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ENabling **S**af**E** **M**ulti-**B**rand p**L**atooning for **E**urope

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Revision history

Version	Date	Author	Summary of changes	Status
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3	29/11/2018	John Vissers (TNO)	Update according to feedback of coordinator	
4	29/11/2018	Alessandro (CLEPA)	WP2 review update	
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7	14/12/2018	Marika Hoedemaeker	Alignment on platoon level A description where the driver remains responsible	Ready for EC submission
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9	14/4/2020	Dehlia Willemsen	Updated following review by EC	To be approved by the coordinator and WP2 leader

10	05-05-2020	Edoardo Mascalchi	Updated and approved
11	10-05-2020	Marika Hoedemaeker	Approved

TABLES

FIGURES

1. EXECUTIVE SUMMARY

1.1. Context and need of a multi brand platooning project

Context

Platooning technology has made significant advances in the last decade, but to achieve the next step towards deployment of truck platooning, an integral multi-brand approach is required. Aiming for Europe-wide deployment of platooning, 'multi-brand' solutions are paramount. It is the ambition of ENSEMBLE to realise pre-standards for interoperability between trucks, platoons and logistics solution providers, to speed up actual market pick-up of (sub)system development and implementation and to enable harmonisation of legal frameworks in the member states.

Project scope

The main goal of the ENSEMBLE project is to pave the way for the adoption of multi-brand truck platooning in Europe to improve fuel economy, traffic safety and throughput. This will be demonstrated by driving up to seven differently branded trucks in one (or more) platoon(s) under real world traffic conditions across national borders. During the years, the project goals are:

- Year 1: setting the specifications and developing a reference design with acceptance criteria
- Year 2: implementing this reference design on the OEM own trucks as well as perform impact assessments with several criteria
- Year 3: focus on testing the multi-brand platoons on test tracks and international public roads

The technical results will be evaluated against the initial requirements. Also, the impact on fuel consumption, drivers and other road users will be established. In the end, all activities within the project aim to accelerate the deployment of multi-brand truck platooning in Europe.

Abstract of this Deliverable

This deliverable consists of 2 parts:

- Platoon levels
- Use cases

This document is a first version of these 2 topics and it will be further refined during the project, after other investigations like HMI and functional safety and practical experience. The main purpose is to start the early development of demo trucks. The version in month 30 (D2.3) will be the final version.

- Platoon levels: The platoon levels as envisioned by the ENSEMBLE consortium are defined. Platoon level A is detailed and for platoon level B and C the first outlook is given which will be detailed more during the ENSEMBLE project which will be reflected in D2.3. Platoon level A is defined in line with the intended demonstration at the end of the project on public road. The main properties of platoon level A are:
    - Longitudinal coordinated automated control for the whole velocity range from 0 to maximum cruise velocity (depending on country regulations)
    - Maximum number of trucks of 7 is considered for platoon level A in ENSEMBLE

- A minimum time gap of 0.8 seconds @ maximum cruise velocity (depending on country regulations)
- New members of a running platoon can only join from the rear.
- Under adverse conditions like bad weather, slopes, etc.… the drivers have the responsibility to increase the time gap or disengage the platoon completely.
- The driver is responsible for the dynamic drive task in case of system failures. The system needs to be fail safe.
- Interaction with platooning services and infrastructure is technically available

- Use cases: The high-level use cases for platoon level A are detailed. First of all the methodology how to derive the use cases is defined and after that the high level use cases for platoon level A and additional one-lines / assumptions are added which can together be used for the detailed use cases as may be part of the technical deliverables (e.g. D2.4, D2.8).
  The main high level use cases of platoon level A are:

  - Platoon formation
    - Platoon formation based on generic match making (Orchestrated non real-time)
    - Platoon formation based on just extended awareness (Orchestrated real-time)
  - Engaging to platoon
    - Join from behind by single vehicle
    - Merge from behind by existing platoon
  - Platooning
    - Steady state platooning
    - Follow to stop (&go)
    - Emergency braking (caused by AEB system or manual overrule)
    - Platoon gap adaptation
      - I2V interaction
      - Cut-in (long time)
      - Cut-in (short time) (“Cut-through”)
      - System status (e.g. packet loss)
  - Disengage platoon
    - Leave
    - Split

2. INTRODUCTION

2.1. Background

The main goal of the ENSEMBLE project is to pave the way for the adoption of multi-brand truck platooning in Europe to improve fuel economy, traffic safety and throughput. This will be demonstrated by driving seven differently branded trucks in one (or more) platoon(s) under real world traffic conditions across national borders.

Following objectives are defined:

1. Interoperable Platooning: When forming a scalable, multi-brand truck platoon, the vehicles must be compatible to ensure correct and safe operation.

2. Safe platooning: Safety is one of the key aspects to ensure acceptance of platooning technology. In ENSEMBLE, this will be achieved by 1) designing fail-safe and fault-tolerant mechanisms, which include the safe interaction both within the platoon and with other road users. This will be supported by secure wireless communication. Furthermore, 2) ENSEMBLE will approach the relevant authorities to jointly define road approval requirements, also taking into account impact of platoons on the road and infrastructure like e.g. road wear, geometry, platooning management and required V2I communication.

3. Real-life platooning: The intended practical tests on test tracks and in real life serve a three-fold purpose: 1) “learning by doing” testing across a C-ITS corridor in Europe, 2) assess the impact on traffic, infrastructure and logistics, while gathering relevant data of critical scenarios and 3) promote multi-brand platooning through a final event.

4. Embedded platooning: The platooning concept should allow for seamless integration into the (logistic) value chain. Hence the fourth objective in ENSEMBLE is to design an interface to cloud-based services to embed the platooning concept into the logistics chain.

The concept of the envisioned technology to implement above objectives, consists of a hierarchical platooning system with interacting layers. The envisioned concept is presented in Figure 2-1.

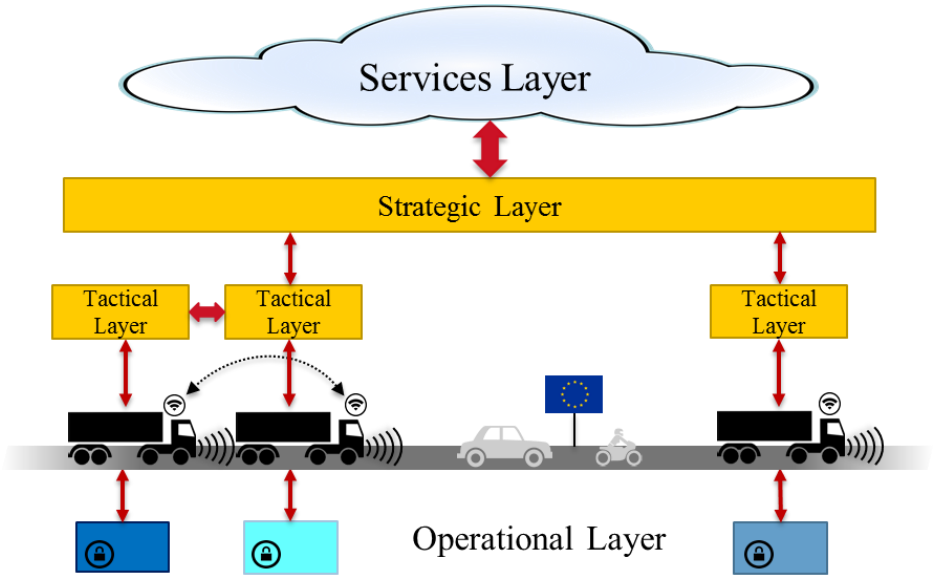


Figure 2-1. Layered concept of ENSEMBLE

The different layers have the following responsibilities:

- The service layer represents the platform on which logistical operations and new initiatives can operate.

- The strategic layer is responsible for the high-level decision-making regarding the scheduling of platoons based on vehicle compatibility and Platooning Level (see below), optimisation with respect to fuel consumption, travel times, destination, and impact on highway traffic flow and infrastructure, employing cooperative ITS cloud-based solutions. In addition, the routing of vehicles to allow for platoon forming is included in this layer. The strategic layer is implemented in a centralised fashion in so-called traffic control centres. Long-range wireless communication by existing cellular technology is used between a traffic control centre and vehicles/platoons and their drivers.

- The tactical layer coordinates the actual platoon forming (both from the tail of the platoon and through merging in the platoon) and platoon dissolution. In addition, this layer ensures platoon cohesion on hilly roads, and sets the desired platoon velocity, inter-vehicle distances (e.g. to prevent damaging bridges) and lateral offsets to mitigate road wear. This is implemented through the execution of an interaction protocol using the short-range wireless inter-vehicle communication (i.e. V2X). In fact, the interaction protocol is implemented by message sequences, initiating the manoeuvres that are necessary to form a platoon, to merge into it, or to dissolve it, also taking into account scheduling requirements due to vehicle compatibility.

- The operational layer involves the vehicle actuator control (e.g. accelerating/braking, steering), the execution of the aforementioned manoeuvres, and the control of the individual vehicles in the platoon to automatically perform the platooning task. Here, the main control task is to regulate the inter-vehicle distance or velocity and, depending on the Platooning Level, the lateral position relative to the lane or to the preceding vehicle. Key

performance requirements for this layer are vehicle-following behaviour and (longitudinal and lateral) string stability of the platoon, where the latter is a necessary requirement to achieve a stable traffic flow and to achieve scalability with respect to platoon length, and the short-range wireless inter-vehicle communication is the key enabling technology.

Furthermore the concept foresees in a staged introduction of platooning along different platooning levels, which will be defined in the course of the project. The definition of “platooning levels of automation” will comprise elements like e.g. the minimum time gap between the vehicles, whether there is lateral automation available, driving speed range, operational areas like motorways, etc.. Three different levels are anticipated; called A, B and C.

2.2. Aim of ENSEMBLE

Aiming for Europe-wide deployment of platooning, ‘multi-brand’ solutions are paramount. It is the ambition of ENSEMBLE to realise pre-standards (i.e., mature input for standardisation) for interoperability between trucks, platoons and logistics solution providers, to speed up actual market pick-up of (sub)system development and implementation and to enable harmonisation of legal frameworks in the member states. As such, a technology readiness level (TRL) of 7 is aimed for.

2.3. Aim and structure of this report

The objective of this document is to derive the platoon levels and use cases which form the basis for the further specification and implementation of the functions within all the layers of ENSEMBLE.

Platoon level A definition and use cases is elaborated on the work as presented in D2.1 (Requirements Review from EU projects D2.1 ENSEMBLE).

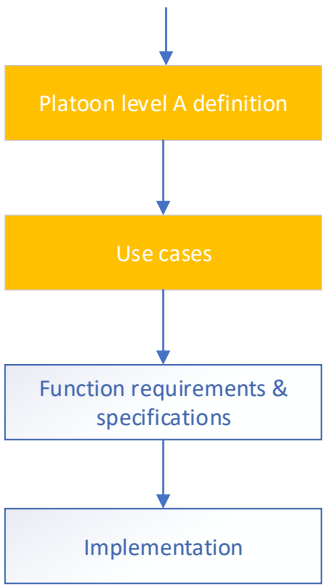


Figure 2-2: Design flow

The first part of this report will detail the platoon levels as envisioned by the ENSEMBLE consortium. Platoon level A is detailed and for platoon level B and C the first outlook is given which

will be detailed more during the ENSEMBLE project which will be reflected in D2.3. Platoon level A is defined in line with the intended demonstration at the end of the project on public road.

The final part of the report will detail the use cases for platoon level A. First of all the methodology how to derive the use cases is defined and after that the high level use cases for platoon level A are defined. Also additional assumptions are added which can be used for the detailed use cases that are part of the technical deliverables (e.g. D2.4, D2.8).

3. PLATOONING LEVELS

3.1. Introduction

In order to break down the complexity of deploying multi-branded truck platooning on public roads different platoon Levels are defined. The Platooning Levels facilitate a stepwise approach to deployment of platooning on public roads, where the “first” Platooning Level defined in ENSEMBLE can be deployed in the near future. The idea of Platooning Levels has emerged since the commonly accepted automation levels of the SAE J3016 have shortcomings when applied to platooning. The first level in the SAE levels of driving automation involves either longitudinal or lateral vehicle automation, whereas the driver is responsible to detect safety-critical events and take appropriate action. Level 2 involves both longitudinal and lateral automation, with the same driver responsibility as in level 1. In level 3, the driver responsibility is decreased to only take action upon a warning by the automation system. Only in level 4 and higher, the driver has no driving task anymore for part or all of the journey. Truck platooning, however, involves driving at short inter-vehicle distances for an extended period of time. As a consequence the driver cannot be held responsible for timely intervention in case of safety-critical events such as hard braking. Furthermore the platoon as a whole can be seen as a system of interconnected systems with specific requirements.
Hence, the first three SAE automation levels are not directly applicable for the platooning application. Consequently, the need arises to create a different automation level classification for heavy duty vehicles that takes into account the explained needs of Platooning. The definition of “platooning levels of automation” will comprise elements like the minimum time gap between the vehicles, whether there is lateral automation available, driving speed range, operational areas like motorways, etc.. Three different levels are seen for now – called platoon level A, B and C.
It remains an action to decide how the definition of the platoon levels will be taken up by the road authorities. Ensemble generates in T6.5 (standardisation) recommendations on how to integrate the defined platoon levels in existing SAE J3016 or any other accepted methodology

3.2. Platooning level A, B & C; big differentiators

Three different levels of platooning are seen by the ENSEMBLE consortium, as for now. In this deliverable platoon level A is further detailed, whereas platoon level B and C will be detailed later in the project towards D2.3. Platoon Level B and C should be seen as first thoughts for future work due to the fact the gained experiences with platoon level A needs to be considered as well.

Table 1: High level platoon levels overview

	Platooning level A	*Platooning level B*	*Platooning level C*
Longitudinal automation	Leading truck: manual or advanced assist system (e.g. ACC) Following & trailing vehicle: Autonomous longitudinal control (CACC, CAEB, Cxxx, ...)	*Leading truck: manual or advanced assist system (e.g. ACC) Following & trailing vehicle: Autonomous longitudinal control (CACC, CAEB, Cxxx, ...)*	*Leading truck: manual or advanced assist system (e.g. ACC) Following & trailing vehicle: Autonomous longitudinal control (CACC, CAEB, Cxxx, ...)*
Lateral automation	Driver	*In lane + lane*	*Full automation from*

	Optionally: in lane by system (standalone vehicle)	*changes (coordinated)*	*A to B*
Operation area	Triggered by driver in dedicated areas (e.g. highway)	*Dedicated areas (e.g. highway)*	*Dedicated areas (e.g. highway + parking areas)*
Fault tolerance	Longitudinal degradation functionality	*Longitudinal & lateral degradation functionality*	*Longitudinal & lateral degradation functionality*
Platoon engaging	Only from behind (by single truck & existing platoon)	*From behind (by single truck & existing platoon) and from the front by single truck*	*From behind (by single truck & existing platoon), from the front by single truck and merging of single trucks in existing platoon*
System & environment monitoring	System itself + Driver (environment)	*System itself*	*System itself*
Fallback of the DDT (dynamic driving task)	Driver; as long it is safe and the driver can react in time	*System (for x seconds)*	*System*
Safe state	Fail-safe (driver in control after reaction time of the driver)	*Stopped in ego lane or rightmost lane*	*Stopped in safe stop area (e.g. fuel station)*
Timegap (Steady state @ 80 kph)	>0.8s	*>0.5s*	*>0.3s*
Maximum number of trucks	7 (maximum for simulations & verifications)	*No principle technical limitation as for now*	*No principle technical limitation as for now*
Platoon formation (orchestrated) possible	Yes	*Yes*	*Yes*

3.3. Platooning level A description

To describe **platooning level A** more in detail following cluster were used:

- Platoon characteristics
- Relevant high-level manoeuvres
- HMI/Driver interaction
- Environmental conditions
- Vehicle configuration

1. **Platoon characteristics:**
    a. The Following Truck(s) and Tailing truck are automated in longitudinal direction (Acceleration/Deceleration) by means of decentralized coordinated time gap adaptation.
    b. Lateral control (steering) remains at the driver responsibility (driver may turn on steering assist or active steering based on local sensors in the truck. The lateral functions are not coordinated on platoon level).

c. The time gap is at minimum 0.8s at maximum cruise velocity while steady state driving if string stability and vehicle performance is given. If this time gap can't be reached also larger time gaps (e.g. up to 1.5s) are possible. Actual time gap "range" (per truck) depends on OEM strategy, condition (e.g. downhill driving, speed, infrastructure advice, string stability), HMI driver preference (short, long) to be comfortable with, …
d. The speed range of the platoon varies from 0 to the maximum set speed of the driver in accordance to the allowed speed of the specific country. Engaging or formation of the platoon application is only possible above a certain speed (first assumption is 30 km/h). Only autonomous braking is allowed below a certain speed (first assumption is 30 km/h).
e. In accordance to SAE J3016 the fall back performance of Dynamic Driving task remains at the driver therefore a fail-safe system architecture is sufficient as long as it complies with safety assessment.
f. The leading truck has the option to control the vehicle speed by advanced driver support systems (like advanced ACC, CC,..) or manually (acceleration/deceleration).
g. The maximum number of trucks considered in ENSEMBLE for platooning level A is up to 7. In practise this means that for simulation and testing purposes a maximum number of 7 will be considered. In general the technical choices will be made using scalability as a requirement. Actual number on the road may be different due to authority, road or technical restrictions.
h. Each ego vehicle driver activates it's platooning system only on allowed highways and released roads.
i. The platoon needs to be operated in a safe way.
    - Since the communication system is not 100% reliable (e.g. V2V communication) the time gap needs to be adapted (increased) accordingly in an automatized way („graceful degradation").
    - Road restrictions may cause a demand for an increased time gap or reduce of maximum velocity. This is communicated via e.g. I2V.
    - The platoon can handle cut-in and cut-through situations and react in a safe manner to that (e.g. gap adaptation)
    - Based on the safety assessment the driver(s) may obtain safety critical tasks in case of a malfunctioning longitudinal control.
    - Situations when a truck in the platoon performs full braking (either by the system (e.g. AEB) or by the driver (overrule)) shall be handled automatically in a safe manner.
j. All members of the platoon shall be equipped with wireless V2V communication and environmental perception sensors.
k. All members of the platoon shall be able to perform each role (leading, following, trailing) in a platoon.
l. Automated re-ordering of the platoon is excluded.

