C-V2X Use Cases and Service Level Requirements Volume III

5GAA Automotive Association
Technical Report

CONTACT INFORMATION:
Executive Manager – Thomas Linget
Email: liaison@5gaa.org

MAILING ADDRESS:
5GAA c/o MCI Munich
Neumarkter Str. 21
81673 München, Germany
www.5gaa.org

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Contents

1 Scope

The present report contains the third volume (Volume III) of 5GAA Work Group 1 (WG1) agreed Use Case (UC) descriptions for Use Cases developed and consolidated within by 5GAA.

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 standardisation activities, e.g. in 3GPP. These Use Case descriptions are maintained and updated based on input from the different work activities.

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 nonspecific.
- 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-200XXX, 'TR C-V2X Use Cases and Service Level Requirements Vol I V3.0', 2025
[3]	5GAA T-200XXX, 'TR C-V2X Use Cases and Service Level Requirements Vol II V3.0', 2025
[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 Abbreviations and Definitions

3.1 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
OB:	Operator Backend (manages the system participants)
SLR:	Service Level Requirement (solution-agnostic requirements of a Use Case)
UC:	Use Case (high-level execution of an application in a particular situation with a specific purpose)
UB:	User Backend (user request processing – mainly linked to or part of VB)
V2X:	Vehicle-to-Everything
VB:	Vehicle Backend (e.g. OEM remote engagement/disengagement, authorisation of handover, engine start etc.)

3.2 Definitions

Furthermore, for the purposes of the present document the following definitions/ explanations apply:

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

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.

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

User stories: User stories are specific variations of one Use Case.

V: On-board vehicle operation sub-system

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 realisation of Use Cases does partially preclude applications performing various tasks supporting the Use Cases, such as collecting information, analysing, etc. which will depend on the individual Use Case. However, these preconditions are not part of the Use Cases themselves, and are therefore not considered in detailed descriptions. Furthermore, radio symbols in figures indicate a connected vehicle. The templates for Use Case descriptions, the classification scheme and the general methodology that WG1 has developed for the description of the Use Cases as well as 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 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 reactions to currently not detectable behaviours such as acceleration and braking from vehicles in the lane ahead.
Category	Convenience, safety.
Road Environment	Urban, rural, highway.
Short Description	HV tries to adjust its speed efficiently to better react to the leading vehicle (RV) and 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 adapts its velocity while keeping a certain distance. Remote Vehicle (RV): the vehicle that is driving in front of HV.
Vehicle Roles	HV: follows RV while adapting speed and keeping a certain distance. RV: drives 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	HV needs to call off the Use Case once the safety of either HV or RV is in danger. This can be done using other data than kinematics or position information, such as emergency messages or sensory detection. As HV adapts its behaviour to 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(s). This does not impact the Use Case running in other vehicles.
Geographic Scope	Global.
Illustrations	N/A
Pre-Conditions HV	▸ 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 uses this information and can identify that it belongs 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	N/A
Post-Conditions	N/A
Information Requirements	Basic vehicle status data.

User Story	Description
User Story #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.
User Story #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 higher inter-vehicle distance.
Service Level Reliability	**%**	99.9	Rationale for the SLR is the high importance of availability in this function. Safety is typically assured by monitoring and, if outages are detected, reverting to a 'safe state' or 'function degrade'. This, however, should be avoided where possible for the sake of the perceived quality by the users.
Velocity	**[m/s]**	60	Support up to approx. 210 km/h, similar to current ACCs .

Vehicle Density	**[vehicle/km^2]**	12,000	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 (2σ)	As the function will also rely on vehicle sensors, the longitudinal position accuracy is much more relevant than the lateral position accuracy, which 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 and 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 and 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 higher inter-vehicle distance. Acceleration and deceleration are tightly integrated with HV control and thus need low latency.

Service Level Reliability	**%**	99.9	Rationale for the SLR is the high importance of availability in this function. Safety is typically assured by monitoring and, if outages are detected, reverting to a 'safe state' or 'function degrade'. This, however, should be avoided where possible for the sake of the perceived quality by the users.
Velocity	**[m/s]**	60	Support up to approx. 210 km/h, similar to current ACCs .
Vehicle Density	**[vehicle/km^2]**	12 ,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 (2σ)	As the function will also rely on vehicle sensors, the longitudinal position accuracy is much more relevant than the lateral position accuracy, which 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

5.1.2 School Bus Warning

Use Case Name	School Bus Warning
User Story	A vehicle is approaching a location where a school bus is currently halted to load/unload passengers and the two vehicles receive a warning when the driver does not follow the traffic rules applying to this situation.
Category	Safety.
Road Environment	Intersection, urban, rural.
Short Description	HV approaches a stopped school bus clearly indicating that passengers are nearby. If the driver is not following the traffic rules applying, such as stopping until the bus is moving again, a warning is given.
Actors	Vehicles (HV), school bus (RV)
Vehicle Roles	Host Vehicle, Remote Vehicle.
Roadside Infrastructure Roles	Temporary stop sign by school bus.
Other Actors' Roles	N/A

Goal	Avoid dangerous situations for drivers and pedestrians at school bus stops.
Needs	Equipped with V2X radio.
Constraints/ Presumptions	HV and RV can send the right information – equipped with the right technology and messages.
Geographic Scope	Global, United States.
Illustrations	
Pre-Conditions	See constraints.
Main Event Flow	▸ A school bus is stopped and sends this information out. ▸ Vehicles approaching the stopped school bus receive the information, and themselves send out information about their driving status. ▸ The school bus receives the information of the vehicle approaching it.
Alternative Event Flow[1]	▸ A school bus is stopped and sends this information to a V2X application server. ▸ The application server gathers the information and forwards it to vehicles approaching the area.
Post-Conditions	▸ The information of the vehicle is available to the bus. ▸ The information of the bus is available to the vehicle.
Information Requirements	Car status (vehicle speed, acceleration/deceleration, location, trajectory, etc.); bus status (stop status and other vehicle status information).

User Story	Detailed description and specifics
User Story #1	School Bus Warning where a driver is warned of a stationary school bus.
User Story #2	School Bus Information where a driver is informed of a stationary school bus.
User Story #3	School Bus Driver Warning where the school bus driver is warned of an approaching vehicle.

User Story #1 School Bus Warning			
SLR Title	**SLR Unit**	**SLR Value**	**Explanations/Reasoning/Background**
Range	**[m]**	200	Distances expected in urban areas to adapt the speed.
Information Requested/ Generated	**Quality of information/ Information needs**	300 bytes	N/A
Service Level Latency	**[ms]**	100	Time range for urgent warning.

[1] Alternative event flows in this document are not intended as replacements for the main event flow; they are intended to represent different possible flows.

Service Level Reliability	**%**	99.9	Requires high-level reliability.
Velocity	**[m/s]**	19.4	Expected maximum speed allowed in areas with bus stops.
Vehicle Density	**[vehicle/km^2]**	12,000	Maximum densities in urban areas.
Positioning Accuracy	**[m]**	1 (1 σ)	Position needs to be reliable enough to reach lane-level accuracy.
Interoperability/ Regulatory/ Standardisation Required	**[yes/no]**	Yes/Yes/Yes	Required to reach interoperability.
User Story #2 School Bus Information			
SLR Title	**SLR Unit**	**SLR Value**	**Explanations/Reasoning/Background**
Range	**[m]**	500	Distance to allow for preparation of the driver.
Information requested/ generated	**Quality of information/ Information needs**	300 bytes	N/A
Service Level Latency	**[ms]**	2000	Allows enough time to prepare for the situation.
Service Level Reliability	**%**	99	N/A
Velocity	**[m/s]**	19.4	Expected maximum speed allowed in areas with bus stops.
Vehicle Density	**[vehicle/km^2]**	12,000	Maximum densities in urban areas.
Positioning Accuracy	**[m]**	1 (1σ)	Position needs to be reliable enough to reach lane-level accuracy.
Interoperability / Regulatory / Standardisation Required	**[yes/no]**	Yes	Required to reach interoperability.
User Story #3 School Bus Driver Warning			
SLR Value	**Explanations/ Reasoning/ Background**	**SLR Value**	**Explanations/Reasoning/Background**
Range	**[m]**	200	Distances expected in urban areas to adapt the speed.
Information requested/ generated	**Quality of information/ Information needs**	300 bytes	N/A
Service Level Latency	**[ms]**	100	Time range for urgent warning.
Service Level Reliability	**%**	99.9	Requires high-level reliability.
Velocity	**[m/s]**	19.4	Expected maximum speed allowed in areas with bus stops.

Vehicle Density	**[vehicle/km^2]**	12,000	Maximum densities in urban areas.
Positioning Accuracy	**[m]**	1 (1 σ)	Position needs to be reliable enough to reach lane-level accuracy.
Interoperability / Regulatory / Standardisation Required	**[yes/no]**	Yes	Required to reach interoperability.

