in the current version of this document.

5.7 Society and Community

No new use cases were added in this category in the current version of this document.

6 Conclusions & Next Steps

The present document contains the third set of use case descriptions developed in 5GAA and consolidated by 5GAA WG1. One of the goals of these UC descriptions is to provide the possibility to derive requirements for 5G networks.

The results of this report, and of the future use case descriptions and related communication requirements, are intended to serve as input for the work of other WGs in 5GAA, as well as sources for input and feedback to standardization activities, e.g. in 3GPP.