2. **Relevant high-level Manoeuvres:**
    - Platoon Formation (no re-ordering)
    - Platoon Engaging (only from the rear)
    - Platooning
    - Platoon Disengaging

The high level manoeuvres in platooning level A are placed in context of each other. Within the manoeuvres already specific use case examples are given which will be detailed in this report and further specified (functionality) in D2.4 and D2.6.

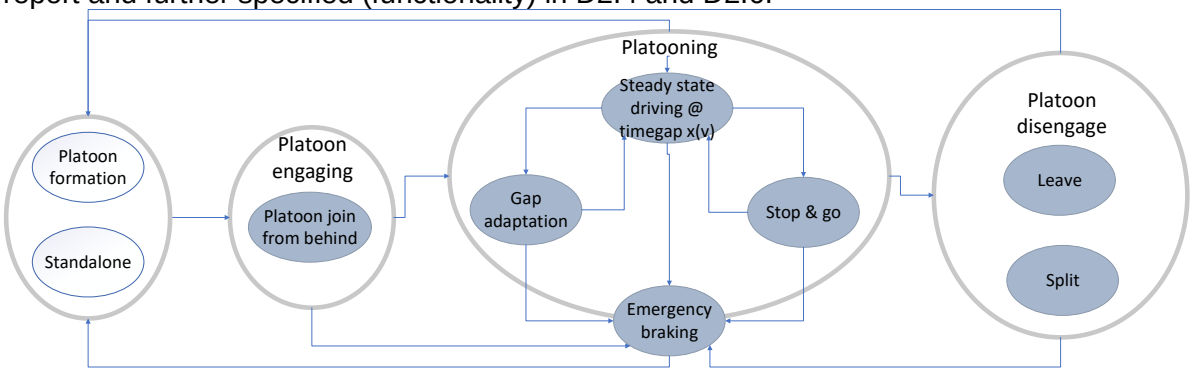


Figure 3-3: High level manoeuvres interaction

3. **HMI/Driver interaction (OEM specific):**
    a. The Leading -, Following – and Trailing Truck driver needs a special education and training to do platooning.
    b. Happy/successful flow: The HMI reflects in principle the high level manoeuvres. In this way the transition from manually driving to automatized driving and vice versa needs to be transparent for the driver.
        - The HMI provide the possibility to switch on and off Platooning system (sending announcement via V2V if switched on),
        - Accept or deny Platoon formation / Engaging is processed in an automated way without driver confirmation.
        - Driver has the possibility to disengage from the platoon (platoon → standalone)
        - The HMI may have different information shown on the display depending on the trucks position within the Platoon
        - Changes that do not require input or actions from the drivers can also indicated in the HMI, e.g. new L-truck, ego-vehicles (new) position in the platoon, in order to keep the driver in-the-loop.
    c. Failure: Depending on the safety assessment some dedicated requirements may come up.
    d. Driver overruling “Intentional”: The driver either brakes or steers away (exits, change lanes) upon agreed specifications. Such intentional events in the platoon which requires input, actions or awareness from the other drivers should be clearly indicated in the HMI.
    e. Driver overruling “Unintentional”: The HMI should alert the drivers. If the driver has not taken longitudinal control the platoon system mitigate the criticality of the situation and the system initiate a minimum risk manoeuvre like adapting the time gap.

4. **Environmental conditions:**
    a. The platoon shall be able to drive on released roads
    b. The current intention is that passing/close through toll gate area needs to be considered by the system. Depending on the type of tollgate (either conventional or normal highway with overhanging camera/toll system) the reaction of the system

may differ. Ego vehicle truck e.g. need to reduce the transmit power due to regulatory reasons (see ETSI TS 102 792 V1.1.1).
During the project the handling of tollgates will be further discussed from both safety (e.g. loosing V2V communication due to reducing power), HMI and technical perspective which may change the view of handling the tollgates.

c. Platoon should remain in tunnels (although GPS fix may be lost) as long as Platooning is given
    - Driver leaves platoon if a special restriction (e.g. platooning not allowed in the tunnel) is present
    - Platoon engaging is automatically prohibited
d. If an unforeseen environmental condition changes (slope, curves,…) or the one of the truck drivers perceives a critical situation he is able to leave the platoon and informs why.
e. The driver is responsible to monitor the environment and may decide when it is not safe anymore to platoon / if the time gap needs to be adapted.

5. **Vehicle configuration:**
   There is no limitation regarding the vehicle configuration foreseen as long the ego vehicle fulfils the minimum platooning capabilities. The decision if a truck could become a platoon candidate or a leader remains at the OEM.

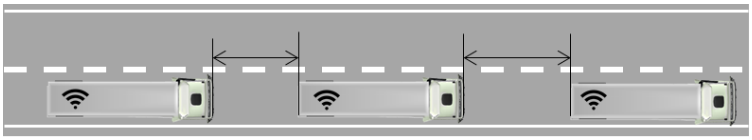
Remark: Depending on the functional safety analysis the description may change. Updates will be reflected in D2.3.

4. USE CASES PLATOONING LEVEL A

4.1. Introduction

To derive use cases, more specific the high level use cases, a methodology must be followed to assure a level of completeness. In this section the methodology to derive a use case from a scenario will be discussed.

Use-cases describe how a system shall respond under various conditions to interactions from the user of the system or surroundings, e.g. other traffic participants or road conditions. The user is called actor on the system and is often but not always a human being. In addition, the use-case describes the response of the system towards other traffic participants or environmental conditions. The use-cases are described as a sequence of actions, and the system shall behave according to the specified use-cases. The use-case often represents a desired behaviour or outcome.
The goal of the use cases here is to be able to derive the functionalities (and related requirements) as needed for the ENSEMBLE project which will be further specified in the deliverable 2.4 and 2.6. The template that will be used for the use cases within this document is the following.

ID	Unique identifier.
Name	Name of the use case.
Story	Short description of the use case
Initial condition	State of the environment (infrastructure & vehicles), system (vehicle, platooning system, …) & driver (in each vehicle).
Trigger	E.g. Driver pushes the platoon system activation button on the HMI
Diagram	Sketch:  Legend of the sketch icons: Other vehicle HMI Fault / failure Stand still object Decreasing velocity Increasing velocity “Cloud” / Service Driver V2X Other Sequence in time: *Bullet points* 1. *A* 2. *A* 3. *A*
Final condition	State of the environment (infrastructure & vehicles), system (vehicle, platooning system, …) & driver (in each vehicle).

As a result, a use case is a detailed scenario including the manoeuvres, ODD and events.

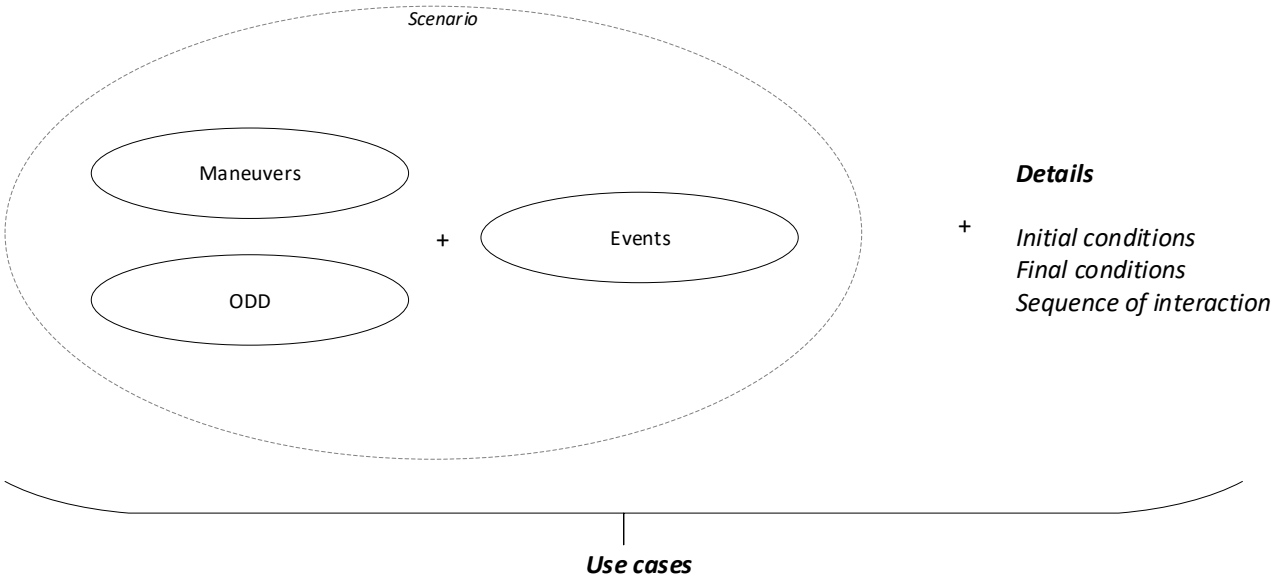


Figure 4-4: Scenario → use case

A scenario is a quantitative description of the ego vehicle, its activities and/or goals, its static environment, and its dynamic environment. From the perspective of the ego vehicle, a scenario contains all relevant events.
In ENSEMBLE scenarios will mainly be used for scenario based assessment. Scenarios will be described not as an entity for the development process, but will be described by the following parts:

- Manoeuvre ("activity")
- ODD (operational design domain)
- Events

The scenarios will be extended towards use cases which add more information regarding specific internal system interactions, specific interactions with the actors (e.g. driver, I2V) and will add different flows (normal & alternative) where necessary.

4.2. Manoeuvre ("activity")

4.2.1. Introduction to Manoeuvre ("activity")

A particular (dynamic) behaviour which a system can perform (from a driver or other road user perspective) and that is different from standing still, is being considered a manoeuvre.
The manoeuvres are on a high level comparable to what can be presented to the user on e.g. the HMI considering the "mode" of the system so that he is informed.

4.2.2. Platooning level A manoeuvres

The platoon behaviour, both orchestrated platooning and ad-hoc platooning can be described by 4 manoeuvres, see **Figure 4-5**:

Ad-hoc non real-time: this does not really make sense

Ad-hoc V2V Real-time – Bottom up:

- Situation: Vehicles driving in very close proximity and randomly form platoon whilst driving
- Max. range: Limited by range of DSRC (e.g. 300 – 800 m, from 802.11p ITS G5 specifications)
- Matching: made by the drivers (decentralised)
- Instrumentation: only DSRC V2V communication
- Potential applications: multi-brand, multi-fleet platooning with very high adoption rates
- Applicable layers: mainly the operational and strategic layers

Orchestrated non real-time – Top down:

- Situation: Vehicles widely apart but with significant platooning potential (in time and distance). Form platoons while driving of while standing still (using parking spots)
- Max. range: Limited by micro-business case and time-to-platoon
- Matching: Planned in advance from planning/TMS data (centralised)
- Instrumentation: DSRC (V2V) + long range communication (cellular) + GPS positioning apps
- Potential applications: mono-brand and multi-brand, mono-fleet platooning
- Applicable layers: mainly the strategic and services layers

Orchestrated real-time:

- Situation: Match made while driving for vehicles in relative close proximity (max. 2000 m inter-vehicle distance) or using parking areas for longer distance platooning
- Max. range: Limited by time-to-platoon and micro-business case
- Matching: through cloud-based / telematics solutions (centralised). Match accepted by drivers (decentralised)
- Instrumentation: DSRC (V2V) + long range communication (cellular) + GPS positioning apps
- Potential applications: mono-brand and multi-brand, multi-fleet platooning
- Applicable layers: all layers from operations to service level

The manoeuvres are the result from the works as described in the state of the art documentation (Requirements Review from EU projects D2.1 ENSEMBLE).

Reflecting to orchestrated and ad-hoc platooning, the main difference between ad-hoc platooning and orchestrated platooning is the involvement of a platoon formation process for orchestrated platooning to strategically find platoons / vehicles that can platoon together to benefit from it (e.g. from logistical perspective or fuel perspective).

- Platoon formation
- Platoon engaging
- Platooning
- Platoon disengaging

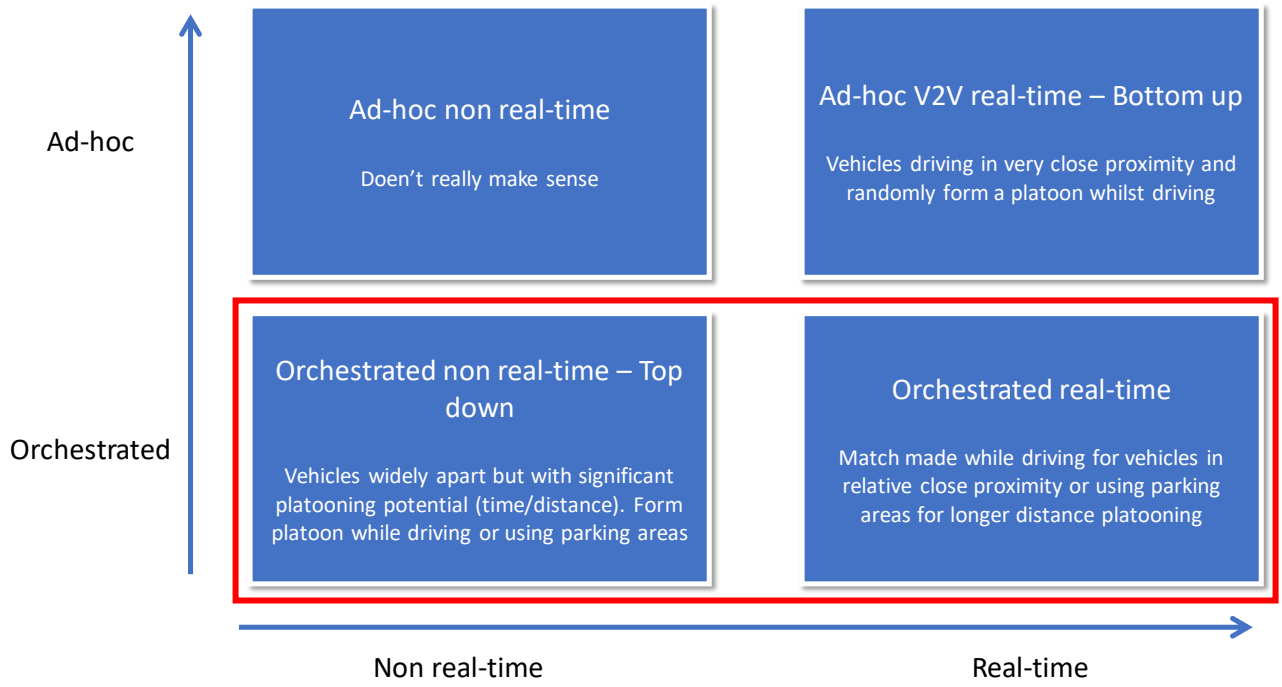


Figure 4-5: Platoon formation (red box); from [TNO 2017 R10629]

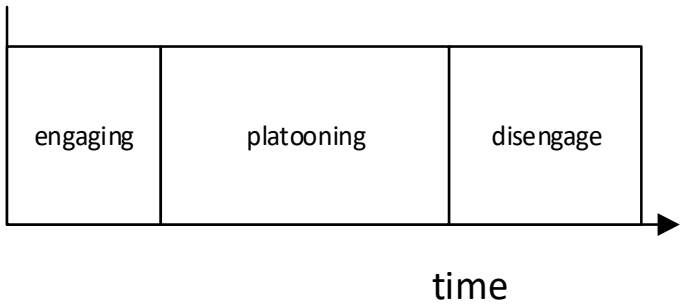


Figure 4-6: Manoeuvre example in a time sequence for ad-hoc platooning

For each of the manoeuvres a definition will be given.

Table 2: Manoeuvres of Ensemble for platoon level A

ID	Manoeuvre name	Description
M1	Platoon formation	Platoon formation is the process before platoon engaging in which it is determined if and in what format (e.g. composition) trucks can/should become part of a new / existing platoon. Platoon formation can be done orchestrated real time or non-real time. Platoon candidates may receive instructions during platoon formation (e.g. to adapt their velocity, to park at a certain location) to allow the

		start of the engaging procedure of the platoon.
M2	Platoon engaging	Using wireless communication (V2V), the Platoon Candidate (single vehicle or existing platoon) sends an engaging request to the platoon target (single vehicle or existing platoon) in front. When conditions are met, the system starts to decrease the time gap between the trucks to the platooning time gap.
M3	Platooning	A group of two or more automated cooperative vehicles are in line, maintaining a close distance using wireless communication (V2V), typically such a distance to reduce fuel consumption by air drag, to increase traffic safety by use of additional ADAS-technology, and to improve traffic throughput because vehicles are driving closer together and take up less space on the road.
M4	Platoon disengage	The ego-vehicle can decide to leave the platoon, to split the platoon into 2 new platoons (only a following truck can perform this action). When conditions are met the truck(s) starts to increase the gap between the trucks to a safe non-platooning gap. The disengaging is completed when the gap is large enough which is depends on the operational safety based on vehicle dynamics and human reaction times is given.