5.1.3 Traffic Light Pre-emption

Use Case Name	Traffic Light Prioritisation
User Story	A Host Vehicle requests traffic lights to be switched to their benefit to permit faster navigation through intersections. This switching can be pre-emptive or (potentially) prioritised.
Category	Safety, traffic efficiency and environmental friendliness, society and community.
Road Environment	Intersection, urban.
Short Description	In certain traffic instances it is important for some road users to have priority at intersections regulated by traffic lights. To permit vehicles with higher traffic priority to pass through faster, this Use Case permits those road users to be prioritised.
Actors	Vehicles, traffic lights, remote operators, application servers.
Vehicle Roles	Host Vehicle.
Roadside Infrastructure Roles	Role of the road and traffic infrastructure (e.g. traffic signs, lights, ramps, etc.)l does not refer to the network infrastructure.
Other Actors' Roles	N/A
Goal	Road users with priority classes have access to green lights faster than vehicles with lesser/ lower priority.
Needs	RSU or vRSU with traffic light information available.
Constraints/ Presumptions	Basic requirements that all actors need to adhere to.
Geographic Scope	Intersections regulated by traffic lights.
Illustrations	Pictorial information exemplifying the Use Case and showing the role of the different actors. 
Pre-Conditions	Signals and traffic control station must be able to handle external actors capable of changing their phase programming.

Main Event Flow	A vehicle with higher priority approaches an intersection The vehicle requests direct access to the traffic light priority according to its class The traffic light logic then grants or adapts its light phases to suit the requirements of the traffic class.
Alternative Event Flow [2]	Request rejected by RSU due to some situation within the intersection
Post-Conditions	The traffic light phases are adapted: ▸ For pre-emption, the light is set to give the vehicle green light immediately. ▸ For prioritisation the vehicle gets shorter red light phases whenever it approaches the traffic light.
Service Level Requirements	See table below.
Information Requirements	SPAT data, priority class data, time of day priority rights.

User Story	Detailed description and specifics
User Story #1 Traffic Light Prioritisation	In this user story, a vehicle without special emergency rights requests priority access to green phases of intersections.
User Story #2 Traffic Light Pre-emption	In this user story an emergency vehicle request the pre-emption of traffic lights for immediate access.

User Story #1/#2			
SLR Title	**SLR Unit**	**SLR Value**	**Explanations/Reasoning/Background**
Range	**[m]**	1000	Expected distance from HV to the concerned intersection, leaving enough time and distance for the intersection phases to be switched and the intersection to be cleared of remaining traffic.
Information Requested/ Generated	**Quality of information/ Information needs**	200	The value should correspond to the data necessary to convey the need for receiving a priority traffic light.
Service Level Latency	**[ms]**	1000	Same as the distance, the latency needs to cover enough time for the adjustments at the traffic light to be made. Even though the priority is beneficial to the vehicle, it leaves enough time for the vehicle to also adjust to the traffic light phase, if the pre-emption and adaptation is not granted.
Service Level Reliability	**%**	99.9	As the request can be resent multiple times, the reliability does not need to be very high.

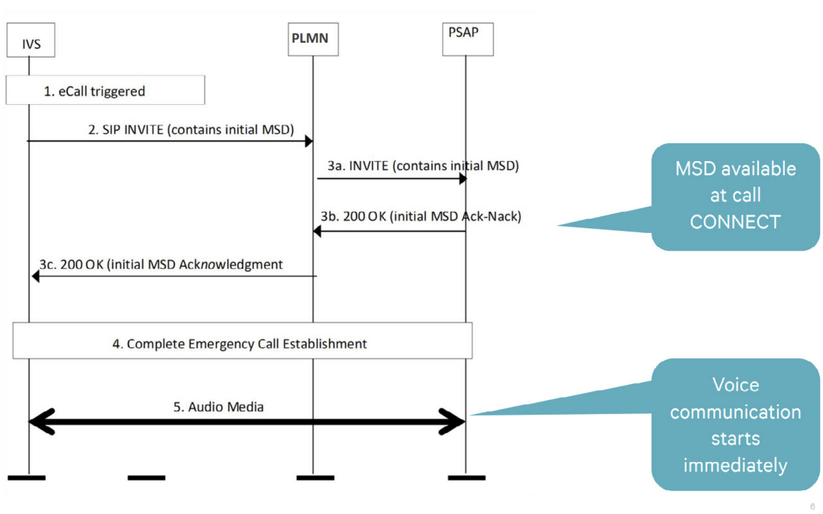
[2] Alternative event flows in this document are not intended as replacements for the main event flow; they are intended to represent different possible flows.

Velocity	**[m/s]**	22.22	The velocity should cover any larger intersection in urban scenarios, hence the somewhat higher speed than would occur in more urban intersections/settings.
Vehicle Density	**[vehicle/km^2]**	12,000	The Use Case needs to function in dense urban areas, where traffic light prioritisation would have a strong impact.
Positioning Accuracy	**[m]**	3 m (3 σ)	As the lane-level location of the vehicle is less important than the communicated trajectory through the intersection, approximate lane-level accuracy is enough.
Interoperability /Regulatory/ Standardisation Required	**[yes/no]**	Yes/Yes/Yes	The system needs to work across multiple infrastructure providers and vehicle manufacturers.

Placeholder Stationary Emergency vehicle Warning

5.1.4 xCall

Use Case Name	eCall
User Story	An xCall is triggered by a vehicle or a passenger in that HV via the IVS in the HV.
Category	Safety.
Road Environment	Intersection, urban, rural, highway (i.e. all environments).
Short Description	An xCall (more commonly known as eCall in Europe) is an emergency voice call, initiated manually or automatically from a vehicle to a public safety answering point (PSAP), supplemented by up to 140 bytes of incident-related data. The minimum set of data (MSD) has been defined by CEN Technical Committee 278 and includes the GNSS-derived location and direction of travel of the vehicle, the vehicle identification number (VIN), and other information to enable the emergency response teams to quickly locate and provide medical and other lifesaving assistance to the accident victims. This MSD is commonly transmitted by eCall. Similarly, systems such as ERA/GlONAS also fall under the term xCall. The HV can establish a communication session via terrestrial networks (TN), non-terrestrial networks (NTN) and/or forward the MSD.
Actors	Host Vehicle, PSAP.
Vehicle Roles	HV initiates the xCall itself.
Road and Roadside Infrastructure Roles	Roadside unit (RSU) serves as data endpoint.
Other Actors' Roles	Vehicle occupants: an xCall can be initiated manually by the vehicle occupants; PSAPs, call centre endpoints.
Goal	By enabling qualified and equipped paramedics to get to the scene within the crucial first hour of the incident, the eCall/xCall system has the potential to: ▸ Save about 2500 lives in the EU each year. ▸ Reduce the severity of injuries by 10% to 15%. ▸ Save EUR 26 billion a year.
Needs	An xCall Infrastructure needs to be available in the region where the call is initiated

Constraints/ Presumptions	The network needs to be stable enough to keep the communication ongoing until first responders arrive at the scene.
Geographic Scope	Global.
Illustrations	To come.
Pre-Conditions	HV is orientated such that TN and/or NTN coverage is possible, i.e. HV shall not be positioned upside down. **Post-crash performance of IVS**: The in-vehicle xCall/eCall system shall transmit the MSD message – providing there is an ETSI prime medium wireless network available to receive the signal – in all crash tests required by regulation for European approval (RD[1] Intelligent transport systems – ESafety – pan-European).
Main Event Flow	HV initiates the eCall/xCall automatically based on crash conditions, or the occupant initiates the call.  Source: https://docbox.etsi.org/Workshop/2021/202103NGeCall_webinar/Ralf_Weber_Next_Generation_eCall_vs_Legacy_eCall.pdf
Alternate Event Flow	N/A
Post-Conditions	N/A
Service-Level Key Performance Indicators	▸ Range. ▸ Information requested/generated. ▸ Service level latency. ▸ Service level reliability. ▸ Velocity. ▸ Vehicle density. ▸ Interoperability/regulatory/standardisation required.
Information Requirements	All data required for the MSD.

User Story #1 Title of User Story			
SLR Title	**SLR Unit**	**SLR Value**	**Explanations/Reasoning/Background**
Range	**[m]**	Global	eCall/xCall shall be available globally

Information Requested/ Generated	**Quality of information/ Information Needs**	UL: 10-20 kbps DL: 10-20 kbps	Values to be verified.
Service Level Latency	**[ms]**	1000 4000 100	Call establishment shall start after 1 second RD[1]. Transmission of MSD within 4 seconds RD[1]. Voice quality in line with 'mobile telephony service' RD[1].
Service Level Reliability	**%**	99.x	Might need three different values for calling, MSD transmission, voice latency.
Velocity	**[m/s]**	Stationary City : 22.2m/s Highway: 70m/s	Also available if vehicle is non-stationary (threats, etc.).
Vehicle Density	**[vehicle/km^2]**	12,000	References to **simultaneous** eCall/xCall activations are: ▸ 40,000 activations per month in UK (extrapolated from actual data indicating 10,000 activations/ month and 1 automated activation per hour). This is independent of whether there is terrestrial coverage or not. ▸ French study suggesting that seven activations can be expected in the EU (**outside** terrestrial coverage).
Positioning Accuracy	**[m]**	0.1m~0.5m (2 σ)	Position must be accurate enough to determine the correct vehicle in multi-vehicle accidents
Interoperability / Regulatory / Standardisation Required	**[yes/no]**	Yes/Yes/Yes	All is necessary as interoperability across different systems is necessary.

5.1.6 Interactive UGR Crossing

Use Case Name	Interactive UGR Crossing
User Story #1	**Interactive UGR Crossing without traffic light** A UGR expresses intent to cross a crosswalk without traffic lights. Vehicles approaching the area in which the UGR intends to cross receive the message and send an acknowledgment and acceptance/refusal message. If the vehicles accept, they subsequently adapt their behaviour to allow the UGR to cross safely. Upon receiving these positive acknowledgments from the vehicles, the UGR may cross the street. Upon reaching the other side of the street, the UGR may send another message to the vehicles confirming that they have finished crossing.
Category	Traffic efficiency.
Road Environment	Urban, marked crosswalk without traffic light.

Short Description	▸ A UGR is preparing to cross the crosswalk. ▸ After signalling this intent, nearby vehicles acknowledge and reassure the UGR that the request is accepted. ▸ If accepted, the UGR starts crossing. ▸ As the UGR is crossing, vehicles are informed when the zone in front of them is cleared so they may continue driving. The UGR double checks with vehicles just before moving in front of them that they are clear to move forward.
Actors	Vehicle(s), UGR(s).
Vehicle Roles	Remote Vehicle.
Road/Roadside Infrastructure Roles	N/A
Other Actors' Roles	N/A
Goal	Improved traffic safety and efficiency at crosswalks and awareness for vehicles.
Needs	N/A
Constraints/ Presumptions	A UGR is preparing to cross the crosswalk, but there are no traffic lights.
Geographic Scope	Crosswalk without traffic lights.
Illustrations	N/A
Pre-Conditions HV	▸ UGR in pedestrian areas should be allowed by regulation. ▸ Velocity of UGRs in pedestrian areas should be regulated (e.g. 20 km/h = 5.6 m/s).
Pre-Conditions RVs	N/A
Main Event Flow	▸ UGR approaches marked crosswalk without traffic lights. ▸ UGR expresses intent to cross. ▸ Approaching vehicles receive the message and perform target classification. ▸ If a vehicle determines that it can accommodate the request, it acknowledges UGR and notifies nearby vehicles that it is participating in the request. ▸ When UGR receives sufficient evidence that it is safe to cross (may vary with number of lanes and vehicles present), crossing is initiated. ▸ While the UGR is crossing, it may send information (e.g. PSMs, VAMs, BSMs, CAMs) notifying stopped vehicles of its progress. ▸ Upon reaching the other side of the crosswalk, UGR may send another message to the vehicles confirming that the crossing is complete. ▸ When vehicles are safe to proceed after UGR crossing is complete, they begin moving again.
Alternative Event Flow	▸ If a vehicle has sent a positive acknowledgment but an unavoidable (exceptional) situation arises, such as having to accommodate an emergency vehicle, UGR should receive a NACK warning which effectively cancels the previously notification. ▸ UGR initiates communication with other vehicles after the vehicle that sent the NACK has passed/crossed.
Post-Conditions	UGR may send a session-closing message to vehicles notifying them of a successful crossing.

Information Requirements	▸ Accurate positioning. ▸ UGR ID. ▸ Local map data (with information about crosswalk locations and to determine how many lanes are involved and how many vehicles need to stop).

User Story #1 (Interactive UGR Crossing without Traffic Lights)			
Service Level Requirement	**SLR Unit**	**SLR Value**	**Explanations/Reasoning/Background**
Range	**[m]**	300	Message does not need an extreme range, as it is only expected to reach nearby vehicles that could stop for UGRs at a crosswalk.
Information Requested/ Generated	**Quality of information/ Information needs**	64 Kbps	UGR can send a 'heartbeat' message (including location data e.g. PSM, VAM) after a small 'request' message; the vehicle only needs to send acknowledgment.
Service Level Latency	**[ms]**	200	Slower messaging does not result in safety risks in this Use Case, a manoeuvre will only be initiated upon agreement.
Service Level Reliability	**%**	99.9	Again, since a manoeuvre will only be initiated upon agreement, dropped messages will not result in safety risk and severe traffic efficiency degradation.
Velocity of Vehicles	**[m/s]**	13.9	Upper end of the speed that a vehicle will be driving at on a road where UGR crossing would take place (50 km/h).
Vehicle Density	**[vehicle/km^2]**	12,000	This Use Case is expected to mostly happen in less densely populated areas, since visibility at intersections is mostly good, speeds are limited to around 50 km/h.
Positioning	**[m]**	0.2 (3σ)	If UGR is standing next to a roadway, it only takes a slight position error to place them in the middle of the street on a map, or directly in the trajectory of a vehicle. Alternatively, if UGR is crossing a small error could falsely indicate to a nearby vehicle that the pedestrian is on the sidewalk.
Interoperability/ Regulatory/ Standardisation Required	**[yes/no]**	Yes/No/Yes	Interoperability due to different OEMs and robot manufacturers. A standardised protocol is needed.

User Story #2	**Interactive UGR Crossing with Request-Driven Traffic Lights** UGR expresses intent to cross a crosswalk where there is a set of traffic lights operated by request (i.e. the traffic lights will be changed to green to cross only when requested). Approaching vehicles and/or RSE receive the message and send an acknowledgment and acceptance/refusal message. In the RSE case, the traffic lights can be changed for UGR to cross. If the vehicles accept the request, they subsequently adapt their behaviour allowing UGR to cross safely. Upon reaching the other side of the street, UGR may send another message to RSE and/or vehicles confirming the completed crossing.
Category	Traffic efficiency.
Road Environment	Urban, marked crosswalk with traffic lights operated by request.
Short Description	▸ A UGR is preparing to cross the crosswalk. ▸ After signalling this intent, nearby vehicles acknowledge to reassure UGR that the request is accepted by the vehicles or RSE. ▸ If accepted, UGR starts crossing. During the crossing vehicles and/or RSE are kept informed and notified when the zone in front of them is clear so they may continue driving. ▸ UGR double checks with vehicles just before moving in front of them that they are clear to move forward.
Actors	Vehicle(s), UGR, RSE.
Vehicle Roles	Remote Vehicle.
Road/Roadside Infrastructure Roles	RSE receives messages from UGRs (request to cross) and vehicles (response to UGR request), and controls the traffic lights based on the requests and responses.
Other Actors' Roles	N/A
Goal	Improved traffic safety and efficiency at crosswalks and awareness for vehicles.
Needs	N/A
Constraints/ Presumptions	UGR is preparing to cross a crosswalk with request-driven traffic lights.
Geographic Scope	Crosswalk with traffic lights.
Illustrations	N/A
Pre-Conditions HV	▸ UGR in pedestrian areas should be allowed by regulation. ▸ Velocity of UGRs in pedestrian area should be regulated (e.g. 20km/h = 5.6m/s).
Pre-Conditions RVs	N/A

Main Event Flow	▸ UGR approaches a crosswalk. ▸ UGR expresses intent to cross and asks traffic lights to turn to green for the crossing. ▸ RSE (and approaching vehicles) receives the message which includes UGRs' intent to cross. ▸ The RSE determines that it can accommodate the request – (Optional) RSE acknowledges and notifies UGR (and nearby vehicles) that it will accept/reject the request or plan for changing traffic signal phase ▸ When the traffic light turns green, UGR starts crossing. ▸ While UGR is crossing, it may send information (e.g. PSMs, VAMs) notifying stopped vehicles (and RSE) of its progress. ▸ Upon reaching the other side of the crosswalk, UGR may send another message to RSE (and vehicles) confirming the completed crossing – (Optional) After receiving the message, RSE may change the traffic light to red. ▸ When vehicles are safe to proceed after UGR crosses, they begin moving again.
Alternative Event Flow	▸ UGR approaches a crosswalk. ▸ UGR expresses intent to cross at the current existing green light phase. ▸ Approaching vehicles and RSE receive the message which includes UGRs' intentions. ▸ A vehicle determines that it can accommodate the request (since it is still stopped at the traffic light), it acknowledges UGR/RSE and notifies nearby vehicles that it is participating in the request. ▸ When UGR (and RSE) receives sufficient evidence that it is safe to cross (may vary with number of lanes and vehicles present) – (Optional) RSE extends green light phase for the crossing – UGR starts crossing ▸ While UGR is crossing, it may send information (e.g. PSMs, VAMs) notifying stopped vehicles (and RSE) of its progress. ▸ Upon reaching the other side of the crosswalk, the UGR may send another message to the vehicles (and RSE) confirming the completed crossing. ▸ When vehicles are safe to proceed after UGR crosses, they begin moving again.
Post-Conditions	UGR may send a session-closing message to RSE (and/or vehicles) notifying them of a successful crossing.
Information Requirements	▸ Accurate positioning. ▸ UGR ID. ▸ Local map data (information about the location of crosswalks).