4.3. ODD (operational design domain) & vehicle configuration

4.3.1. Introduction to ODD (operational design domain) & vehicle configuration

The ODD should describe the specific conditions under which a given automation function is intended to function. The ODD is the definition of where (such as what roadway types and speeds) and when (under what conditions, such as day/night, weather limits, etc.) an automation function is designed to operate.
The ODD would include the following information at a minimum to define each automation functions capability limits/boundaries:
• Roadway types (interstate, local, etc.) including infrastructure elements (e.g. traffic lights, toll gates) on which the automation function is intended to operate safely;
• Geographic area (city, mountain, desert, etc.);
• Speed range;
• Environmental conditions in which the automation function will operate (weather, daytime/night-time, etc.); and
• Other domain constraints.
Next to the ODD also the vehicle configuration needs to be in place. Example properties are mass, brake capabilities.

4.3.2. Platooning level A ODD (operational design domain) & vehicle configuration

It is expected that the final ODD and vehicle configuration will change during the ENSEMBLE project and will be fully defined after functional safety analysis (task 2.4). When no sensor to

monitor the ODD is available, the driver will be in charge of ODD monitoring.
Functional safety discussion will include at least the following points.
Environmental conditions & certain traffic:

- Low visibility conditions (Fog / Night time driving /Sun's glare); minimum visibility of X
- Heavy traffic (slower speeds); maximum traffic density of X
- Slippery road conditions (Ice / Rain); minimum grip level of X
- Emergency vehicle approaching
- Humans or big animals on the road
- Approaching a scene of an accident

Infrastructure

- Highway or comparable road
- Driving uphill; maximum gradient of X
- Driving downhill; maximum gradient of X
- Driving in tunnels
- Driving near highway entry/exit ramps
- Obstacle on the lane; minimum obstacle size of X
- Curve radius of the road; minimum road curvature of X
- Unexpected object/vehicle on the road shoulder
- Special zone policy (toll gates, construction zones, bridges, city-limits)
- Maximum velocity per country in the EU

Vehicle configuration

- EBS status
  - Unlearned
  - Partly learned (mass only)
  - Fully learned
  - False learned
- Air pressure
  - 8 to 12bar
- Temperature braking pads/disc
  - Env. Temp. to 350°C
- Braking pads aging
  - Brand new (green)
  - Glazed brake discs
  - Used
  - Aged
- Vehicle mass
  - At least 12t to 44t. Higher and lower masses to be further discussed and analysed during the project.

The parameters (X) values need to be agreed which will be done within task 2.4. The value of the parameters will be reflected later in e.g. the update of this document, being D2.3.

4.4. Event

4.4.1. Introduction to event

An event marks the time instant at which a transition of a state occurs, such that before and after an event, the system is in a different state.

Helpful here is to look at the interfaces that the “system” has with external context. If we consider here the strategic, tactical and operational layer as the “system” (as the service layer will only be implemented with an “example application” and see the infrastructure which is studied in ENSEMBLE as input/output) then the following main interfaces will be there for the system:

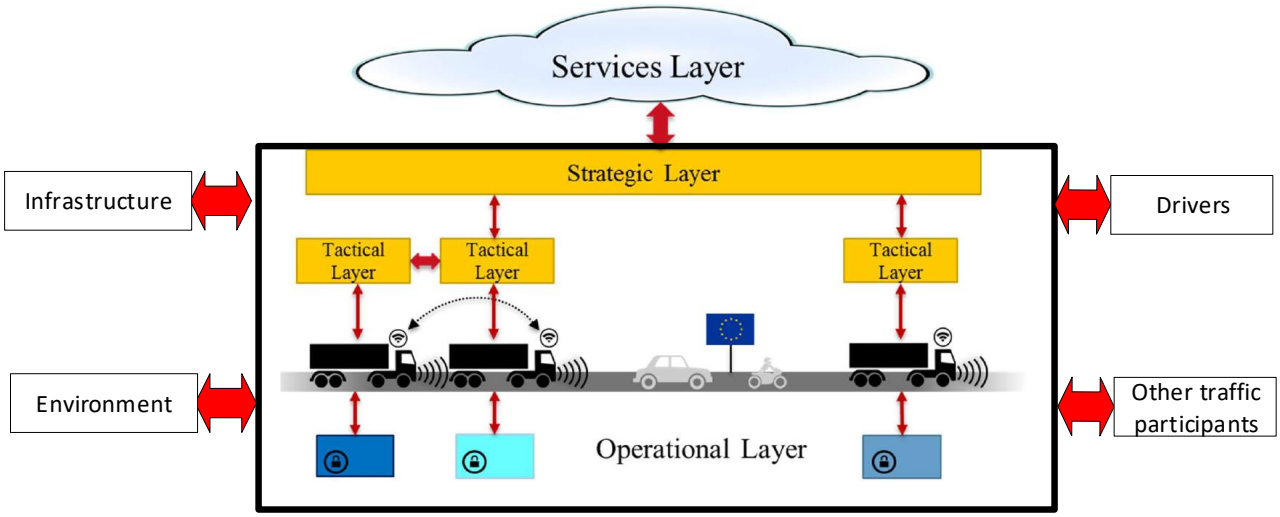


Figure 4-7: Main interfaces

It can be observed that interaction with the driver, other traffic participants, the environment (e.g. visible lane markers and weather conditions), the platoon service provider (I2V/IOT) and the infrastructure (via I2V or road sign recognition) is included.

4.4.2. Platooning level A events

Below a list with obvious events is defined which will be used to derive the high level use cases within this document. The list is a set which contains the most important external events and is based on experience from the D2.1, state of the art.

Table 3: Events of Ensemble

ID	Event name	Description
E1	Cut-in	The cut-in object (car, motorcycle, truck) can cut-in anywhere in the platoon and also the duration may vary. Once the cut-in vehicle leaves the platoon this is called a cut-out action. Depending on the duration of the cut-in the reaction of the system may vary.
E2	Normal braking vehicle (to stop) in front of the leader	This is a typical event which happens in dense traffic when approaching a traffic jam. The vehicle in front of the platoon slowly decelerates because of the traffic jam. The platoon system has to handle this situation in a safe way.
E3	Emergency braking by a platoon truck (either by driver / AEB)	Both the AEB system and the driver may cause full braking (maximum braking) which is an event that shall be handled in the platoon.
E4	Limit received via	Via I2V certain limits can be received (e.g. gap, velocity) which

	I2V	are relevant for a special zone on the road (e.g. at a bridge).
E5	Failure of the system / system status (e.g. packet loss)	Because of a system failure or limited performance of system components (e.g. packet loss) a certain reaction of the platoon system may be required. Some options are handover to the driver (transition of control) or gap adaptation.

4.5. Platooning level A use cases

Here the high level use cases shall be reflected which form the basis to derive the technical specifications as reflected in e.g. D2.4 and D2.6. The goal of the use cases is to describe the application level behavior of the whole platooning system.
The high level use cases are derived from the manoeuvres and events earlier defined:

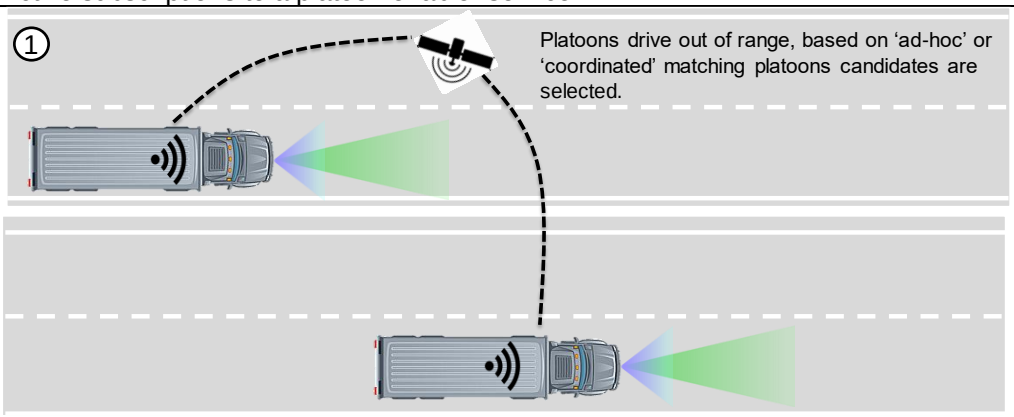
- Platoon formation
  - Platoon formation based on generic match making (Orchestrated non real-time)
  - Platoon formation based on just extended awareness (Orchestrated real-time)
- Engaging to platoon
  - Join from behind by single vehicle
  - Merge from behind by platoon
- Platooning
  - Steady state platooning
  - Follow to stop (&go)
  - Emergency braking (caused by AEB system or manual overrule)
  - Platoon gap adaptation
    - I2V interaction
    - Cut-in (long time)
    - Cut-in (short time) (“Cut-through”)
    - System status (e.g. packet loss)
- Disengaging platoon
  - Leave
  - Split

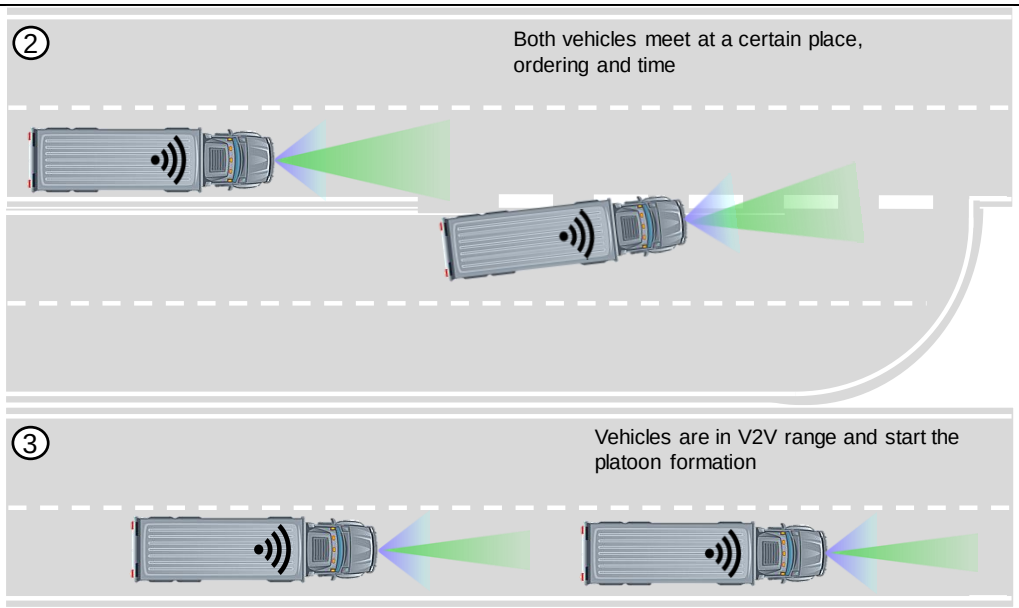
If there are relevant environmental conditions to mention where we expect specific system behaviour, then a “one liner / assumption” with the desired reaction of the system is defined. This can form the basis for the detailing later in the specification phase of the project (D2.4, D2.6 and WP4). The one liner / assumption can be found in section 4.5.5.
The use cases will reflect the minimum implementation to make the function work. Optimization features to optimize the behaviour will be elaborated in D2.4. An example is an advice system to the driver what the advised current cruise velocity is. This would optimise the platoon velocity in combination with still having the possibility to engage by a new truck.

4.5.1. Platoon formation

Platoon formation based on generic match making (Orchestrated non real-time)

ID	1.1
Name	1.1: Platoon formation – based on generic match making (Orchestrated non real-time)
Story	At least two separated trucks have active subscriptions to a platoon enabler service. The platoon enabler service will give a recommendation based on some business logic that the two vehicles should form a platoon at some location and at some time in

<table>
<tr><td></td><td>the future. The rendez-vous could be in a few seconds or in a few days.
Information about the planned platoon along with a ticket valid for the platoon is sent from the offboard system to the vehicles. An offboard service can help with platoon awareness to help coordinate vehicles to the rendezvous.
At the rendez-vous the two vehicles identify and authorize each other with help of the platooning ticket. After this normal engage procedure can start.</td></tr>
<tr><td>Initial condition</td><td>
<table>
<tr><td>Operation area:</td><td>Any of the operational area inside the ODD for Platooning Level A</td></tr>
<tr><td>Environmental conditions:</td><td>Any environmental condition inside the ODD for Platooning Level A</td></tr>
<tr><td>Target vehicle(s):</td><td>Truck or active platoon registered with the platoon enabler.</td></tr>
<tr><td>Ego vehicle (s):</td><td>Truck or active platoon registered with the platoon enabler.</td></tr>
<tr><td>Application status target vehicle(s):</td><td>Steady state platooning (active platoon) or standalone (single vehicle)</td></tr>
<tr><td>Application status Ego vehicle</td><td>Steady state platooning (active platoon) or standalone (single vehicle)</td></tr>
<tr><td>Driver status target vehicle(s):</td><td>Aware</td></tr>
<tr><td>Driver status Ego vehicle</td><td>Aware</td></tr>
<tr><td>System status</td><td>No failure</td></tr>
</table>
</td></tr>
<tr><td>Trigger</td><td>Active subscriptions to a platoon enabler service</td></tr>
<tr><td>Diagram</td><td> 
</td></tr>
</table>



1.1 The platoon enabler (offboard service) matches some vehicles by sending a recommendation to form a platoon together. The recommendation is based on the business logic of that service and may take into account as much information as the fleet owner is willing to share with that service (no need to standardize)
[Optional] Example rFMS connection to enable live matching

1.2 The platoon enabler sends information to the two vehicles about the platoon opportunity. This may be done just before they should start or well in advance. Information in the platoon opportunity may include
- Recommended Rendez-vous point and time
- Opportunity duration
- Recommended split point
- Platoon Ticket for Identification and authorization
- What service it originated from (The vehicle may be connected to several platoon enablers)
- Validity parameters (e.g. time, location, valid vehicles, …)
- Recommended platoon configuration e.g. vehicle order (this could be put in a driver app as well, then no standardization needed)

1.3 Vehicle activates platooning (enters driving alone state)

1.4 [Optional] Relay ego vehicle information to planned partners via the platoon enabler service (extended platoon awareness). Standardization needed

1.5 [Optional] Service specific extended platoon awareness e.g driver apps that relays information to each other. No standardization needed so it do not interact with the vehicle. It is up to each service

2 Vehicles are in V2V range of each other and identify its partner
[Optional] Drivers manually arrange vehicles in right order

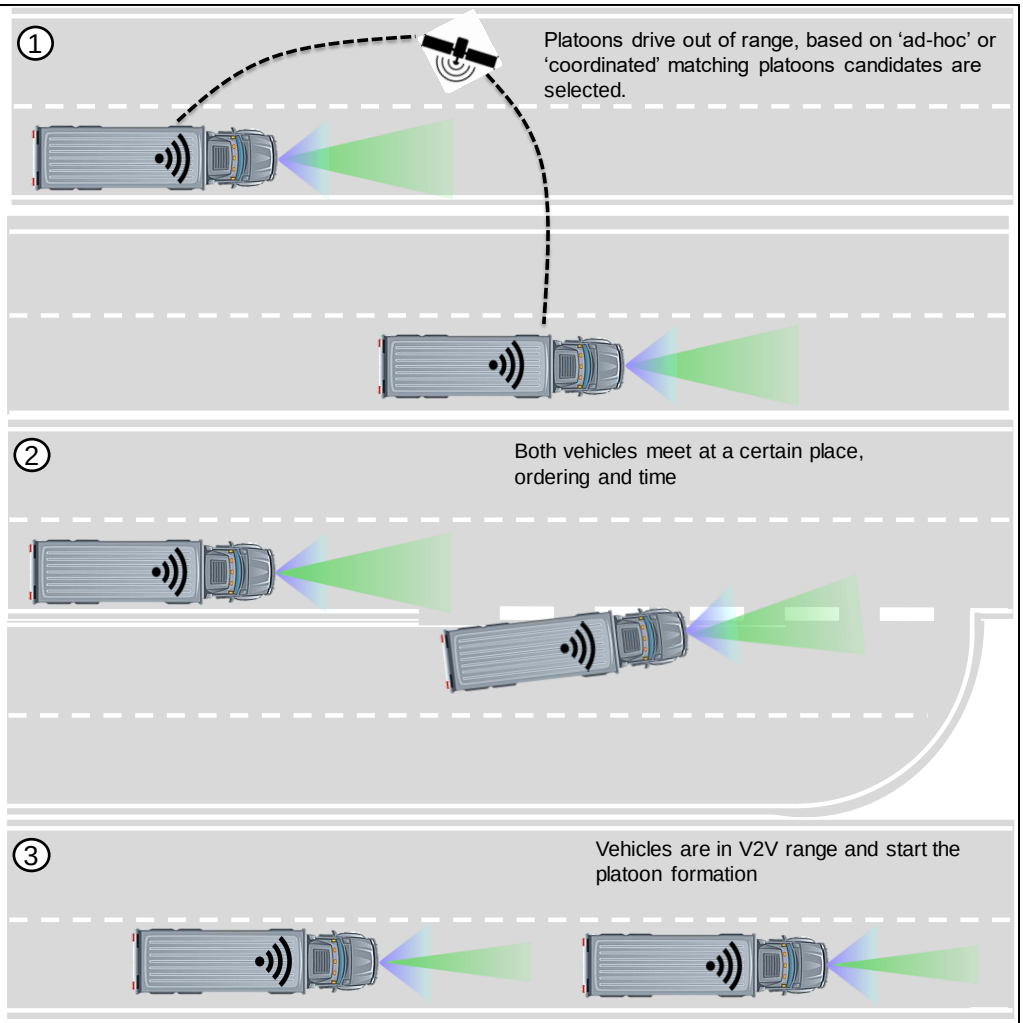
3 Vehicles starts “Platoon engage”-use case with optional authentication and authorization parameters set

Final condition	Operation area:	Any of the operational area inside the ODD for Platooning Level A
	Environmental conditions:	Any environmental condition inside the ODD for Platooning Level A
	Target vehicle(s):	Truck or active platoon within V2V range of ego vehicle(s)
	Ego vehicle (s):	Truck or active platoon within V2V range of target vehicle(s).