User Story #2 (Interactive UGR Crossing with Request-Driven Traffic Lights)			
Service Level Requirement	**SLR Unit**	**SLR Value**	**Explanations/Reasoning/Background**
Range	**[m]**	300	Message does not need an extreme range, as it only expected to reach nearby vehicles that could stop for UGRs at a crosswalk.
Information Requested/ Generated	**Quality of information/ Information needs**	64 Kbps	UGR can send a 'heartbeat' message (including location data e.g. PSM, VAM) after a small 'request' message; the vehicle only needs to send acknowledgment.
Service Level Latency	**[ms]**	200	Slow messaging does not result in safety risks in this Use Case because a manoeuvre will only be initiated upon agreement.
Service Level Reliability	**%**	99.9	Again, since a manoeuvre will only be initiated upon agreement, dropped messages will not result in safety risk and severe traffic efficiency degradation.
Velocity	**[m/s]**	13.9	Upper end of the speed that a vehicle will be driving at on a road where UGR crossing would take place (50 km/h).
Vehicle Density	**[vehicle/km^2]**	12,000	This Use Case is expected to mostly happen in less densely populated areas, since visibility at intersections is mostly good, speeds are limited around 50 km/h.
Positioning	**[m]**	0.2 (3σ)	If a UGR is standing next to a roadway, it only takes a slight position error to place them in the middle of the street on a map, or directly in the trajectory of a vehicle. Alternatively, if the UGR is crossing, a small error could falsely indicate to a nearby vehicle that the pedestrian is on the sidewalk.
Interoperability/ Regulatory/ Standardisation Required	**[yes/no]**	Yes/No/Yes	Interoperability due to different OEMs and robot manufacturers. 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

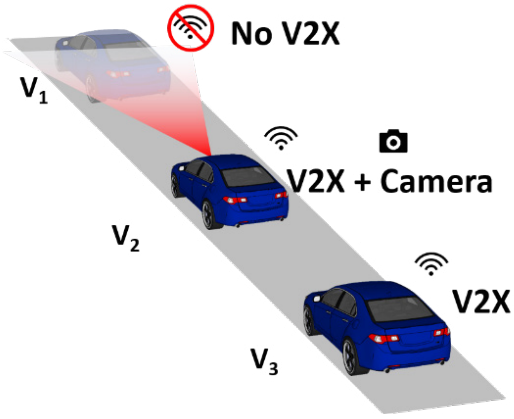
5.4 Autonomous Driving

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, classify them, and create an overlay with their own sensor data (environmental perception). ▸ The receiving vehicle analyses the shared data and generates or comes to a 'verdict' in conjunction 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; RV receives information collected by 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 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 RV(s).
Goal	Share dynamic objects and road-participant information detected by vehicles to extend their perception/awareness of the environment.
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: ▸ HV is able to detect dynamic objects and road-participants based on its sensor data. ▸ HV is able to associate the detections with a certain confidence. ▸ HV is able to communicate the detected dynamic objects. Note: same applies if RSU is detecting and sharing detected objects.
Geographic Scope	Global.

Illustrations

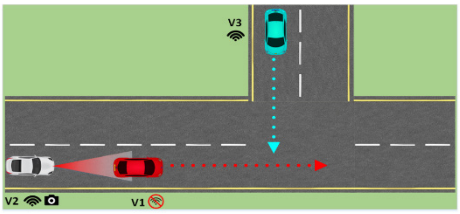
Basic Use Case.



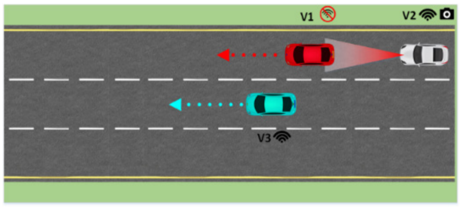
- On-board vehicle sensors on Host Vehicle (V_2), such as camera , RADAR etc., infers information about surrounding vehicles (V_1).
- On-board unit (OBU) on HV transmits data about the detected object (V_1).
- All other V2X vehicles (V_3) understand information such as position, direction and speed of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

Examples of safety applications based on shared sensor data.

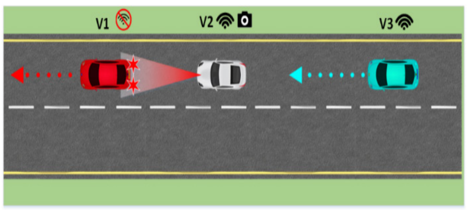
1. Intersection Collision Warning (ICW)



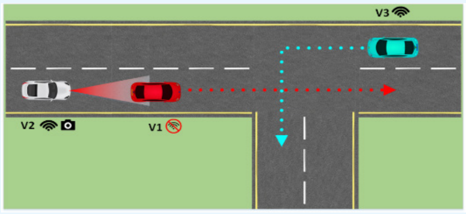
2. Blind Spot Warning (BSW)



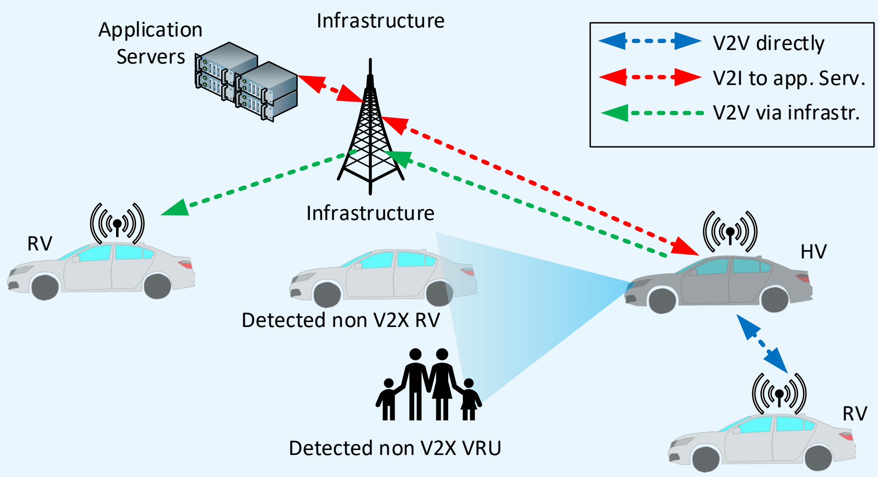
3. Electronic Emergency Brake Lights (EEBL)



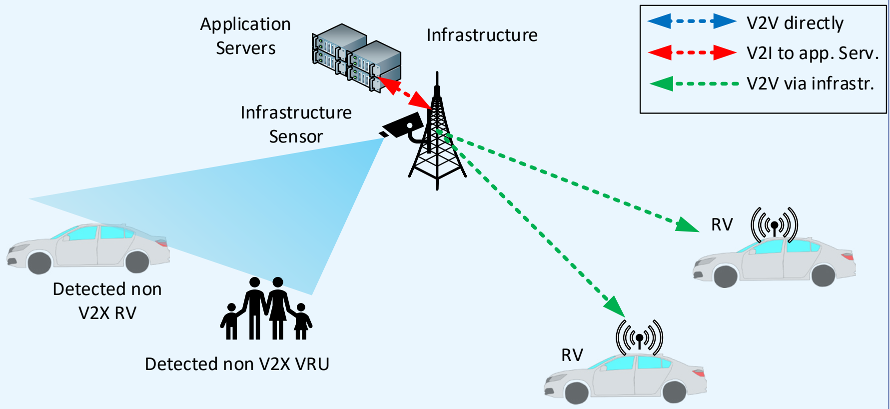
4. Left Turn Assist (LTA)



V2V vs. V2I Vehicle Sensor-sharing



Infrastructure Sensor-sharing



Pre-Conditions	▸ 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 reliable real-time representation of the environment.
Main Event Flow	▸ HV/RSU detects a dynamic objects or road-participants. ▸ HV/RSU sends out processed information from its sensors. ▸ RVs approach the scenario application zone and receive information directly from HV/RSU.

Alternate Event Flow	▸ HV detects dynamic objects or road-participants. ▸ HV sends out processed information from its sensors to the V2X application server. ▸ AS gathers and redistributes the object information to the concerned RVs. ▸ RVs approach the scenario application zone and receive information from the V2X AS.
Post-Conditions	Information on the detected dynamic objects and road-participants is available and considered by RV(s) 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]**	Scenario 1: 300 m Scenario 2: N/A	Minimum range assuming the maximum speed in a highway and 4 seconds response time for AVs. Needs to reach an application server (AS).
Information Requested/ Generated	**Quality of information/ Information needs**	300 bytes/per message 1400 bytes/per message	The message sent from HVs to RVs or AS contains detected event/object types (barriers, road work, bad weather, etc.), location, priority, etc., and the message is sent by an event trigger. The maximum size of the message is assumed to be 300 bytes. This size depends on the number of objects detected placed into the message by the sending vehicle
Service Level Latency	**[ms]**	100	Similar or same latency as for 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/object 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]**	Scenario 1: Yes/Yes/Yes Scenario 2: 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). Regulatory oversight for safety related issues is needed. Standardisation is required in the sense that the format for sensor data exchange should be commonly understood by all involved vehicles.

5.4.2 Non-analysed Sensor Signal Sharing

Use Case Name	Non-analysed Sensor Signal Sharing (previously named Unclassified Sensor Data Sharing for AVs)
User Story	Non-analysed sensor data perceived by other road users (e.g. other vehicles, VRUs) on the road and/or infrastructure are provided/transmitted to HV. The relevant sensor data are shared as a stream that could be used for HV's sensor fusion. In general, non-analysed sensor data provided by other road entities – and which contain non-analysed dynamic and/or static objects on the road – are used to increase the trust level of the car's own sensor observations, and extend its viewing range. Note: Instead of pre-analysing the sensor data stream at or on the providing entity side, 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 is provided/receives non-analysed 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 requests meta-data that helps to 'qualify' the specific sensor data shared (location of the camera, codec, etc.). ▸ Automated HV can subscribe to the non-analysed 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 HV receives the provided non-analysed sensor data, analyses it and then makes a decision based on the outcome. ▸ This process 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, Remote Vehicle, roadside infrastructure.

Vehicle Roles	HV represents the vehicle consuming the non-analysed sensor data when it is provided by other road users (RV, roadside infrastructure) to HV. RVs (other neighbouring vehicles) are represented as mainly moving (or static) objects in the non-analysed 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	N/A
Goal	Increases trust in 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). ▸ 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. ▸ HV can subscribe to the non-analysed 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-analysed sensor data and announce this as a service. ▸ HV is equipped with devices that receive and process non-analysed sensor data streams from other vehicles, road infrastructure.
Main Event Flow	▸ Entering the area covered by sensors, including non-analysed sensor-sharing services provided by other road users (e.g. other vehicles, VRUs) on the road and/or infrastructure (e.g. RSU), HV and road users or road infrastructure perform an initial 'handshake' to establish a non-analysed sensor-sharing service communication link. ▸ During the service establishment, specific meta-data (e.g. technical capabilities, location of the camera, codec, etc.) are exchanged and agreed on. ▸ If infrastructure is involved, as a basic functionality, the infrastructure's sensors track all moving vehicles (including HV) so their location is known ▸ Optionally: infrastructure or other road user and the HV agree on an ID for HV that will be used as identification inside a uni-casted environment data. ▸ HV is authenticated and enabled to receive authorised data from the remote road user or infrastructure. ▸ Authorised HV receives the provided non-analysed sensor data stream, analyses the data and makes decisions for the dynamic driving task based on the outcome.
Alternate Event Flow	N/A

Post-Conditions	▸ HV has left the area covered by sensors including non-analysed sensor-sharing service provided by other road users and road infrastructure. ▸ HV finished the manoeuvre it had requested for the non-analysed sensor data stream. ▸ After sign-off is performed HV continues using its own sensors only.
Information Requirements	▸ Road user sensor data (RADAR, LIDAR, camera, etc.) including video streams and meta-data describing the technical capabilities, service announcements, 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 and precise/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 on 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 1280 x 720, frame rate 30 Hz, colour depth 8 bit, 24 bit resolution (e.g. with H.264). LIDAR streaming: assumes 35 Mbps.

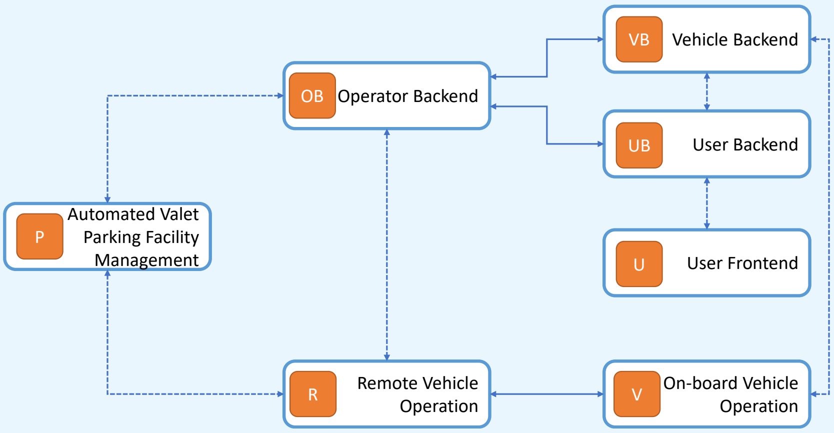
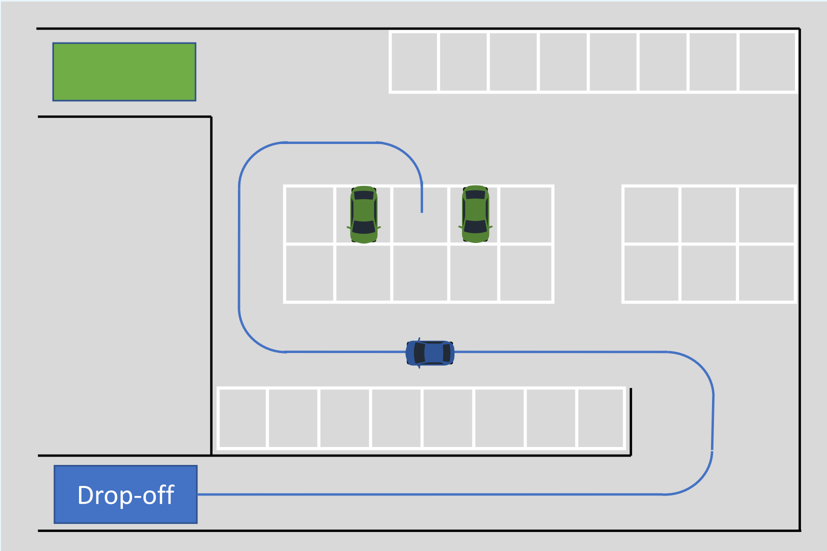
Service Level Latency	**[ms]**	50	The latency requirement for a video frame depends on the vehicle speed and heading as well as pitch angle changes. Latency of 50 ms should be kept, lower values would increase the experience of this function. Additional delays would lead to additional buffering in the rear vehicle. 50 ms is the considered sufficient for 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 at 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 -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 500 ms. ▸ Service discovery and see-through establishment within 1000 ms will help the HV driver activate the requested HD sensor-sharing service quickly and make a fast decisions whether to proceed (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. Maximum speed will match the traffic levels in different regions.
Vehicle Density	**[vehicle/km^2]**	12,000	Even though use in urban areas is more unlikely, it should still be available. Two vehicles are involved in this Use Case at a time.
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]**	Scenario 1: Yes/Yes/ Yes Scenario 2: Yes/Yes/ Yes	Interoperability between different OEMs' vehicles is needed. Regulatory oversight for safety related issues 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 Name	Automated Valet Parking
User story	When a vehicle arrives at the designated handover zone [4], the driver leaves the vehicle and authorises it to be parked using an Automated Valet Parking System (AVPS).
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 handover zone. ▸ The driver hands the vehicle over to the AVPS. ▸ The vehicle is parked in an automated manner in 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.
Actors	Vehicle, driver (user), AVPS (of type 1, 2 or 3).
Vehicle Roles	Host Vehicle 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. ▸ RV operation sub-system constructs an accurate surroundings environment model (of the HV) through the information received from sensors, control units and communication units, and provides the driving paths and/or manoeuvre instructions for HV. ▸ The AVP management sub-system provides, for example, a high-definition map and sensor information inside the parking area. It is connected to the parking facility management system. ▸ The OEM backend system connects to HV, validates AVP requests, and collects driving data directly from the vehicle. The OEM backend is connected to the AVP management system to authorise 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 the processes. The parking facility management system manages access to the garage and manages parking slot reservations and assignments. It also incorporates information from the AVP sub-system for parking spot availability.
Goal	Enable the parking of an HV through AVP without the presence of a driver and passengers.
Needs	▸ HV shall enable AVP driving functionality and communication with the AVP management sub-systems. ▸ The parking area shall provide accurate and timely surrounding environment information in the parking area using equipment located inside the facility, e.g. high-resolution camera, LIDAR etc., to operate and supervise the AVP mission.
Constraints/ Presumptions	▸ HV provides the capability (either type 1, 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, as well as ad-hoc parking arrangements.
Geographic Scope	Anywhere.