	Application status target vehicle(s):	Steady state platooning (active platoon) or standalone (single vehicle)	
	Application status Ego vehicle	Engaging possible	
	Driver status target vehicle(s):	Aware	
	Driver status Ego vehicle	Aware	
	System status	No failure	

Platoon formation based on just extended awareness (Orchestrated real-time)

ID	1.2	
Name	1.2: Platoon formation – based on just extended awareness (Orchestrated real-time)	
Story	At least two separated trucks have active subscriptions to a platoon enabler service. The platoon enabler service will give a recommendation based on some business logic that the two vehicles should form a platoon at some location and at some time in the future. This may be a dynamic point that is real time communicated to the vehicles. Information about the planned platoon along with an optional ticket valid for the platoon is sent from the offboard system to the vehicles. An offboard service will help with platoon awareness to help coordinate vehicles to the rendez-vous. Optionally at the rendez-vous the two vehicles identify and authorize each other with help of the platooning ticket. After this normal engage procedure.	
Initial condition	Operation area:	Any of the operational area inside the ODD for Platooning Level A
	Environmental conditions:	Any environmental condition inside the ODD for Platooning Level A
	Target vehicle(s):	Truck or active platoon registered with the platoon enabler.
	Ego vehicle (s):	Truck or active platoon registered with the platoon enabler.
	Application status target vehicle(s):	Steady state platooning (active platoon) or standalone (single vehicle)
	Application status Ego vehicle	Steady state platooning (active platoon) or standalone (single vehicle)
	Driver status target vehicle(s):	Aware
	Driver status Ego vehicle	Aware
	System status	No failure
Trigger	Active subscriptions to a platoon enabler service	

Diagram	

1.1 Vehicle activates platooning (enters driving alone state)
1.2 The platoon enabler (offboard service) matches some vehicles to form a platoon together. The recommendation is based on the business logic of that service and may take into account as much information as the fleet owner is willing to share with that service (no need to standardize). Both vehicles have an rFMS connection to the platoon enabler to enable live matching.
1.3 [Optional] The platoon enabler sends information to the two vehicles about the platoon opportunity. Information in the platoon opportunity may include
- Recommended Rendez-vous point and time
- Opportunity duration
- Recommended split point
- Platoon Ticket for Identification and authorization
- What service it originated from (The vehicle may be connected to several platoon enablers)
- Validity parameters (e.g. time, location, valid vehicles, …)
- Recommended platoon configuration e.g. Vehicle order (this could be put in a driver app as well, then no standardization needed)

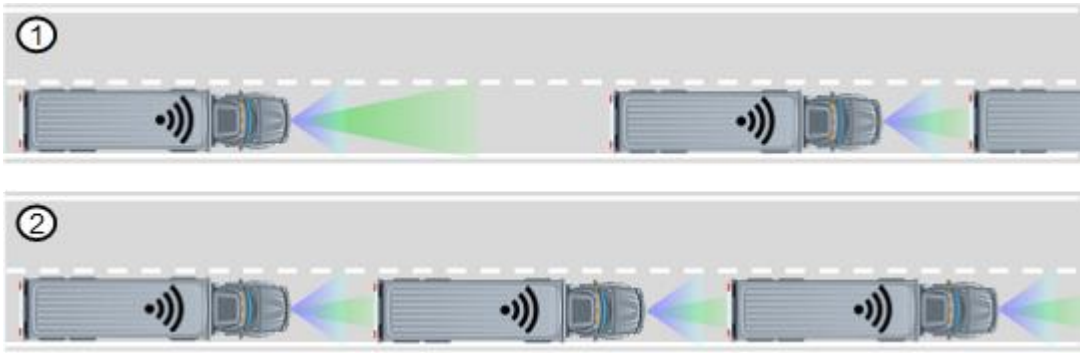
1.4 Relay ego vehicle information to planned partners via the platoon enabler service (extended platoon awareness). (Standardization needed)
1.5 [Optional] Service specific extended platoon awareness e.g. driver apps that relays information to each other. No standardization needed so it do not

<table>
<tr><td></td><td>interact with the vehicle. It is up to each service
2 Vehicles are in V2V range of each other and identify its partner
2.1 [Optional] Drivers manually arrange vehicles in right order
3 Vehicles start “Platoon engage”-use case (Optionally uses a platooning ticket to identify and authorize the join to make sure they are the planned platoon and belong to the same service)</td></tr>
<tr><td>Final condition</td><td>
<table>
<tr><td>Operation area:</td><td>Any of the operational area inside the ODD for Platooning Level A</td></tr>
<tr><td>Environmental conditions:</td><td>Any environmental condition inside the ODD for Platooning Level A</td></tr>
<tr><td>Target vehicle(s):</td><td>Truck or active platoon within V2V range of ego vehicle(s)</td></tr>
<tr><td>Ego vehicle (s):</td><td>Truck or active platoon within V2V range of target vehicle(s).</td></tr>
<tr><td>Application status target vehicle(s):</td><td>Steady state platooning (active platoon) or standalone (single vehicle)</td></tr>
<tr><td>Application status Ego vehicle</td><td>Engaging possible</td></tr>
<tr><td>Driver status target vehicle(s):</td><td>Aware</td></tr>
<tr><td>Driver status Ego vehicle</td><td>Aware</td></tr>
<tr><td>System status</td><td>No failure</td></tr>
</table>
</td></tr>
</table>

4.5.2. Engaging to platoon

The “engage to platoon from behind” use case is the main use case for adding one more vehicle to the platoon. The use case merging an existing platoon to another platoon or single platoon candidate vehicle from behind is from a technical perspective similar, so here the focus is only on describing how a single vehicle joins a platoon or single platoon candidate vehicle from behind.

<table>
<tr><td>ID</td><td>2.1</td></tr>
<tr><td>Name</td><td>Join from behind by single vehicle</td></tr>
<tr><td>Story</td><td>Using wireless communication (V2V), the Platoon Candidate (single vehicle or existing platoon) sends an engaging request to the platoon target (single vehicle or existing platoon) in front. When conditions are met the system starts to decrease the time gap between the trucks to the platooning time gap.</td></tr>
<tr><td>Initial condition</td><td>
<table>
<tr><td>Operation area:</td><td>Any of the operational area inside the ODD for Platooning Level A</td></tr>
<tr><td>Environmental conditions:</td><td>Positive conditions for platooning, other conditions detected either by driver or system.</td></tr>
</table>
</td></tr>
</table>

	Target vehicle(s):	Steady state platoon or a single platoon candidate that can accept to be extended with one more vehicle. The platoon is signalling that the platoon is joinable by the trailing truck.
	Ego vehicle (s):	Driven at a safe distance behind the last vehicle of the platoon: • Single platoon candidate or last vehicle in platoon must be within sensor view and in lane. • Single platoon candidate or last vehicle in platoon must be within V2V range (able to communicate reliably). Not necessary to have V2V contact with other vehicles in the platoon. • No intruder between Ego and target vehicle. • Velocity within platooning range. Advanced assist system (e.g. ACC) activated.
	Application status target vehicle(s):	Platooning HMI: Platooning status on HMI.
	Application status Ego vehicle	advanced assist system (e.g. ACC) HMI: Platooning candidate
	Driver status target vehicle(s):	Aware
	Driver status Ego vehicle	Aware
	System status	No failure of internal systems and communication (V2V) is online. Sensors characteristics required for platooning ok.
Trigger	• The ego application and the platoon application is in 'Joinable' mode. • The ego vehicle detects a joinable signal through V2V communication (message to be inserted).	
Diagram	<u>Use case sequence:</u>  1.1 The ego vehicle evaluates platooning opportunity and verifies conditions to initiate join action. 1.2 The ego vehicle sends a request to join to the target vehicle. 1.3 The platoon system evaluates the join request and accepts the request. The trailing vehicle can perform this automated action using the shared platoon state of the platoon. 1.4 The V2V platooning communication is setup, including security and encryption keys. 1.5 Both ego and target vehicles start the platoon communication. 1.6 Both vehicles optionally report the join event to their respective platoon enablers (offboard). 2.1 The ego vehicle closes the distance to the platooning distance. 2.2 If needed the platoon reduces speed to enable the ego vehicle to join the platoon. 2.3 Once the distance gap is decreased the platoon is in steady state platooning and if	

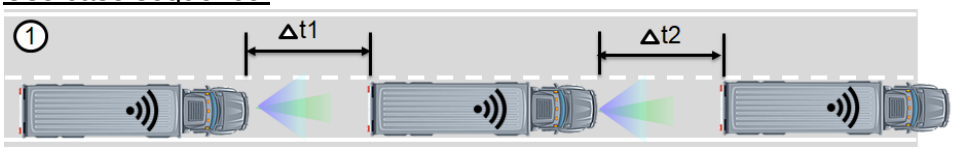
	needed the speed is increased to target speed.	
Final condition	Operation area:	Any of the operational area inside the ODD for Platooning Level A
	Environmental conditions:	N/A
	Target vehicle(s):	Steady state platooning with now the newly added truck being the new trailing truck.
	Ego vehicle (s):	Steady state platooning as the trailing truck.
	Application status target vehicle(s):	Platooning Shows platooning status on HMI
	Application status Ego vehicle	Platooning Shows platooning status on HMI
	Driver status target vehicle(s):	Aware
	Driver status Ego vehicle	Aware
	System status	Steady state platooning

4.5.3. Platooning

Steady state platooning

The “steady state platooning” use case is the main use case for platooning and describes a platoon running at short inter vehicle distance/time in an efficient formation within the longitudinal control limits described for steady state platooning.

ID	3.1	
Name	Steady state platooning	
Story	A group of two or more automated cooperative vehicles are in line, maintaining a close distance using wireless communication (V2V), typically such a distance to reduce fuel consumption by air drag, to increase traffic safety by use of additional ADAS-technology, and to improve traffic throughput because vehicles are driving closer together and take up less space on the road.	
Initial condition	Operation area:	Any of the operational area inside the ODD for Platooning Level A
	Environmental conditions:	Positive conditions for platooning, other conditions detected either by driver or system.
	Target vehicle(s):	Steady state platoon • Vehicle in front within sensor view, except leading truck. • Vehicle in front within V2V range for the following truck. Reception from minimum 1 closest vehicle in front and to the back are required. • Vehicle in front within V2V range for the trailing truck. Reception from minimum 1 closest vehicle in front is required. Control messages over V2V are sent according to specification.
	Ego vehicle (s):	Steady state platoon • Vehicle in front within sensor view, except leading truck. • Vehicle in front within V2V range for the following

<table>
<tr><td></td><td>
<table>
<tr><td></td><td>truck. Reception from minimum 1 closest vehicle in front and to the back are required.
• Vehicle in front within V2V range for the trailing truck. Reception from minimum 1 closest vehicle in front is required.
Control messages over V2V are sent according to specification.</td></tr>
<tr><td>Application status target vehicle(s):</td><td>Platooning
HMI: Platooning status</td></tr>
<tr><td>Application status Ego vehicle</td><td>Platooning
HMI: Platooning status</td></tr>
<tr><td>Driver status target vehicle(s):</td><td>Aware</td></tr>
<tr><td>Driver status Ego vehicle</td><td>Aware</td></tr>
<tr><td>System status</td><td>All systems are ok.</td></tr>
</table>
</td></tr>
<tr><td>Trigger</td><td>Transition to steady state platooning because relative velocity and relative distance between the trucks within steady state tolerances.</td></tr>
<tr><td>Diagram</td><td><u>Use case sequence:</u>
 

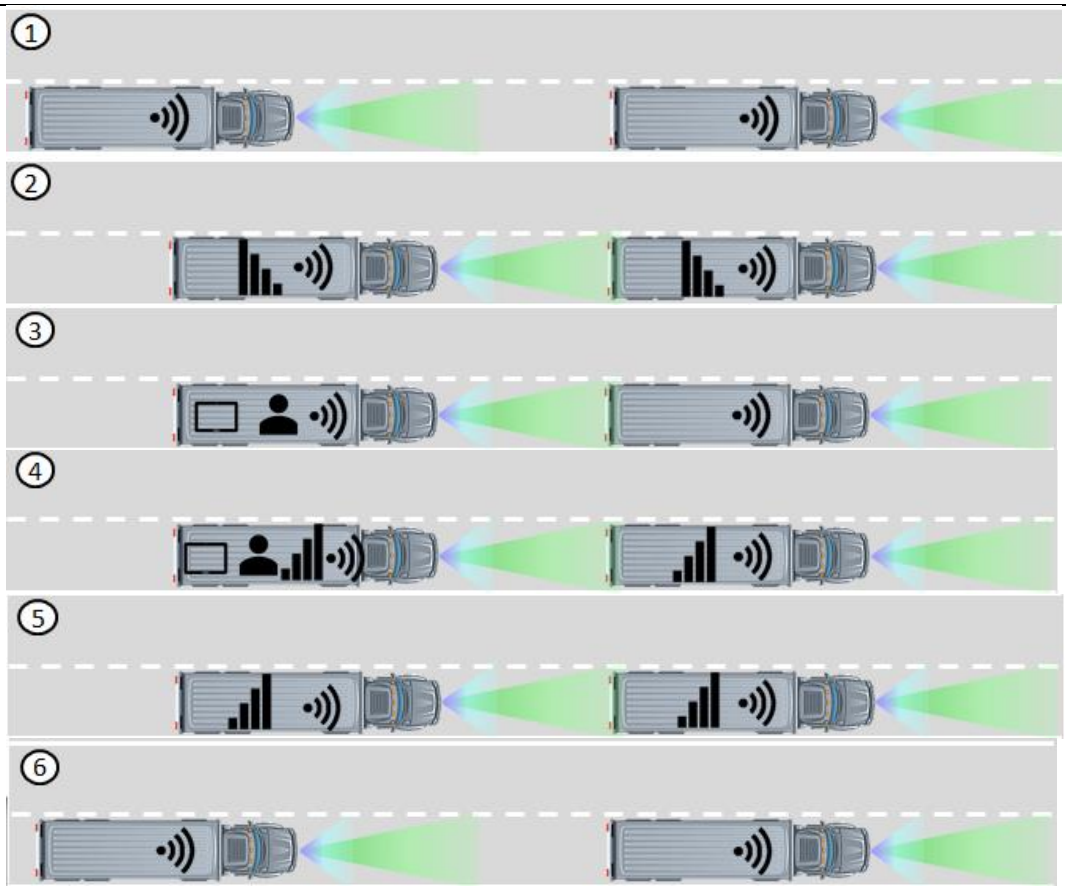
1.a The ego vehicle is receiving platooning information via V2V from vehicles in the platoon. At least from the one in front for the trailing truck and from the one to the back for the leading truck.
1.b The ego vehicle is broadcasting information on V2V to be consumed by the other platoon members.
1.c The ego vehicle regulates safe distance and speed based on V2V, sensor and vehicle internal information.
1.d The ego vehicle sends optionally information to Off Board to be made available to other cloud services
• Platooning status
• Platoon events
1.e The ego vehicle optionally listens to Off Board signals (e.g. to receive platoon formation suggestion)
1.f Follow traffic regulations is the responsibility of each driver.
1.g If the ego vehicle cannot keep up or close a gap it signals that via V2V forward.
1.h If the lead vehicle receives information that a platoon member cannot keep up or close gap the driver can choose to adjust speed / acceleration.</td></tr>
<tr><td>Final condition</td><td>
<table>
<tr><td>Operation area:</td><td>Any of the operational area inside the ODD for Platooning Level A</td></tr>
<tr><td>Environmental conditions:</td><td>Positive conditions for platooning, other conditions detected either by driver or system.</td></tr>
<tr><td>Target vehicle(s):</td><td>Steady state platoon
• Vehicle in front within sensor view, except leading truck.
• Vehicle in front within V2V range for the following truck. Reception from minimum 1 closest vehicle in front and to the back are required.
• Vehicle in front within V2V range for the trailing</td></tr>
</table>
</td></tr>
</table>

		truck. Reception from minimum 1 closest vehicle in front is required. Control messages over V2V are sent according to specification.
	Ego vehicle (s):	Steady state platoon • Vehicle in front within sensor view, except leading truck. • Vehicle in front within V2V range for the following truck. Reception from minimum 1 closest vehicle in front and to the back are required. • Vehicle in front within V2V range for the trailing truck. Reception from minimum 1 closest vehicle in front is required. Control messages over V2V are sent according to specification.
	Application status target vehicle(s):	Platooning HMI: Platooning status
	Application status Ego vehicle	Platooning HMI: Platooning status
	Driver status target vehicle(s):	Aware
	Driver status Ego vehicle	Aware
	System status	All systems are ok.