Illustrations	 Logical AVP system architecture (according [4]); Key 1 operator interface, key 2 management interfaces. 
Pre-Conditions	AVP type 1 and 3 only: ▸ HV enables high accuracy positioning. ▸ HV vehicle must be able to autonomously drive based on the provided path.

Main Event Flow	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, and trajectory calculation are all done by the AVPS' RV operation sub-system. ▸ Path or trajectory information, i.e. motion guidance (like 'forward 10 m'), as well as pose estimation are transferred to HV. In the 'command mode', the path can also be sent for the whole parking manoeuvre and just the velocity is adapted continuously through cyclic commands. Steering is done in the vehicle based on the location sensed by the infrastructure and the target path. ▸ Vehicle motion control according the 'motion guidance' received is performed by HV's on-board vehicle operation sub-system. All AVP types: ▸ The AVPS provides the current state and position to the user. ▸ The owner/user may request a pick-up.
Alternative Event Flow	HV arrives in the pick-up/drop-off area, and the user requests to handover the driving authority to the AVPS. AVP type 1: ▸ A high-definition map of the AVP parking facility is provided to the HV's on-board vehicle operation sub-system, as well as the driving destination (parking spot). ▸ Route planning, object and event detection, localisation, trajectory calculation as well as vehicle motion control are performed by the HV's on-board vehicle operation sub-system. ▸ The AVPS provides the current state and position to the user. ▸ The owner/user may request a pick-up.
Alternative Event Flow	HV arrives in the pick-up/drop-off area, and the user requests to handover the driving authority to the AVPS. 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 on-board sensors and the AVPS' remote vehicle operation sub-system. ▸ Localisation, trajectory calculation and vehicle motion control are performed by HV's on-board vehicle operation sub-system. ▸ The AVPS provides the current state and position to the user. ▸ The owner/user may request a pick-up.
Post-Conditions	The HV has reached its destination and has been successfully parked in the designated spot or returned to the handover 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 synchronisation, heartbeat. ▸ HV information (e.g. type, size, height, turn radius). ▸ HV's state.

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, RADAR) installed and operated by the AVPS service provider, as well as HV's status updates, the AVP remote operation sub-system builds an environmental model and provides manoeuvre instructions (e.g. driving direction, speed, acceleration, distance). This information is sent to HV in order to steer (by RV operation) along a calculated path to the designated parking position.
Main Event Flow	▸ HV arrives in the pick-up/drop-off/handover zone area, and the user requests to handover the driving authority to the AVPS. ▸ The driver leaves HV and hands over authority to the AVPS. ▸ Destination assignment, route planning, object and event detection, pose estimation, trajectory calculation are all done by the AVPS sub-system RV operation. ▸ Motion guidance commands (e.g. driving direction, speed, acceleration, distance), as well as pose estimation are transferred to HV. ▸ HV executes manoeuvres based on commands received via its motion control. ▸ Regular feedback is sent from HV to the AVP RV operation sub-system as the manoeuvres are being executed. ▸ The AVPS provides the current state and position to the user. ▸ HV, operated by the AVP's RV operation sub-system, is parked at the designated parking spot. ▸ The owner/user may request a pick-up.

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 a parking facility where motion control via AVPS is conducted.
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 Mbps (cyclic status message from AVPS to HV), up to 2 Mbit/s (non-cyclic messages, manoeuvre instructions sent from AVPS)	From HV to AVPS: cyclic message regarding the motion control (includes curvature, velocity, yaw rate, driving direction, shift position) of HV to RV operation sub-system. Repetition rate assumed to be 10 Hz. From the experience of trials the data rate of 0.2 Mbps can be derived. From AVPS to HV: small size cyclic status message (10 Hz) to confirm availability of the AVPS/communication. Either separate or combined with information on driving motion instructions towards the available parking spot sent from the RV operation sub-system. The data are several kBytes, and the rate depends on path- or trajectory related data elements being transmitted. At present, data rates are based on existing trials, further details will evolve from these current standardisation 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 80 ms. Present latencies are based on existing trials, further details will evolve from current standardisation 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 to [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. Assuming 5-10% of the parking spaces for the number of RVs, up to 1000 vehicles and 50-100 AVP spots can be derived.
Positioning Accuracy	**[m]**	N/A	Positioning accuracy is controlled by AVPS and depends on its targeted performance (e.g. how close to park vehicles to each other, constraints or obstructions in the parking facility/structure).

Interoperability/ Regulatory/ Standardisation Required	**[yes/no]**	Yes/Yes/Yes	Regulation is needed, since authorities may need to specify, for example, the maximum speed, etc. Regional regulation for AVP type 2, where applicable, could consider the use of a 'black box' linking AVPS to regulatory bodies. Interoperability and standardisation are also needed since vehicles from different OEMs will be supported by the AVPS. 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: this may be done by an on-board camera or one 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

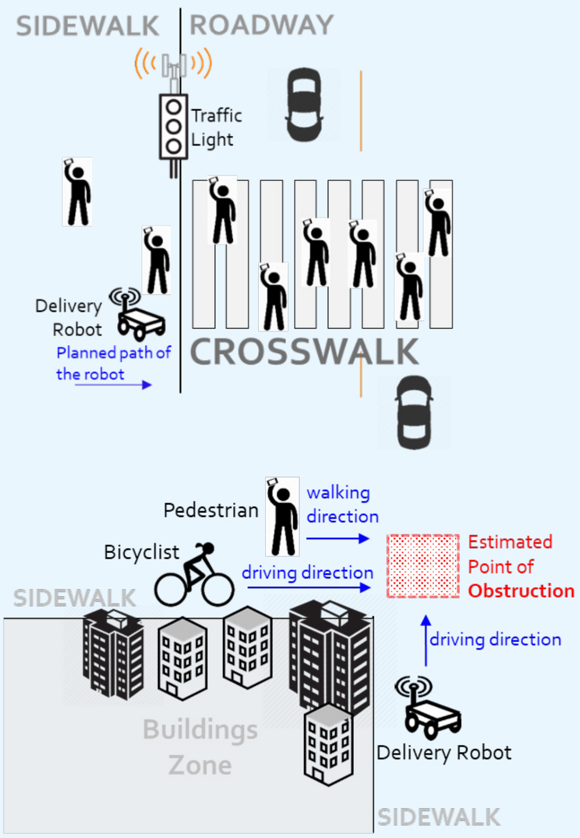
No new Use Cases were added in this category in the current version of this document.

5.6 Traffic Efficiency and Environmental Friendliness

No new Use Cases were added in this category in the current version of this document.

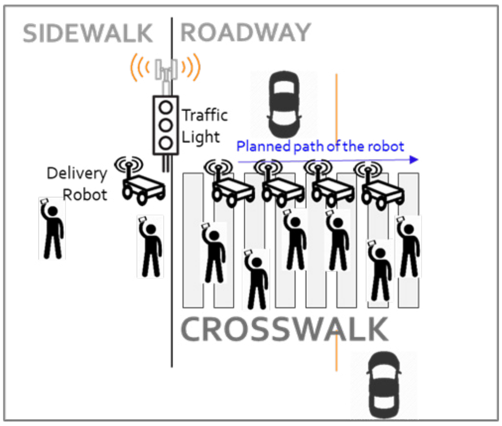
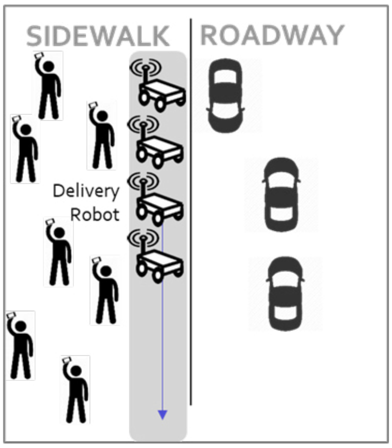
5.6.1 Yielding Right-of-Way to VRUs

Use Case Name	Yielding Right-of-Way to VRUs
User Story #1	**Yielding Right-of-Way to VRUs: Individual Operation** According to regulations in certain countries, unmanned ground robots (UGR), such as personal delivery devices, must yield or give the right-of-way to all pedestrians and cyclists in pedestrian areas including sidewalks and crosswalks. If UGR is driving in a pedestrian area and is likely or expected to interrupt/intersect a vulnerable road user's path it must change route/operation to avoid the disruption/obstruction (even if there is no/low risk of imminent collision between UGR and VRU).
Category	VRU safety, traffic efficiency.
Road Environment	Urban.
Short Description	UGR receives information about other road users including VRUs (i.e. pedestrians and cyclists) from roadside equipment (and other road users and UGRs), so it tries to adjust its speed, heading, and route to avoid obstructing VRUs on crosswalks/sidewalks.
Actors	UGR, roadside infrastructure, VRUs.
Vehicle Roles	N/A
Road/Roadside Infrastructure Roles	▸ Roadside equipment collects information about VRUs on crosswalks/sidewalks by using sensors deployed on RSE or by receiving messages (e.g. VAM, PSM, BSM, CPM, SDSM) from road users. ▸ RSE sends the collected information to UGR.
Other Actors' Roles	(Optional) VRUs send information notifying RSE (and other road users) of their presence/status.
Goal	Improve safety for VRUs and improve traffic efficiency, when VRUs and UGRs share the pedestrian areas.
Needs	The operation of UGRs must comply with regulations.
Constraints/ Presumptions	UGRs need to be able to collect information about VRUs in the vicinity and perform adjustments to their manoeuvres based on the information.
Geographic Scope	Pedestrian area including sidewalks and crosswalks.