Follow to stop (&go)

For the “follow to stop” use case two flows will be presented, the main flow and the alternative flow. Currently it is considered that both flows can be implemented by the OEMs.

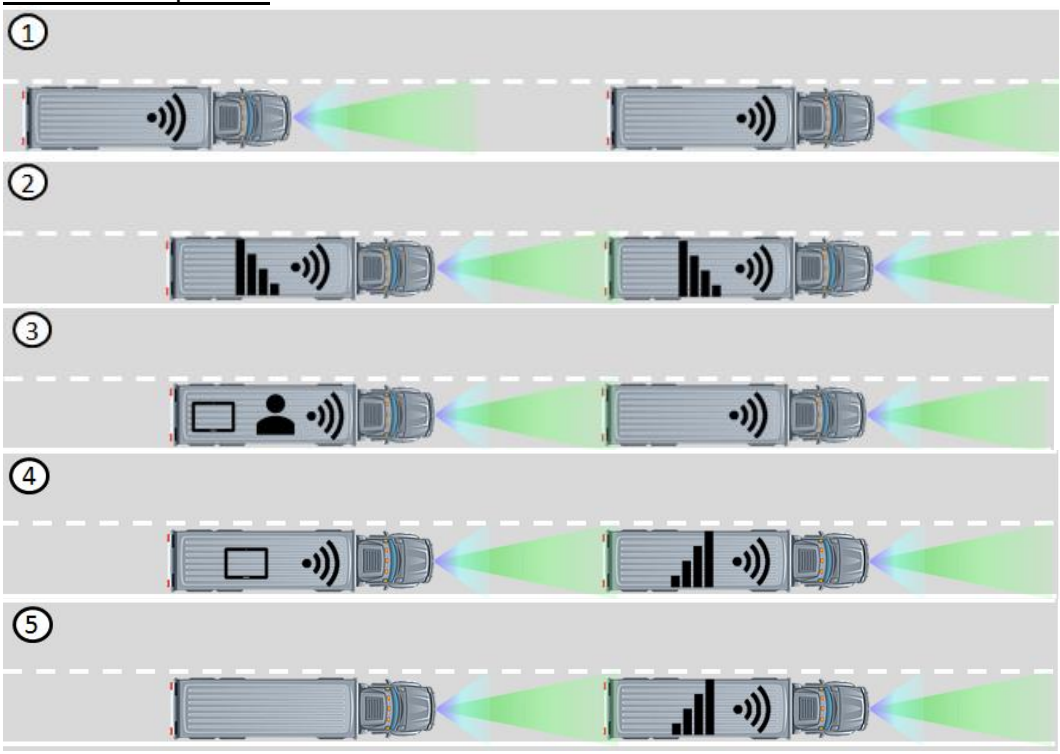
ID	3.2.1	
Name	Follow to stop Main Flow	
Story	In an established steady state platoon; leader is reducing the speed below a certain velocity (first assumption is 30kph) due to ‘normal event’ (traffic jam, toll gate…). The following vehicles will follow the deceleration request, then give back the longitudinal control to the driver when there is no more deceleration request. The driver of the followers should then intervene to come back in platooning condition; If the condition are met, platoon reform automatically (=> no dissolution during the event)	
Initial condition	Operation area:	Any of the operational area inside the ODD for Platooning Level A
	Environmental conditions:	Any environmental condition inside the ODD for Platooning Level A
	Target vehicle(s):	Steady state platooning
	Ego vehicle (s):	Steady state platooning
	Application status target vehicle(s):	Platooning Shows platooning status on HMI
	Application status Ego vehicle	Platooning Shows platooning target active on HMI
	Driver status target vehicle(s):	Aware
	Driver status Ego vehicle	Aware
	System status	No failure of internal system
Trigger	Leading truck velocity < a certain velocity kph (first assumption is 30kph)	
Diagram	Use case sequence:	



1 Initial state : steady state platooning
2 Target vehicle brake, V= below a certain velocity kph (first assumption is 30kph)., follower follow brake request
3 Target vehicle stop decelerating , Platooning mode on hold, V2V active, HMI inform the driver
4 Target vehicle increase speed, (C-A)CC de-activated, V2V active, follower driver press accelerator pedal
5 When follower reach a certain velocity kph (first assumption is 30kph)., C-ACC is active again automatically or resumed by driver
6 Final state : steady state platooning

Final condition	Operation area:	Any of the operational area inside the ODD for Platooning Level A
	Environmental conditions:	Any environmental condition inside the ODD for Platooning Level A
	Target vehicle(s):	Platooning Shows platooning status on HMI
	Ego vehicle (s):	Platooning Shows platooning target active on HMI
	Application status target vehicle(s):	Aware
	Application status Ego vehicle	Aware
	Driver status target vehicle(s):	No failure of internal system
	Driver status Ego vehicle	Steady state platooning mode

	System status	Steady state platooning mode

ID	3.2.2	
Name	Follow to stop Alternative Flow	
Story	In an established steady state platoon; leader is reducing the speed below a certain velocity kph (first assumption is 30kph) due to 'normal event' (traffic jam, toll gate…). The following vehicles will follow the deceleration request, then give back the longitudinal control to the driver when there is no more deceleration request. The driver of the followers should then intervene to come back in platooning condition; if the driver do not intervene until x sec, the truck enter in a leave use case.	
Initial condition	Operation area:	Any of the operational area inside the ODD for Platooning Level A
	Environmental conditions:	Any environmental condition inside the ODD for Platooning Level A
	Target vehicle(s):	Steady state platooning
	Ego vehicle (s):	Steady state platooning
	Application status target vehicle(s):	Platooning Shows platooning status on HMI
	Application status Ego vehicle	Platooning Shows platooning target active on HMI
	Driver status target vehicle(s):	Aware
	Driver status Ego vehicle	Aware
	System status	No failure of internal system
Trigger	Leading truck velocity < a certain velocity kph (first assumption is 30kph).	
Diagram	<u>Use case sequence:</u> 	

	1 Initial state : steady state platooning 2 Target vehicle brake, V= below a certain velocity kph (first assumption is 30kph), follower follow brake request 3 Target vehicle stop decelerating , Platooning mode on hold, V2V active, HMI inform the driver 4 Target vehicle increase speed, (C-A)CC deactivated, V2V active, follower do not take over 5 The follower enters in 'Leave' use case
Final condition	

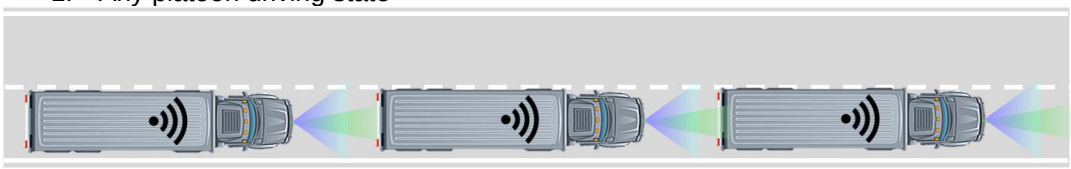
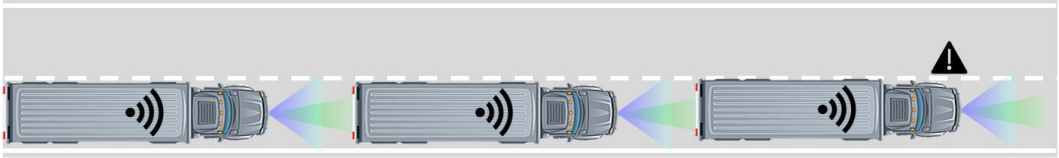
Operation area:	Any of the operational area inside the ODD for Platooning Level A
Environmental conditions:	Any environmental condition inside the ODD for Platooning Level A
Target vehicle(s):	Steady state platooning mode
Ego vehicle (s):	Enter in Leave use case
Application status target vehicle(s):	Platooning Shows platooning status on HMI
Application status Ego vehicle	Leaving Shows status on HMI
Driver status target vehicle(s):	Aware
Driver status Ego vehicle	Aware
System status	No failure of internal system

Emergency braking

The current description is the input for the functional safety (& SOTIF) analysis of this use case within WP2. The actual desired reaction of the system may differ because of the outcome of the functional safety analysis. This will be documented either in D2.4 or deliverables related to task 2.4 (functional safety) being D2.11 & D2.12.

ID	3.3
Name	Emergency Braking
Story	The ego truck is part of a platoon and any of the trucks ahead (in the platoon) performs an Emergency Braking. The ego truck performs an Emergency Braking and decelerates safely to avoid collision. Other trucks in the platoon behind the ego vehicle also perform an Emergency Braking and decelerate safely.
Initial condition	

Operation area:	Any of the operational area inside the ODD for Platooning Level A
Environmental conditions:	Any environmental condition inside the ODD for Platooning Level A
Target vehicle(s):	Leader or Follower of a Platoon
Ego vehicle (s):	Follower or Trailer of a Platoon at a given target time gap to the forward vehicle.
Application status target vehicle(s):	Any platooning state (so not in standalone state)
Application status Ego	Any platooning state (so not in standalone state)

	vehicle	
	Driver status target vehicle(s):	Aware
	Driver status Ego vehicle	Aware
	System status	No failure
Trigger	The truck in front of the ego vehicle initiates an Emergency Brake. The status “emergency brake” is triggered by: • An immediate (predicted) deceleration of the front truck of >4 m/s² [UN R 131] • The driver is actuating emergency braking • If there is an AEB event in the forward vehicles of the platoon. • Any of the trucks in front broadcast an “emergency brake event” (trigger for the ego vehicle coming from any of the forward cooperative vehicles in the platoon)	
Diagram	1. Any platoon driving state  2. Emergency Braking trigger detected  3. Ego truck reacts in the following way: • If front truck evaluates a possible collision (e.g with the radar or via V2V/I2V event) then the front truck transmits that via V2V. • The ego truck shall react in order to avoid the collision in respect to the target vehicle with an OEM specific brake strategy. Remark: ○ If there are two or more trucks preceding the target vehicle who initiates the emergency braking event, the Platoon is automatically split. ○ The remaining Platoon members will continue to drive • Ego truck broadcasts its intended and actual deceleration immediately via V2V • HMI: Inform the driver • Executes emergency braking until the emergency situation is no longer present or the ego vehicle has stopped completely • HMI: warning messages to the drivers about the ongoing Emergency brake (AEB) 	
Final condition	The final condition of the system depends on the exit velocity of the ego-vehicle. Here we define 2 cases, a and b. In the final condition the a and b refer to the final condition linked to this case. The 2 cases are: a) Vehicle moving with low speed (< 30 kph) or in standstill condition’	

<table>
<tr><td></td><td>
b) Vehicle moving with a speed above the 30 kph
In general: Drivers are responsible to resume in both cases.
<table>
<tr><td>Operation area:</td><td>Any of the operational area inside the ODD for Platooning Level A</td></tr>
<tr><td>Environmental conditions:</td><td>Any environmental condition inside the ODD for Platooning Level A</td></tr>
<tr><td>Target vehicle(s):</td><td>a. Vehicle moving with low speed (< 30 kph) or in standstill condition
b. Vehicle moving with a speed above the 30 kph</td></tr>
<tr><td>Ego vehicle (s):</td><td>a. Vehicle moving with low speed (< 30 kph) or in standstill condition
b. Vehicle moving with a speed above the 30 kph</td></tr>
<tr><td>Application status target vehicle(s):</td><td>a. Truck leave platoon, continue standalone
b. HMI: Driver can resume platooning.</td></tr>
<tr><td>Application status Ego vehicle</td><td>a. Truck leave platoon, continue standalone
b. HMI: Driver can resume platooning.</td></tr>
<tr><td>Driver status target vehicle(s):</td><td>Aware</td></tr>
<tr><td>Driver status Ego vehicle</td><td>Aware</td></tr>
<tr><td>System status</td><td>No failure</td></tr>
</table>
</td></tr>
</table>

Platoon gap adaptation

I2V interaction

<table>
<tr><td>ID</td><td>3.4.1</td></tr>
<tr><td>Name</td><td>Platoon gap adaptation because of I2V interaction</td></tr>
<tr><td>Story</td><td>Prerequisite: guidelines for zone policy have been setup to take into account the time between notification and execution of the zone policy to avoid high decelerations at the rear of the platoon. This means that the platoon needs time (and distance) to realise the policy (e.g. larger time gap, different speed) before arriving at the zone.

A platoon is running in steady state platooning.

I2V communication informs all passing vehicles in the platoon of a zone policy stating (for example, but not limited to): increased distances between vehicles for a specific zone defined (for example, but not limited to) by GPS locations for start and end. Alternatively, it could be a specific speed, or lateral positioning, etc...

Upon notification, the platoon coordinates to apply the required zone policy to the platoon configuration.

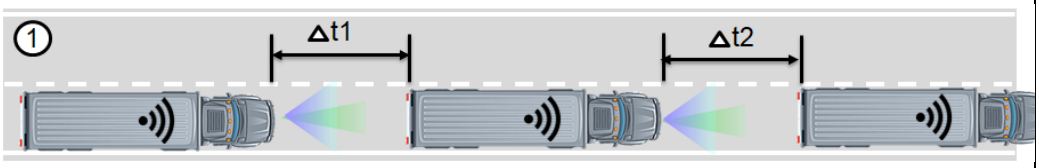
At the end of the zone, the platoon implements its previous configuration.</td></tr>
<tr><td>Initial condition</td><td>
<table>
<tr><td>Operation area:</td><td>Any of the operational area inside the ODD for Platooning Level A</td></tr>
<tr><td>Environmental conditions:</td><td>Positive conditions for platooning, other conditions detected either by driver or system.</td></tr>
</table>
</td></tr>
</table>

<table>
<tr><td></td><td>
<table>
<tr><td>Target vehicle(s):</td><td>Steady state platoon
Vehicle in front within sensor view, except leading truck.
Vehicle in front within V2V range for the following truck. Reception from minimum 1 closest vehicle in front and to the back are required.
Vehicle in front within V2V range for the trailing truck. Reception from minimum 1 closest vehicle in front is required.
Control messages over V2V are sent according to specification.</td></tr>
<tr><td>Ego vehicle (s):</td><td>Steady state platoon
Vehicle in front within sensor view, except leading truck.
Vehicle in front within V2V range for the following truck. Reception from minimum 1 closest vehicle in front and to the back are required.
Vehicle in front within V2V range for the trailing truck. Reception from minimum 1 closest vehicle in front is required.
Control messages over V2V are sent according to specification.</td></tr>
<tr><td>Application status target vehicle(s):</td><td>Platooning
HMI: Shows platooning status: platooning active, platoon specific information and functions.</td></tr>
<tr><td>Application status Ego vehicle</td><td>Platooning
HMI: Shows platooning status: platooning active, platoon specific information and functions.</td></tr>
<tr><td>Driver status target vehicle(s):</td><td>Aware</td></tr>
<tr><td>Driver status Ego vehicle</td><td>Aware</td></tr>
<tr><td>System status</td><td>All systems are ok.</td></tr>
</table>
</td></tr>
<tr><td>Trigger</td><td>Reception of message from V2I (road side, off board or on board (map)) from the road operator indicating a recommended zone policy (for e.g. distance for the platoon for a specific road section) by all vehicles.

Since there might not be a backend in Level A platooning, the example to be used in the demonstration can be V2I with a road side unit.</td></tr>
<tr><td>Diagram</td><td>Sequence in time

1. Any platoon driving state
 
2. All trucks of platoon receives instructions from I2V as they drive in front of an I2V to reduce speed due to specific traffic, including a specific GPS zone for the start and the end of the zone policy.</td></tr>
</table>

3. The platoon coordinates internally to take into account the required policy within the zone (change of speed, change of inter-vehicle distance, etc). Driver is informed via HMI of gap adaptation.