Illustrations	 Depicting a single or individual UGR.
Pre-Conditions HV	▸ UGR in pedestrian areas should be allowed by the regulation. ▸ Velocity of UGRs in pedestrian area should be regulated (e.g. 20 km/h = 5.6 m/s).
Pre-Conditions RVs	N/A
Main Event Flow	▸ UGR is operating in a pedestrian area, e.g. sidewalk/crosswalk. ▸ UGR receives information about VRUs and the area (e.g. location density/ distribution/number of VRUs, width/length of the sidewalk/crosswalk) provided by RSE/VRUs or a service provider. ▸ UGR uses the information and can judge whether it will interrupt/obstruct VRU's path. ▸ If it is expected/likely that UGR will obstruct VRU's path in the pedestrian area, it changes its route/operation, for example – By making a detour around the area crowded by VRUs – By pausing its operation (or not entering the sidewalk) and waiting until the VRUs on the sidewalk pass by – Etc.
Post-Conditions	None.
Information Requirements	▸ Accurate positioning. ▸ Location/density/distribution/number of VRUs in the pedestrian area. ▸ Local map data (to understand width/length of pedestrian areas).

User Story #1 Yielding Right-of-Way to VRUs: Individual Operation			
Service Level Requirement	**SLR Unit**	**SLR Value**	**Explanations/Reasoning/Background**
Range	**[m]**	300	Message does not need an extreme range, as it only needs to reach nearby UGRs that should yield the right-of-way to VRUs.
Information Requested/ Generated	**Quality of information/ Information needs**	~3 Mbytes per message 300 bytes x 10,000 (VRU density)	VRUs and/or RSE need to provide kinematics and position information (e.g. using PSM/VAM/CPM/SDSM) to inform UGRs of the VRUs' presence/status
Service Level Latency	**[ms]**	200	Exchange of messages must happen quickly, but the latency should be defined considering the reaction time of UGRs The reaction time includes time required for data processing at the UGR (e.g. decoding/analysis of messages received from other road users, judge whether the UGR will interrupt VRU traffic).
Service Level Reliability	**%**	99.9	The reliability should be sufficient to guarantee QoS. 99.9%. Sensors deployed on UGRs can help to avoid the obstruction.
Velocity of UGRs	**[m/s]**	5.6	20 km/h = 5.6 m/sec
Reaction Time of UGRs	**[sec]**		The reaction time includes time required for data processing at the UGR (e.g. decoding/analysis of messages received from other road users, judge whether the UGR will interrupt VRU traffic)
Vehicle Density	**[vehicle/km^2]**	-	-
VRU Density	**[VRU/km^2]**	Concerned VRUs: ~300 total Present VRUs per km^2: ~10,000	Figures given only for urban areas, since we consider this one as the more critical case with regards to vehicle number/ density. Concerned VRUs are those near streets, not counting workers in offices or the like. However, for total network load, etc, all VRUs in the given area have to be considered.
Positioning	**[m]**	1	very exact positioning might not be needed.
Interoperability/ Regulatory/ Standardisation Required	**[yes/no]**	Yes/Yes/Yes	Interoperability due to different UGR manufacturers, in communication between UGRs, UGR-RSE, and UGR-VRU. Regulation is needed to determine whether to allow driving of UGRs in pedestrians areas. A standardised protocol might be needed.

User story #2	**Yielding Right-of-Way to VRUs: Group Operation** According to regulations in certain countries, UGRs must yield the right-of-way to all pedestrians and cyclists in pedestrian areas including sidewalks and crosswalks. When multiple UGRs drive in the pedestrian area and it is expected the UGRs could interrupt VRUs' paths, several UGRs may change their route/operation to avoid the obstruction by grouping together similar to platooning/clustering use cases. This action can be taken even when there is no/low risk of imminent collisions between the UGR and VRUs.
Category	VRU safety, traffic efficiency.
Road Environment	Urban.
Short Description	▸ UGR receives information about VRUs and UGRs from RSE, fleet operator/service provider (and other road users and UGRs). ▸ UGR tries to adjust its speed, heading, and route in cooperation with other UGRs to minimise the area occupied by UGRs on the sidewalk/crosswalk. ▸ The information provided includes position and speed as well as the heading and acceleration of the UGR(s) running in the vicinity of the ego-UGR ▸ UGRs could drive in a single line and occupy minimal space by running one after other along roads to avoid interrupting/obstructing VRUs.
Actors	UGRs, roadside infrastructure and VRUs.
Vehicle Roles	N/A
Road/Roadside Infrastructure Roles	▸ Roadside equipment collects information about VRUs (e.g. pedestrians, cyclist) and UGRs on crosswalks/sidewalks by using on-board sensors or by receiving messages (e.g. VAM, PSM, BSM, CPM, SDSM) from road users or fleet operators/service providers. ▸ RSE sends the collected information to UGRs. ▸ RSE may provide UGRs manoeuvre instructions.
Other Actors' Roles	▸ (Optional) VRUs send information notifying RSE (and other road users) of their presence/status. ▸ (Optional) UGR fleet operators/service providers send information notifying RSE of UGRs presence/status.
Goal	Improve safety for VRUs and better pedestrian traffic efficiency, when VRUs and UGRs share the pedestrian areas.
Needs	N/A
Constraints/ Presumptions	UGRs need to be able to collect information about VRUs in the vicinity and adjust their behaviour based on information and inputs from infrastructure, fleet operator, service providers.
Geographic Scope	Pedestrian area including sidewalks and crosswalks.

Illustrations	  Depicting multiple UGRs.
Pre-Conditions HV	UGR in pedestrian areas should be allowed by the regulation. Velocity of UGRs in pedestrian area should be regulated. (e.g. 20 km/h = 5.6 m/s)
Pre-Conditions RVs	N/A
Main Event Flow	▸ UGR is operating in a pedestrian area, e.g. sidewalk/crosswalk. ▸ UGR receives information about VRUs, other UGRs, and the area (e.g. location density/distribution/number of VRUs, width/length of the sidewalk/crosswalk) from RSE/VRUs or UGR fleet operators/service providers. ▸ UGR uses the information and can judge whether it will interrupt VRU traffic. ▸ If it is expected/likely that UGRs will obstruct VRUs in the pedestrian area, they change route/operation, for example – By making a detour around the area crowded by VRUs – By pausing operation (or not entering the sidewalk) and waiting until the VRUs on the sidewalk pass by – Etc.
Post-Conditions	None.

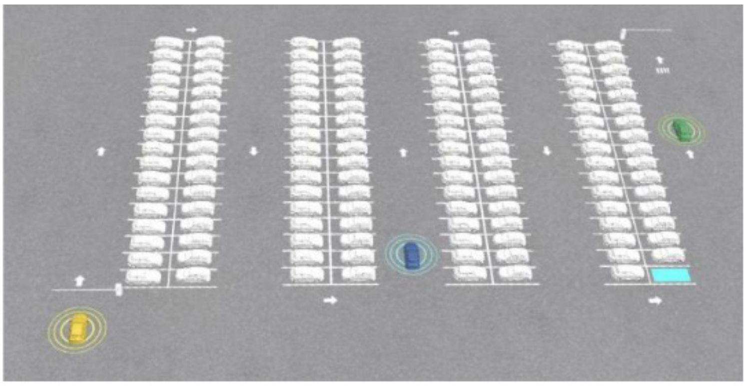
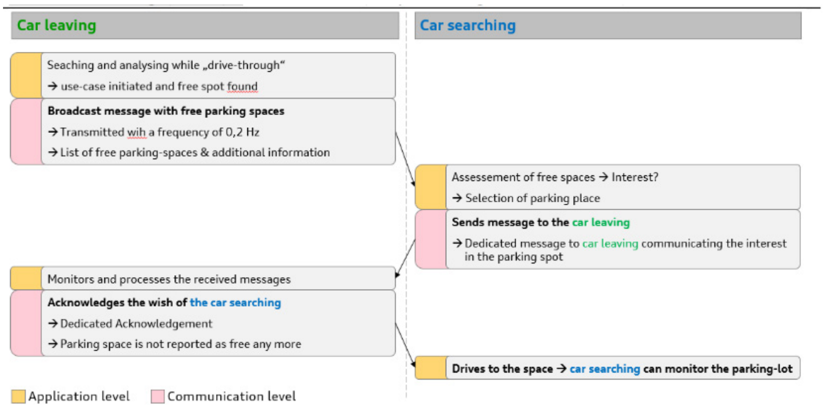
Information Requirements	▸ Accurate positioning. ▸ Location/density/distribution/number of VRUs in the pedestrian area. ▸ Local map data (to understand width/length of pedestrian areas). ▸ UGR behaviour/manoeuvre instructions (e.g. planned path, speed, acceleration, heading, etc.).