4. At the end of the section of infrastructure, the platoon resumes its former configuration in coordinated fashion.

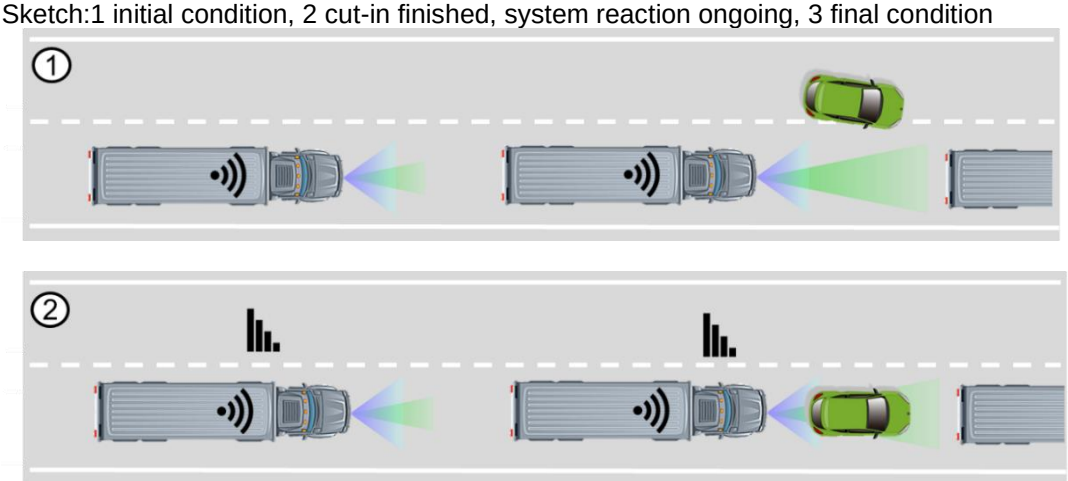
Final condition

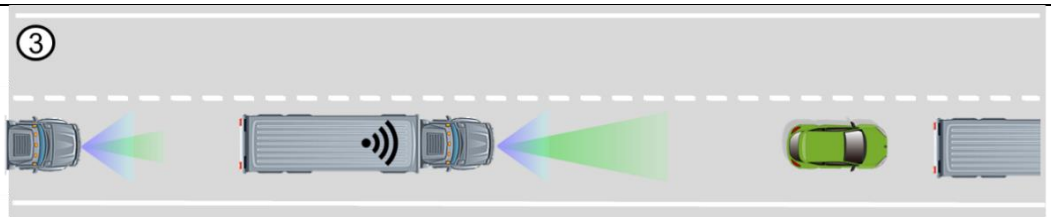
Operation area:	Any of the operational area inside the ODD for Platooning Level A
Environmental conditions:	Positive conditions for platooning, other conditions detected either by driver or system.
Target vehicle(s):	Steady state platoon • Vehicle in front within sensor view, except leading truck. • Vehicle in front within V2V range for the following truck. Reception from minimum 1 closest vehicle in front and to the back are required. • Vehicle in front within V2V range for the trailing truck. Reception from minimum 1 closest vehicle in front is required. • Control messages over V2V are sent according to specification.
Ego vehicle (s):	Steady state platoon • Vehicle in front within sensor view, except leading truck. • Vehicle in front within V2V range for the following truck. Reception from minimum 1 closest vehicle in front and to the back are required. • Vehicle in front within V2V range for the trailing truck. Reception from minimum 1 closest vehicle in front is required. • Control messages over V2V are sent according to specification.
Application status target vehicle(s):	Platooning HMI: Shows platooning status: platooning active, platoon specific information and functions.
Application status Ego vehicle	Platooning HMI: Shows platooning status: platooning active, platoon specific information and functions.

	Driver status target vehicle(s):	Aware
	Driver status Ego vehicle	Aware
	System status	All systems are ok.

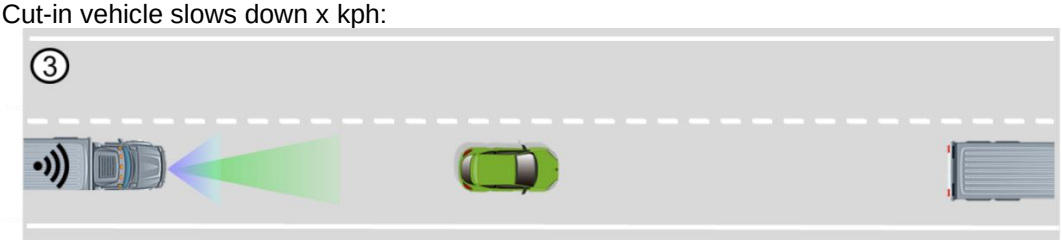
Cut-in (long time)

Cut in use case is described only for cut-in between leader and following truck. The same use case is relevant for every cut-in vehicle within the platoon.

ID	3.4.2	
Name	Cut-in handling within the platoon. Cut in vehicle remains for a long period (as opposed to cut-through).	
Story	Platoon members will based on the cut-in adapt their velocity and gap towards the cut-in vehicle and between the platoon members to assure safety. In principle the platoon will remain as one entity (V2V link up) with an intruder till some exit conditions may apply that cause the platoon to split up.	
Initial condition	Operation area:	Any of the operational area inside the ODD for Platooning Level A
	Environmental conditions:	Any environmental condition inside the ODD for Platooning Level A
	Target vehicle(s):	Vehicle with equal velocity to the platoon plans to cut in between the leading truck and following truck (ego vehicle in this use case) of the platoon. Vehicle is driving on the other lane.
	Ego vehicle (s):	Steady state following truck of a platoon in steady state (see steady state use case).
	Application status Ego vehicle(s)	Platooning HMI: Shows platooning status
	Driver status target vehicle(s):	Aware
	Driver status Ego vehicle	Aware
	System status	No failure
Trigger	Start of a cut-in is detected	
Diagram & sequence	Sketch:1 initial condition, 2 cut-in finished, system reaction ongoing, 3 final condition  Cut-in vehicle remains driving with constant velocity:	



Cut-in vehicle slows down x kph:



Sequence in time:

- Ego vehicle is platooning
- Vehicle cuts-in in front of ego vehicle
- Ego vehicle increases following distance (towards a safe following distance) towards cut-in vehicle by decelerating causing the platoon to go in a standby platoon state with intruder. This means that the longitudinal control will be performed using only local sensors.

Some conditions may apply causing the platoon to split

- IF: ego-vehicle communication with forward truck within the platoon is lost / too low quality, then the platoon is split.

Further research during the project:

- *IF: distance between ego-vehicle and preceding truck of the platoon is more than X m, then the platoon is split*
- *IF: cut-in duration is more than Y s, then the platoon is split*
- *IF: cut-in happens in a tunnel*

Once the platoon is split:

- IF: ego vehicle was trailing (last vehicle in the platoon)
  THEN: ego vehicle becomes standalone
  ELSE: ego vehicle becomes lead vehicle of the remaining platoon
- Platooning vehicles in front of ego vehicle will continue platooning
- HMI: Driver in Ego-vehicle and drivers of the platoon are informed about the cut-ins by means of the current platoon status.

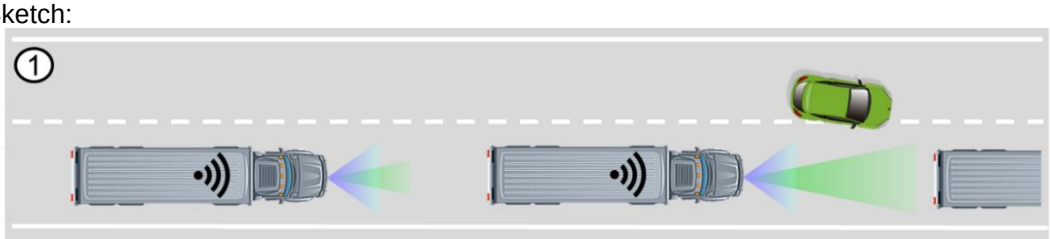
Final condition

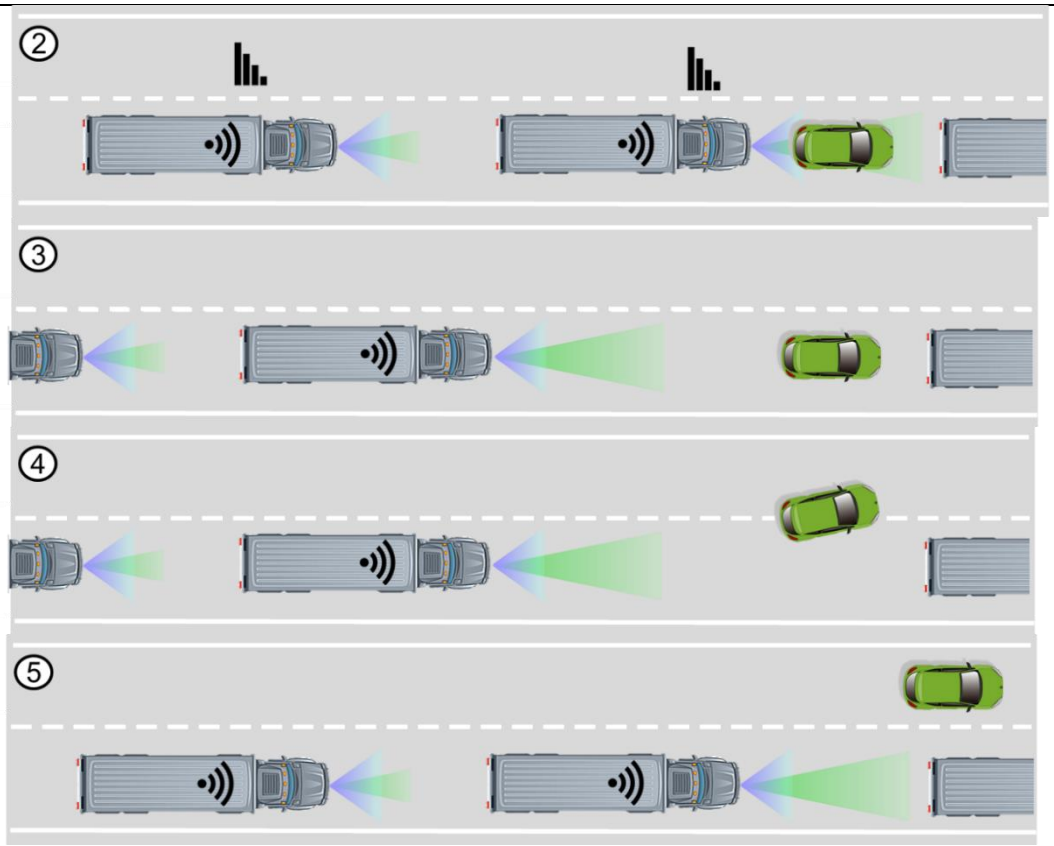
Operation area:	Any of the operational area inside the ODD for Platooning Level A
Environmental conditions:	Any environmental condition inside the ODD for Platooning Level A
Target vehicle(s):	Vehicle driving within the platoon
Ego vehicle and platoon members:	Steady state following the cut-in vehicle at a distance of LSG distance which if applicable is more or equal to the legal limit of the country. Vehicle either part of the original platoon, leader of a new platoon or optionally standalone (if vehicle remains solo after the platoon split).

		Other vehicles either part of original platoon, part of new platoon, or optionally standalone (if vehicle remains solo after the platoon split)
	Application status ego vehicle and platoon members:	Platooning or standalone HMI: Driver is informed about the cut-ins and the current platoon status.
	Driver status target vehicle(s):	Aware
	Driver status Ego vehicle	Aware
	System status	No failure Service layer is updated if there is a new platoon status (e.g. members)

Cut-in (short time) – cut-through

Cut in use case is described only for cut-in between leader and following truck. The same use case is relevant for every cut-in vehicle within the platoon.

ID	3.4.3	
Name	Cut-in handling within the platoon. Cut in vehicle remains for a short period (cut-out).	
Story	Platoon members will adapt their velocity and gap towards the cut-in vehicle and between the platoon members to assure safety. The cut-in remains for a short time followed by a cut-out action. The platoon will automatically reduce the following distance (gap closing) to the rest of the platoon members and continue. Where needed the leader of the platoon will be supported to assist in the gap closing action by an advice to lower its velocity during the gap closing action.	
Initial condition	Operation area:	Any of the operational area inside the ODD for Platooning Level A
	Environmental conditions:	Any environmental condition inside the ODD for Platooning Level A
	Target vehicle(s):	Vehicle with equal velocity to the platoon plans to cut in between the leading truck and following truck (ego vehicle in this use case) of the platoon. Vehicle is driving on the other lane.
	Ego vehicle (s):	Steady state following truck of a platoon in steady state (see steady state use case).
	Application status Ego vehicle(s)	Platooning HMI: Shows platooning status
	Driver status target vehicle(s):	Aware
	Driver status Ego vehicle	Aware
	System status	No failure of internal system and communication (V2V) is online
Trigger	Start of a cut-out is detected while platoon is not split	
Diagram & sequence	Sketch: 	



Sequence in time:

1 Ego vehicle is platooning
2 Vehicle cuts in in front of ego vehicle
3 1) Ego vehicle increases following distance (towards a safe following distance) towards cut-in vehicle by decelerating causing the platoon to go in a standby platoon state with intruder. This means that the nominal longitudinal control will be performed using only local sensors.
2) HMI: Driver in Ego-vehicle and drivers of the platoon are informed about the cut-ins by means of the current platoon status.
4 The cut-in vehicle makes a cut-out action OR before the desired following distance is reached OR if the platoon is still in a platoon standby state with intruder at the desired following distance.
5 Platoon automatically reduces the distance again to the desired platooning distance. If needed (e.g. gap closing too slow) the leading truck is informed about the platoon coherence issue (gap closing too slow). This can be solved by e.g. a temporarily adoption of the cruise velocity of the leading truck to assure that the gap adaptation is done in a limited time. The adaptation can be performed by the driver or if the driver enables by means of an optional automated assist functionality. Platooning vehicles will continue platooning at the original cruise velocity

Final condition		
	Operation area:	Any of the operational area inside the ODD for Platooning Level A
	Environmental conditions:	Any environmental condition inside the ODD for Platooning Level A
	Target vehicle(s):	Vehicle with equal velocity to the platoon plans to cut in between the leading truck and following truck (ego vehicle

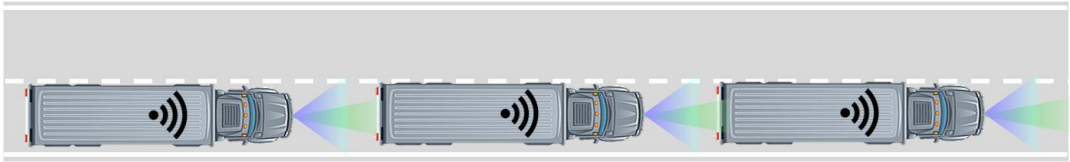
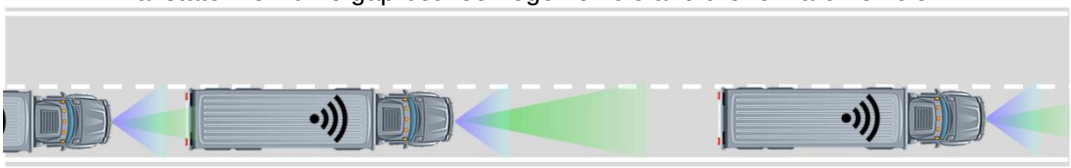
		in this use case) of the platoon. Vehicle is driving on the other lane.
	Ego vehicle (s):	Steady state following truck of a platoon in steady state (see steady state use case).
	Application status Ego vehicle(s)	Platooning HMI: Shows platooning status
	Driver status target vehicle(s):	Aware
	Driver status Ego vehicle	Aware
	System status	No failure of internal system and communication (V2V) is online

System status (e.g. packet loss)

ID	3.4.4
Name	Platoon time gap adaptation because of system status (e.g. packet loss)
Story	The target time gap between trucks must be adapted to a new value. The new target time gap must be reached within a given time interval or before reaching a given location.
Initial condition	Truck in a steady state platoon driving at a given target time gap from the preceding truck.

Operation area:	Any of the operational area defined in Platooning Level A ODD
Environmental conditions:	Any environmental condition inside the ODD for Platooning Level A
Target vehicle(s):	Leader or Follower of a Platoon driving at a given target time gap from preceding truck.
Ego vehicle (s):	Follower or Trailer of a Platoon driving at a given target time gap from preceding truck.
Application status target vehicle(s):	Platooning HMI: Shows platooning status: platooning active, platoon specific information and functions.
Application status Ego vehicle	Platooning HMI: Shows platooning status: platooning active, platoon specific information and functions.
Driver status target vehicle(s):	Aware
Driver status Ego vehicle	Aware
System status	No failure

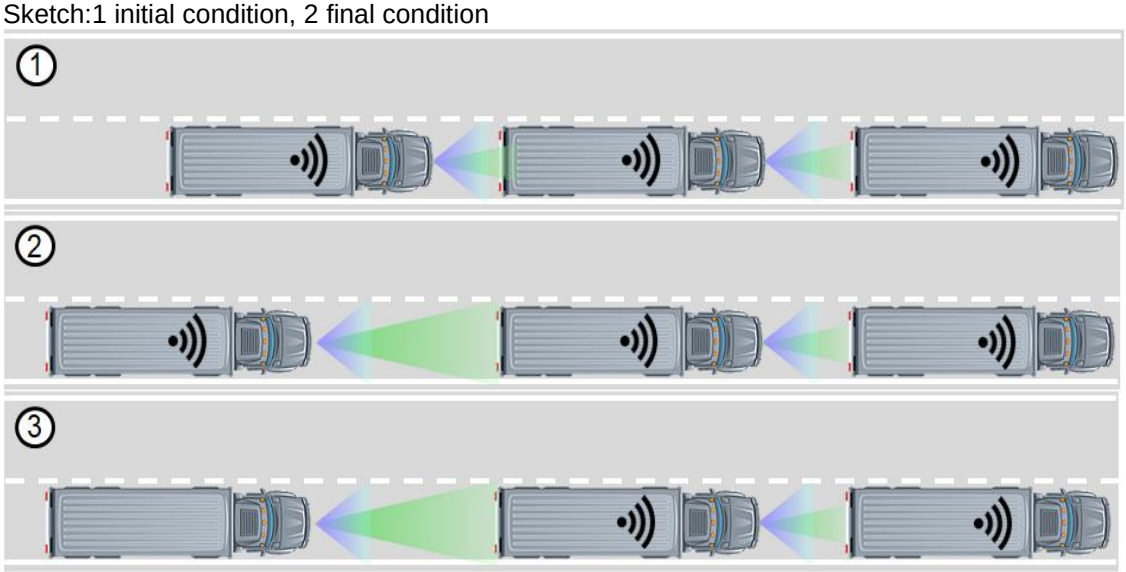
Trigger	The environment has changed so a new target *time gap* between trucks must be applied. No other vehicle between ego truck and front truck. These events trigger it: • Change in road slope • Driver request (due to weather conditions or visibility) • Geo Localization lost/Low location accuracy • Electronic brake system capabilities estimation changed • Administrative request (bridges, toll gates, tunnels, etc.…) • Abnormal situation finished (back to normal operation) • Sensor degradation or improvement (higher/lower uncertainty of sensors) • V2V packets lost with a certain timeframe

<table>
<tr><td>Diagram</td><td>
1. Initial state: current time gap.

2. Time gap shall be adjusted based on the trigger event; safety event shall result in a faster system reaction and time-gap increase whereas other events shall result in smooth transition to prevent increased fuel economy and not create control disturbances.
3. HMI: the gap changes are communicated to the driver
4. Final state: new new time gap between ego vehicle and the forward vehicle.

</td></tr>
<tr><td>Final condition</td><td>Time gap of the ego vehicle to the forward vehicle has been adapted (increased or decreased) and the platoon runs at a steady state with the new gap value. Each truck is expected to take the required actions to adapt the time gap to the forward vehicle
<table>
<tr><td>Operation area:</td><td>Any of the operational area defined in Platooning Level A ODD</td></tr>
<tr><td>Environmental conditions:</td><td>Any environmental condition inside the ODD for Platooning Level A</td></tr>
<tr><td>Target vehicle(s):</td><td>Leading or Following truck of a Platoon driving at the new target time gap from preceding truck. Rest of the platoon remains driving at original time gap.</td></tr>
<tr><td>Ego vehicle (s):</td><td>Following or Trailing truck of a Platoon driving at the new target time gap from preceding truck.</td></tr>
<tr><td>Application status target vehicle(s):</td><td>Platooning
HMI: Shows platooning status: platooning active, platoon specific information and functions.</td></tr>
<tr><td>Application status Ego vehicle</td><td>Platooning
HMI: Shows platooning status: platooning active, platoon specific information and functions.</td></tr>
<tr><td>Driver status target vehicle(s):</td><td>Aware</td></tr>
<tr><td>Driver status Ego vehicle</td><td>Aware</td></tr>
<tr><td>System status</td><td>No failure</td></tr>
</table>
</td></tr>
</table>

4.5.4. Disengage platoon

Leave by trailing truck

<table>
<tr><td>ID</td><td>3.5.1.1</td></tr>
<tr><td>Name</td><td>Leaving Platoon by trailing truck</td></tr>
<tr><td>Story</td><td>While the Platoon is active, the ego vehicle starts the leaving procedure. The system increases the inter-vehicle time gap to the LSG (legal safe gap) in respect to the preceding one and, when it is reached, gives back the control to the driver.</td></tr>
<tr><td>Initial</td><td>
<table>
<tr><td>Operation area:</td><td>Any of the operational area inside the ODD for Platooning</td></tr>
</table>
</td></tr>
</table>

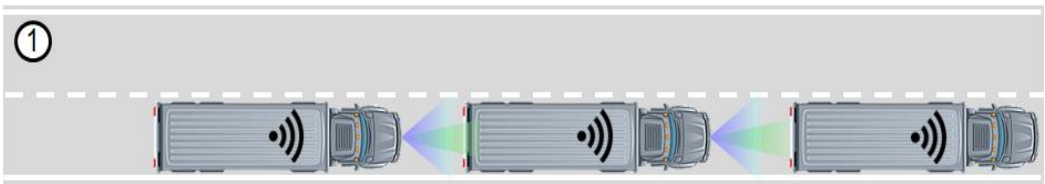
<table>
<tr><td>condition</td><td>
<table>
<tr><td></td><td>Level A</td></tr>
<tr><td>Environmental conditions:</td><td>Any environmental condition inside the ODD for Platooning Level A</td></tr>
<tr><td>Target vehicle(s):</td><td>Steady state following truck of existing platoon.</td></tr>
<tr><td>Ego vehicle (s):</td><td>Steady state trailing truck of existing platoon.</td></tr>
<tr><td>Application status target vehicle(s):</td><td>Platooning
HMI: Shows platooning status: platooning active, platoon specific information and functions.</td></tr>
<tr><td>Application status Ego vehicle</td><td>Platooning
HMI: Shows platooning status: platooning active, platoon specific information and functions.</td></tr>
<tr><td>Driver status target vehicle(s):</td><td>Aware</td></tr>
<tr><td>Driver status Ego vehicle</td><td>Aware</td></tr>
<tr><td>System status</td><td>No failure</td></tr>
</table>
</td></tr>
<tr><td>Trigger</td><td>The ego driver starts the leaving procedure</td></tr>
<tr><td>Diagram</td><td>Sketch:1 initial condition, 2 final condition
 

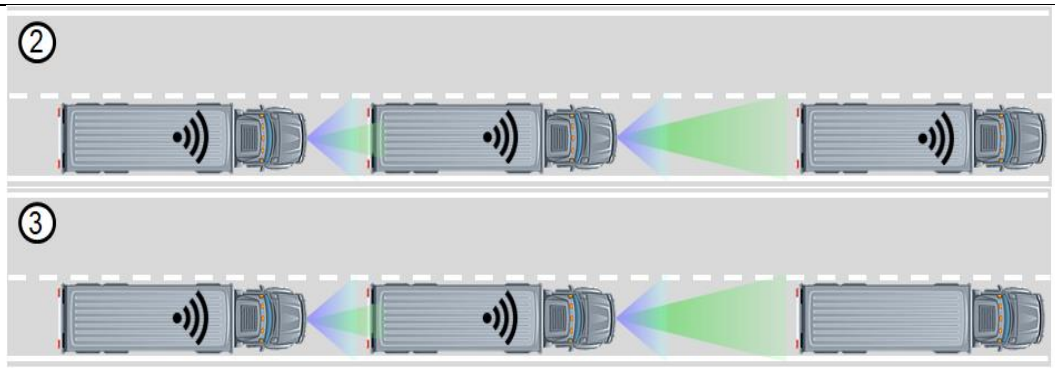
Sequence in time as bullet points:

1.1 The ego application enters “Leave” mode.
1.2 The start of the leaving procedure from the ego vehicle is broadcasted to the other Platoon members through V2V communication (message to be inserted).
2 The ego vehicle starts to increase the inter-vehicle time gap in respect to the target one
3.1 When the LSG is reached, the ego vehicle Platooning communication is disconnected
3.2 When the LSG is reached, the ego vehicle HMI informs the driver that platooning support is no longer available
3.3 When the LSG is reached, the ego vehicle application enters “Stand-alone” mode
3.4 When the LSG is reached, the other Platoon members continue to platoon
3.5 Target vehicle and the remaining Platoon should re-negotiate encryption key</td></tr>
<tr><td>Final condition</td><td>
<table>
<tr><td>Operation area:</td><td>Any of the operational area inside the ODD for Platooning Level A</td></tr>
<tr><td>Environmental conditions:</td><td>Any environmental condition inside the ODD for Platooning Level A</td></tr>
<tr><td>Target vehicle(s):</td><td>Steady state following truck of platoon.</td></tr>
</table>
</td></tr>
</table>

Ego vehicle (s):	Stand-alone state truck driving @ LSG following distance.
Application status target vehicle(s):	Platooning HMI: Shows platooning status: platooning active, platoon specific information and functions.
Application status Ego vehicle	Stand-alone (Stand-alone HMI, could be OEM specific)
Driver status target vehicle(s):	Aware
Driver status Ego vehicle	Aware
System status	Vehicle platform: no failure V2V: same as ”stand-alone” with Platooning functionality active

Leave by leading truck

ID	3.5.1.2	
Name	Leaving Platoon by leading truck	
Story	While the Platoon is active, the leading vehicle starts the leaving procedure. The first following vehicle system increases the inter-vehicle time gap to the LSG; when it is reached, the leading vehicle continues as stand-alone truck, after the proper transition of control to the driver, while the others continue as a new platoon. And the first following vehicle takes over the role of the leading truck in the platoon.	
Initial condition	Operation area:	Any of the operational area inside the ODD for Platooning Level A
	Environmental conditions:	Any environmental condition inside the ODD for Platooning Level A
	Target vehicle(s):	Steady state 1st following truck of existing platoon
	Ego vehicle (s):	Steady state leading truck of existing platoon.
	Application status target vehicle(s):	Platooning HMI: Shows platooning status: platooning active, platoon specific information and functions.
	Application status Ego vehicle	Platooning HMI: Shows platooning status: platooning active, platoon specific information and functions.
	Driver status target vehicle(s):	Aware
	Driver status Ego vehicle	Aware
	System status	No failure
Trigger	The ego driver starts the leaving procedure	
Diagram	Sketch:1 initial condition, 2 final condition 	

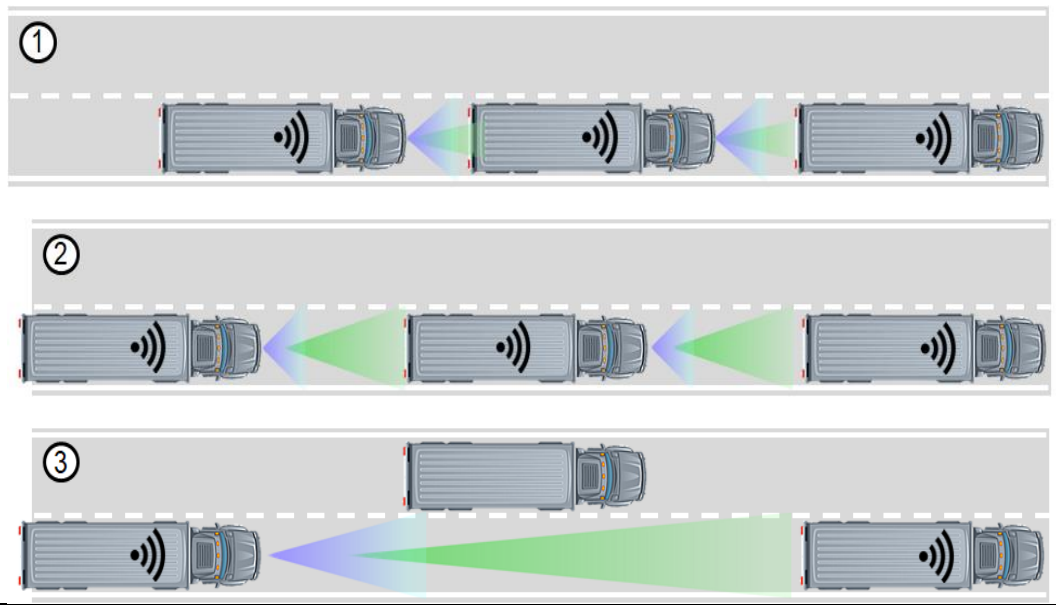


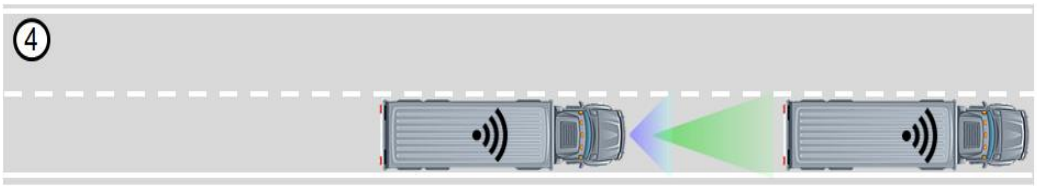
1.1 The ego application enters “Leave” mode.
1.2 The start of the leaving procedure from the ego vehicle is broadcasted to the other Platoon members through V2V communication (message to be inserted).
2 The target vehicle starts to increase the inter-vehicle time gap in respect to the ego one
3.1 When the LSG is reached, the target vehicle communicates it to the ego one through V2V communication (leave notification\request).
3.2 When the LSG is reached, the remaining Platoon members shall assure that they can continue platooning (e.g. if needed re-negotiate the V2V encryption key)
3.3 The HMI of the target vehicle informs the driver about its new role in the Platoon
3.4 The target vehicle becomes the new Platoon leader
3.5 The ego vehicle Platooning communication is disconnected
3.6 The ego vehicle application enters “Stand-alone” mode
3.7 HMI 52ulfil52zed52on for the remaining Platoon members is: see reference to “Steady-state” Platoon UC
3.8 The remaining Platoon members application is: see reference to “Steady-state” Platoon UC

Final condition

Operation area:	Any of the operational area inside the ODD for Platooning Level A
Environmental conditions:	Any environmental condition inside the ODD for Platooning Level A
Target vehicle(s):	Steady state leading truck of the new platoon.
Ego vehicle (s):	Stand-alone state truck driving @ LSG following distance.
Application status target vehicle(s):	Platooning HMI: Shows platooning status: platooning active, platoon specific information and functions.
Application status Ego vehicle	Stand-alone (Stand-alone HMI, could be OEM specific)
Driver status target vehicle(s):	Aware
Driver status Ego vehicle	Aware
System status	Vehicle platform: no failure V2V: same as ”stand-alone” with Platooning functionality active

Leave by following truck

<table>
<tr><td>ID</td><td>3.5.1.3</td></tr>
<tr><td>Name</td><td>Leaving Platoon by follower truck</td></tr>
<tr><td>Story</td><td>While the Platoon is active, one of the follower vehicles (not the leader nor the trailing vehicle) starts the leaving procedure. The first successive vehicle system increases the inter-vehicle time gap to the LSG in respect to the ego vehicle, while the ego increases the inter-vehicle time gap in respect to its preceding vehicle; when both vehicles reach the LSG, the ego vehicle continues as stand-alone truck, after the proper transition of control to the drive. The driver of the original following vehicle makes a cut-out action, then the remaining platoon members will close the gap after the cut-out has been finished and will continue as one platoon.</td></tr>
<tr><td>Initial condition</td><td>
<table>
<tr><td>Operation area:</td><td>Any of the operational area inside the ODD for Platooning Level A</td></tr>
<tr><td>Environmental conditions:</td><td>Any environmental condition inside the ODD for Platooning Level A</td></tr>
<tr><td>Target vehicle(s):</td><td>Steady state truck, successive to the ego, of existing platoon.</td></tr>
<tr><td>Ego vehicle (s):</td><td>Steady state follower truck of existing platoon.</td></tr>
<tr><td>Application status target vehicle(s):</td><td>Platooning
HMI: Shows platooning status: platooning active, platoon specific information and functions.</td></tr>
<tr><td>Application status Ego vehicle</td><td>Platooning
HMI: Shows platooning status: platooning active, platoon specific information and functions.</td></tr>
<tr><td>Driver status target vehicle(s):</td><td>Aware</td></tr>
<tr><td>Driver status Ego vehicle</td><td>Aware</td></tr>
<tr><td>System status</td><td>No failure</td></tr>
</table>
</td></tr>
<tr><td>Trigger</td><td>The ego driver starts the leaving procedure</td></tr>
<tr><td>Diagram</td><td>Sketch:1 initial condition, 4 final condition
 
</td></tr>
</table>



Sequence in time as bullet points:

1. The ego application enters “Leave” mode.

2.a The start of the leaving procedure from the ego vehicle is broadcasted to the other Platoon members through V2V communication (message to be inserted).

2.b The target vehicle starts to increase the inter-vehicle time gap in respect to the ego one, taking into account also the needs of the ego vehicle to increase its gap in respect to the preceding one.

2.c The ego vehicle starts to increase the inter-vehicle time gap in respect to the preceding one

2.d All the trucks HMIs display information about a truck leaving with its position

2.e When the LSG is reached, the target vehicle communicates it to the ego one through V2V communication (leave notification/request).

2.f When the LSG is reached, the ego vehicle communicates it to the preceding one through V2V communication (leave notification/request).

2.g The ego vehicle Platooning communication is disconnected

2.h The ego vehicle HMI informs the driver platooning support is no longer available

2.i The remaining Platoon members should re-negotiate encryption key

3 The ego vehicle application enters “Stand-alone” mode and driver performs cut-out action

4.a The new platoon configuration is visualized in all the remaining platooning trucks HMI

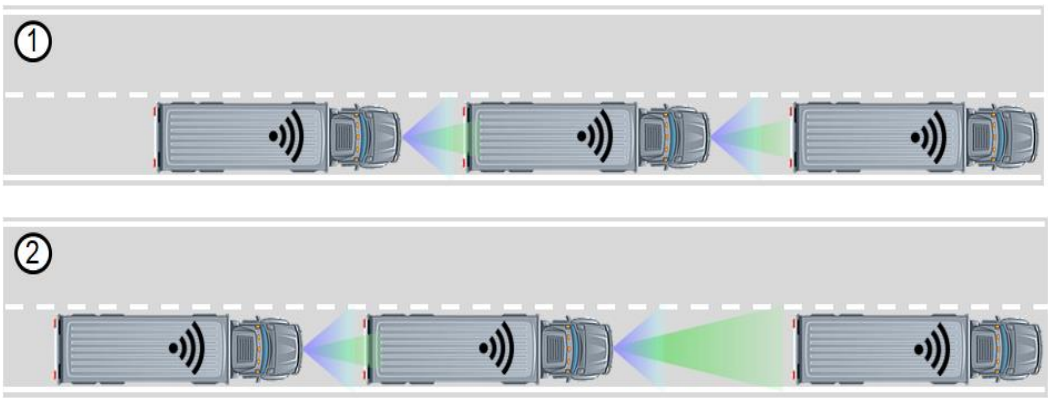
4.b The remaining Platoon members close the gap and continue as a platoon.