User Story #2 Yielding Right-of-Way to VRUs: Group Operation			
Service Level Requirement	**SLR Unit**	**SLR Value**	**Explanations/Reasoning/ Background**
Range	**[m]**	10,000	Assuming V2N: communication range within the coverage of a macro cell.
Information Requested/ Generated	**Quality of information/ Information needs**	Up to 1000 bytes per message (up to 400 Kbps) (Commands from remote driver)	The value is referred from TOD support, user story #2 (Remote driving instructions).
Service Level Latency	**[ms]**	200	With only the instructions to be transmitted from service provider to UGR, latency requirements are more relaxed. The value is referred from TOD support, user story #2 (Remote driving instructions).
Service Level Reliability	**%**	99.999	The transmission of commands from the service provider requires a high level of reliability because this affects the safe and efficient operation of UGRs.
Velocity of UGR	**[m/s]**	5.6	Velocity of UGRs in pedestrian area is regulated/ limited (e.g. 20 km/h = 5.6 m/s).
Vehicle Density	**[vehicle/ km^2]**	Concerned VRUs: ~300 total Present VRUs per km^2: ~10,000 Vehicles: 1500	Figures given only for urban areas, as the more critical case with regards to vehicle number/ density. Concerned VRUs are those near streets, not counting workers in offices or the like. However, for total network load, etc, all VRUs in the given area have to be considered.
Positioning	**[m]**	1 (3 sigma)	Very exact positioning might not be needed.
Interoperability/ Regulatory/ Standardisation Required	**[yes/no]**	Yes/Yes/Yes	Interoperability due to different UGR manufacturers, in communication between UGRs, UGR-RSE, UGR-VRUs. Regulation is needed to determine whether to allow driving of UGRs in pedestrians areas. A standardised protocol might be needed.

5.6.2 Decentralised Parking-Lot Management

Use Case Name	Decentralised parking-lot-management
User Story	Searching for a parking spot in big and crowded parking lots can require a lot of time and thus lead to stress for drivers and passengers. Large outdoor parking lots often lack adequate management systems for signalling or assigning free/available parking spots, which can lead to many cars circling in search of a vacant place. This causes higher congestion, consumes time and fuel, and can lead to incidents and frustration. Often the parking spaces found don't meet the requirements of driver and car (e.g. sufficient size or charging opportunity).
Category	Convenience, traffic Efficiency and Environmental Friendliness

Road Environment	Parking lot (urban).
Short Description	▸ The Use Case is based on the communication between a car driving ▸ through the parking lot, scanning its surroundings, and a car interested ▸ in a free parking space. ▸ The car on the lot may activate its sensors – if the parking density exceeds a set limit – and then scan its surroundings for free parking spaces and their characteristics (e.g. size). ▸ The gathered data is processed and shared with other cars nearby. Those receiving the information can process the data and select (by themselves or via user input) a parking space they are interested in. ▸ The second car then sends a message to the reporting car to outline its interest. ▸ Upon reception, the reporting car acknowledges the interest of the searching car signalling that it may approach the free space, while ▸ scanning the lot for free spaces for other participants.
Actors	Drivers (to select the parking space and drive), cars (equipped with communication- and sensor-systems).
Vehicle Roles	To describe the mechanisms of the Use Case three roles are established: ▸ Car leaving (green): this role describes a car that had been parked on and is moving towards the exit of the parking lot. As it is leaving, the car can continue searching for free parking lots and transmit the gathered information to others nearby. ▸ Car approaching (yellow): this scenario describes a clar that is not yet on the parking lot, but already knows about the driver's intention to park there because of navigation data or similar input. In proximity to the lot, it may report its interest for a certain parking spot (i.e. size/charging). The assignment of a free space early on can avoid the necessity to search the lot and enable direct movement to the free space. ▸ Car searching (blue): this scenario describes a care already driving through the parking lot in search of an available spot. It can be guided to a free space through the reports of other cars and can use its sensors to find alternative spaces when one that it has found is not suitable (too small or offers no charging facility).
Road & Roadside Infrastructure	N/A
Other Actors' Roles	Cloud systems.
Goal	To optimise the process of searching for a suitable parking space on large and often chaotic parking lots.
Needs	▸ Sensors in the cars (everything from basic ultrasound parking-sensors up to high-definition cameras and sensors are usable). ▸ Communication modules to transmit, receive and process the message sending. ▸ Standardised communication architecture: message-data, network/ transport-protocol. ▸ User interface to start/end Use Case and select parking spaces. ▸ For future implementation, integration in overall 'mobility system' to allow for a complete user solution for problems like 'last-mile scenarios'.

Constraints/ Presumptions	▸ Parking sensors and space measuring capabilities. ▸ Communication and standards.
Geographic Scope	Global.
Illustrations	
Pre-Conditions	▸ Communication capabilities. ▸ Wake-up of connectivity module for parking list 'keep alive' vehicle role. ▸ Car approaching (yellow): has to be within a 500 m radius of the parking lot entrance to avoid long reservation periods. ▸ Car leaving (green): was started and left parking spot, sufficiently high parking density (>= 80% measured during >= 15 sec. time spend and >= 15 m driven on the parking lot).
Main Event Flow	▸ Connection lost: a free/available space is only assigned to a searching car, if the whole assignment process shown is fulfilled. Otherwise a space is seen as unoccupied/unreserved. ▸ Multiple interest messages for one vacant space: the first car transmitting its interest in the spot to the reporting car receives the acknowledgement. ▸ Space occupied in the meantime: other cars driving through the lot can check whether spaces reported as vacant are still available and communicate the update/mistake. If a car is already driving towards the now occupied space it may be redirected. ▸ Same space reported by different cars: to avoid a situation where the same parking lot is reported by different cars and the responsibility to assign the space to a searching car is unclear, the cars should review their own information and monitor other messages sent (doubled information should be avoided). ▸ For future implementations a responsibility handover may be considered. 

Alternative Event Flow [3]	A 'keep alive' vehicle maintains the list during its parking and enables future arriving vehicles to access parking spaces. This vehicle in turn becomes the keep alive vehicle.
Alternative Event Flow	▸ Information is additionally sent into the cloud by surrounding intelligent systems like cameras and further sensors or by the vehicles themselves. ▸ Vehicles then approaching the area could then get the latest available information from the cloud.
Post-Conditions	▸ Car approaching (yellow): parked on the lot ▸ Car leaving (green): left the parking lot ▸ Car searching (blue): parked on the lot
Service-Level KPIs	N/A
Information Requirements	▸ New identifiers for parking lots needed to allow communication dedicated to a certain parking lot. ▸ New data frames (similar to TIM frames) with different elements to describe the parking space and its additional features. ▸ The protocol-infrastructure has to be defined to test and set performance indicators.

The following table provides the specific requirements.

User Story #1			
SLR Title	**SLR Unit**	**SLR Value**	**Explanations/Reasoning/Background**
Range	**[m]**	1000	The particular parking lot and a surrounding area of up to 500 m from the entry or 100 m from the exit.
Information Requested/ Generated	**Quality of information/ Information needs # 1 if driver is a machine**	N/A	Parking message.
Information requested/ generated	**Quality of information/ Information needs # 2 if driver is a human**	200 ms -1000 ms	Indication to driver in HMI display – can be OEM specific.
Service Level Latency	**[ms]**	200 ms - 1000 ms	Sharing the list at low speeds does not require frequent updates.
Service Level Reliability	**%**	99.9	Low reliability, as not safety critical.
Velocity	**[m/s]**	5.55	Parking space generally only permits low speeds.
Vehicle Density	**[vehicle/km²]**	12,000	High density of urban environments.
Positioning Accuracy	**[m]**	1 m	Position accuracy less critical than space measuring capabilities.
Interoperability / Regulatory / Standardisation Required	**[yes/no]**	Yes/Yes/Yes	Interoperability due to different OEMs.

5.7 Society and Community

[3] Alternative event flows in this document are not intended as replacements for the main event flow. They are intended to represent different possible flows.

The 5G Automotive Association (5GAA) is a global, cross-industry organisation of over 115 members, including leading global automakers, Tier-1 suppliers, mobile operators, semiconductor companies, and test equipment vendors.
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5GAA is committed to helping define and develop the next generation of connected mobility, automated vehicles, and intelligent transport solutions based on C-V2X.
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No new Use Cases were added in this category in the current version of this document.

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