Alternative flow: if the communication is lost wile/before gap closing then the platoon will continue as 2 separate branches in line with the “split use case”

Final condition

Operation area:	Any of the operational area inside the ODD for Platooning Level A
Environmental conditions:	Any environmental condition inside the ODD for Platooning Level A
Target vehicle(s):	Steady state truck, successive to the ego, of existing platoon.
Ego vehicle (s):	Stand-alone state truck driving @ LSG following distance.
Application status target vehicle(s):	Platooning HMI: Shows platooning status: platooning active, platoon specific information and functions.
Application status Ego vehicle	Stand-alone (Stand-alone HMI, could be OEM specific)
Driver status target vehicle(s):	Aware
Driver status Ego vehicle	Aware
System status	Vehicle platform: no failure V2V: same as ”stand-alone” with Platooning functionality active

Split (following truck)

<table>
<tr><td>ID</td><td>3.5.2</td></tr>
<tr><td>Name</td><td>Split Platoon by follower truck</td></tr>
<tr><td>Story</td><td>While the Platoon is active, one of the follower vehicles (not the leader nor the trailer vehicle) starts the split procedure. The ego vehicle will increases the inter-vehicle time gap in respect to its preceding vehicle; when both vehicles reach the LSG, the original platoon continues as 2 new platoon with the ego vehicle being the leading truck of one of the platoons.</td></tr>
<tr><td>Initial condition</td><td>
<table>
<tr><td>Operation area:</td><td>Any of the operational area inside the ODD for Platooning Level A</td></tr>
<tr><td>Environmental conditions:</td><td>Any environmental condition inside the ODD for Platooning Level A</td></tr>
<tr><td>Target vehicle(s):</td><td>Steady state truck, preceding to the ego, of existing platoon.</td></tr>
<tr><td>Ego vehicle (s):</td><td>Steady state follower truck of existing platoon.</td></tr>
<tr><td>Application status target vehicle(s):</td><td>Platooning
HMI: Shows platooning status: platooning active, platoon specific information and functions.</td></tr>
<tr><td>Application status Ego vehicle</td><td>Platooning
HMI: Shows platooning status: platooning active, platoon specific information and functions.</td></tr>
<tr><td>Driver status target vehicle(s):</td><td>Aware</td></tr>
<tr><td>Driver status Ego vehicle</td><td>Aware</td></tr>
<tr><td>System status</td><td>No failure</td></tr>
</table>
</td></tr>
<tr><td>Trigger</td><td>The events that can trigger the Platoon split are:
• Intruder(s) that remain for a long time (see UC Cut-in (long time))
• More than 1 intruder is present inside the platoon lane (recognised by the relative distance among the two platoon members or by two consecutive cut-ins)
• The ego vehicle is not able to follow the target one anymore (e.g uphill); the target time gap increases up to the threshold the system split the platoon.
• Driver request to split the platoon</td></tr>
<tr><td>Diagram</td><td>Sketch:1 initial condition, 4 final condition
 
Sequence in time as bullet points:

1.1 The ego application enters “Split” mode.
1.2 The start of the splitting procedure from the ego vehicle is broadcasted to the target one through V2V communication (message to be inserted).</td></tr>
</table>

<table>
<tr><td></td><td>1.3 The ego vehicle opens the gap towards the target vehicle
2.1 When the LSG is reached, the ego vehicle condition is communicated through V2V communication (PCM).
2.2 The ego vehicle V2V communication (V2X-PCM) to the target vehicle is disconnected
2.3 The Platoon is split in 2 branches
2.4 Drivers are informed about the changing platoon status with 2 branches, and to which branch s/he belongs.
2.5 The ego vehicle driver is informed about taking new role as platoon leader
2.6 The ego vehicle becomes the new Platoon leader
2.7 The HMI of the ego vehicle informs the driver about its new role in the Platoon
2.8 The new platoon configuration is visualised in both branches trucks HMI
2.9 The two Platoon branches continue to platoon</td></tr>
<tr><td>Final condition</td><td>
<table>
<tr><td>Operation area:</td><td>Any of the operational area inside the ODD for Platooning Level A</td></tr>
<tr><td>Environmental conditions:</td><td>Any environmental condition inside the ODD for Platooning Level A</td></tr>
<tr><td>Target vehicle(s):</td><td>Steady state truck, trailing truck of one of the remaining platoons</td></tr>
<tr><td>Ego vehicle (s):</td><td>Leading ruck of one of the remaining platoons</td></tr>
<tr><td>Application status target vehicle(s):</td><td>Platooning
HMI: Shows platooning status: platooning active, platoon specific information and functions.</td></tr>
<tr><td>Application status Ego vehicle</td><td>Platooning
HMI: Shows platooning status: platooning active, platoon specific information and functions.</td></tr>
<tr><td>Driver status target vehicle(s):</td><td>Aware</td></tr>
<tr><td>Driver status Ego vehicle</td><td>Aware</td></tr>
<tr><td>System status</td><td>Vehicle platform: no failure</td></tr>
</table>
</td></tr>
</table>

4.5.5. Other

For relevant environmental conditions where we expect specific system behaviour, a “one liner / assumption” with the desired reaction of the system is defined. This can form the basis for the detailing later in the specification phase of the project (D2.4, D2.6, D2.8, WP4 etc).
One liner / assumption

- On hilly roads we expect the platoon to remain its cohesion
- Within a tunnel we expect the system to remain platooning if the platoon is formed before the tunnel
- Within a tunnel (more in general a longer section without GPS receival) we do not allow a platoon to engage unless technically possible without GPS receival (to be further investigated) and allowed by the regulations. Following the reason that engaging is not allowed, the if engaging while entering a tunnel engaging will be cancelled.
- Within a tunnel (more in general a longer section without GPS receival) a cut in causes that the platoon will be split in 2 branches in line with the split use case.
- We expect the platoon to be able to perform the engaging, platooning and disengaging actions also in curved road with a curvature radi > 250m

- When driving downhill we expect the individual trucks to adapt the gap to the target (if needed) in front based on operational layer information (e.g. map data, brake system status).
- When during engaging a cut-in is performed within the platoon, the system will react equal to when the cut-in is performed in steady state.
- When during disengage a cut-in is performed within the platoon, the system will react equal to when the cut-in is performed in the steady state. The only difference is that if the gap is sufficiently increased towards the cut-in target that that is a reason to stop the disengage procedure relative to the target in front.
- If ego-vehicle communication with forward truck within the platoon is lost / too low quality, then the platoon is split.
- If the driver performs an unannounced leave action, then the platoon will detect this as a cut-out action (“leave”). The resulting gap will automatically be closed by the remaining partners of the platoon and the platoon will continue with 1 member less.

5. SUMMARY AND CONCLUSION

This report defines the platoon levels within the ENSEMBLE project and the use cases which form the basis for the technical detailing in the rest of WP2 and WP4. This is a first version of this document and it will be further refined during the project, after other investigations like HMI and functional safety and practical experience. The main purpose is to start the early development of demo trucks. The version in month 30 (D2.3) will be the final version.

5.1. Platoon levels

The platoon levels as envisioned by the ENSEMBLE consortium are defined. Platoon level A is detailed and for platoon level B and C the first outlook is given which will be detailed more during the ENSEMBLE project which will be reflected in D2.3. Platoon level A is defined in line with the intended demonstration at the end of the project on public road.

The main properties of platoon level A are:

- Longitudinal coordinated automated control for the whole velocity range from 0 to maximum cruise velocity (depending on country regulations)
- Maximum number of trucks of 7 is considered for platoon level A in ENSEMBLE
- A minimum time gap of 0.8 seconds @ maximum cruise velocity (depending on country regulations)
- New members of a running platoon can only join from the rear.
- Under adverse conditions like bad weather, slopes, etc.… the drivers have the responsibility to increase the time gap or disengage the platoon completely.
- The driver is responsible for the dynamic drive task in case of system failures. The system needs to be fail safe.
- Interaction with platooning services and infrastructure is technically available

5.2. Use cases

The high level use cases for platoon level A are detailed. First of all the methodology how to derive the use cases is defined and after that the high level use cases for platoon level A and additional one-lines / assumptions are added which can together be used for the detailed use cases as may be part of the technical deliverables (e.g. D2.4, D2.8).

The main high level use cases of platoon level A are:

- Platoon formation
  - Platoon formation based on generic match making (Orchestrated non real-time)
  - Platoon formation based on just extended awareness (Orchestrated real-time)
- Engaging to platoon
  - Join from behind by single vehicle
  - Merge from behind by platoon
- Platooning

- Steady state platooning
- Follow to stop (&go)
- Emergency braking
  - Leading truck (caused by AEB system)
  - All trucks (caused by e.g. manual overrule)
- Platoon gap adaptation
  - I2V interaction
  - Cut-in (long time)
  - Cut-in (short time) (“Cut-through”)
  - System status (e.g. packet loss)

- Disengage platoon
  - Leave
  - Split

6. BIBLIOGRAPHY

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Willemsen, D., et al., (2018). Requirements Review from EU projects. D2.1 of H2020 project ENSEMBLE, (www.platooningensemble.eu)

Burgmeijer J.W. et al: TNO 2017 R10629 Eindrapport TKI Two-truck Platoon Matching (2017)

7. APPENDIX A.

7.1. Glossary

Definitions

Term	Definition
Convoy	A group of two or more vehicles driving together in the same direction, not necessarily at short inter-vehicle distances and not necessarily using advanced driver assistance systems
Cut-in	A lane change manoeuvre performed by vehicles from the adjacent lane to the ego vehicle's lane, at a distance close enough (i.e., shorter than desired inter vehicle distance) relative to the ego vehicle.
Cut-out	A lane change manoeuvre performed by vehicles from the ego lane to the adjacent lane.
Cruise velocity	A constant speed as maintained by the vehicle.
Cut-through	A lane change manoeuvre performed by vehicles from the adjacent lane (e.g. left lane) to ego vehicle's lane, followed by a lane change manoeuvre to the other adjacent lane (e.g. right lane).
Ego Vehicle	The vehicle from which the perspective is considered.
Emergency brake	Brake action with an acceleration of <-4 m/s2
Event	An event marks the time instant at which a transition of a state occurs, such that before and after an event, the system is in a different mode.
Fail-safe	A fail-safe in engineering is a design feature or practice that in the event of a specific type of failure, inherently responds in a way that will cause no or minimal harm to other equipment, the environment or to people.
Following truck	Each truck that is following behind a member of the platoon, being every truck except the leading and the trailing truck, when the system is in platoon mode.
Leading truck	The first truck of a truck platoon
Legal Safe Gap	Minimum allowed elapsed time/distance to be maintained by a standalone truck while driving according to Member States regulation (it could be 2 seconds, 50 meters or not present)
Manoeuvre ("activity")	A particular (dynamic) behaviour which a system can perform (from a driver or other road user perspective) and that is different from standing still, is being considered a manoeuvre.
ODD (operational	The ODD should describe the specific conditions under which a given automation function is intended to function. The ODD is the definition of

Term	Definition
design domain)	where (such as what roadway types and speeds) and when (under what conditions, such as day/night, weather limits, etc.) an automation function is designed to operate.
Operational layer	The operational layer involves the vehicle actuator control (e.g. accelerating/braking, steering), the execution of the aforementioned manoeuvres, and the control of the individual vehicles in the platoon to automatically perform the platooning task. Here, the main control task is to regulate the inter-vehicle distance or velocity and, depending on the Platooning Level, the lateral position relative to the lane or to the preceding vehicle. Key performance requirements for this layer are vehicle following behaviour and (longitudinal and lateral) string stability of the platoon, where the latter is a necessary requirement to achieve a stable traffic flow and to achieve scalability with respect to platoon length, and the short-range wireless inter-vehicle communication is the key enabling technology.
Orchestrated platooning	Orchestrated platooning is the involvement of a platoon formation process for orchestrated platooning to strategically find platoons / vehicles that can platoon together to benefit from it (e.g. from logistical perspective or fuel perspective).
Platoon	A group of two or more automated cooperative vehicles in line, maintaining a close distance, typically such a distance to reduce fuel consumption by air drag, to increase traffic safety by use of additional ADAS-technology, and to improve traffic throughput because vehicles are driving closer together and take up less space on the road.
Platoon Automation Levels	In analogy with the SAE automation levels subsequent platoon automation levels will incorporate an increasing set of automation functionalities, up to and including full vehicle automation in a multi-brand platoon in real traffic for the highest Platooning Automation Level. The definition of “platooning levels of automation” will comprise elements like e.g. the minimum time gap between the vehicles, whether there is lateral automation available, driving speed range, operational areas like motorways, etc. Three different levels are anticipated; called A, B and C.
Platoon candidate	A truck who intends to engage the platoon either from the front or the back of the platoon.
Platoon cohesion	Platoon cohesion refers to how well the members of the platoon remain within steady state conditions in various scenario conditions (e.g. slopes, speed changes).
Platoon disengaging	The ego-vehicle can decide to leave the platoon or to split the platoon into 2 new platoons (only a following truck can perform this action). When conditions are met the truck(s) starts to increase the gap between the trucks to a safe non-platooning gap. The disengaging is completed when the gap is large enough which is

Term	Definition
	depends on the operational safety based on vehicle dynamics and human reaction times is given
Platoon engaging	Using wireless communication (V2V), the Platoon Candidate (single vehicle or existing platoon) sends an engaging request to the platoon target (single vehicle or existing platoon) in front. When conditions are met the system starts to decrease the time gap between the trucks to the platooning time gap.
Platoon formation	Platoon formation is the process before platoon engaging in which it is determined if and in what format (e.g. composition) trucks can/should become part of a new / existing platoon. Platoon formation can be done orchestrated real time or non-real time.Platoon candidates may receive instructions during platoon formation (e.g. to adapt their velocity, to park at a certain location) to allow the start of the engaging procedure of the platoon.
Platoon split	The platoon is split in 2 new platoons who themselves continue as standalone entities.
Requirements	Description of system properties. Details of how the requirements shall be implemented at system level
Scenario	A scenario is a quantitative description of the ego vehicle, its activities and/or goals, its static environment, and its dynamic environment. From the perspective of the ego vehicle, a scenario contains all relevant events. Scenario is a combination of a manoeuvre (“activity”), ODD and events
Service layer	The service layer represents the platform on which logistical operations and new initiatives can operate.
Specifications	Description of system properties. Details of how the requirements shall be implemented at system level
Steady state	In systems theory, a system or a process is in a steady state if the variables (called state variables) which define the behaviour of the system or the process are unchanging in time. In the context of platooning this means that the relative velocity and gap between trucks is unchanging within tolerances from the system parameters.
Strategic layer	The strategic layer is responsible for the high-level decision-making regarding the scheduling of platoons based on vehicle compatibility and Platooning Level, optimisation with respect to fuel consumption, travel times, destination, and impact on highway traffic flow and infrastructure, employing cooperative ITS cloud-based solutions. In addition, the routing of vehicles to allow for platoon forming is included in this layer. The strategic layer is implemented in a centralised fashion in so-called traffic control centres. Long-range wireless communication by existing cellular

Term	Definition
	technology is used between a traffic control centre and vehicles/platoons and their drivers.
Tactical layer	The tactical layer coordinates the actual platoon forming (both from the tail of the platoon and through merging in the platoon) and platoon dissolution. In addition, this layer ensures platoon cohesion on hilly roads, and sets the desired platoon velocity, inter-vehicle distances (e.g. to prevent damaging bridges) and lateral offsets to mitigate road wear. This is implemented through the execution of an interaction protocol using the short-range wireless inter-vehicle communication (i.e. V2X). In fact, the interaction protocol is implemented by message sequences, initiating the manoeuvres that are necessary to form a platoon, to merge into it, or to dissolve it, also taking into account scheduling requirements due to vehicle compatibility.
Target Time Gap	Elapsed time to cover the inter vehicle distance by a truck indicated in seconds, agreed by all the Platoon members; it represents the minimum distance in seconds allowed inside the Platoon.
Time gap	Elapsed time to cover the inter vehicle distance by a truck indicated in seconds.
Trailing truck	The last truck of a truck platoon
Truck Platoon	A truck platoon may be defined as trucks that travel together in convoy formation at a fixed gap distance typically less than 1 second apart up to 0.3 seconds. The vehicles closely follow each other using wireless vehicle-to-vehicle (V2V) communication and advanced driver assistance systems
Use case	Use-cases describe how a system shall respond under various conditions to interactions from the user of the system or surroundings, e.g. other traffic participants or road conditions. The user is called actor on the system, and is often but not always a human being. In addition, the use-case describes the response of the system towards other traffic participants or environmental conditions. The use-cases are described as a sequence of actions, and the system shall behave according to the specified use-cases. The use-case often represents a desired behaviour or outcome. In the ensemble context a use case is an extension of scenario which add more information regarding specific internal system interactions, specific interactions with the actors (e.g. driver, I2V) and will add different flows (normal & alternative e.g. successful and failed in relation to activation of the system / system elements).

Acronyms and abbreviations

Acronym / Abbreviation	Meaning
ACC	Adaptive Cruise Control
ADAS	Advanced driver assistance system
AEB	Autonomous Emergency Braking (System, AEBS)
ASIL	Automotive Safety Integrity Level
ASN.1	Abstract Syntax Notation One
BTP	Basic Transport Protocol
C-ACC	Cooperative Adaptive Cruise Control
C-ITS	Cooperative ITS
CA	Cooperative Awareness
CAD	Connected Automated Driving
CAM	Cooperative Awareness Message
CCH	Control Channel
DEN	Decentralized Environmental Notification
DENM	Decentralized Environmental Notification Message
DITL	Driver-In-the-Loop
DOOTL	Driver-Out-Of-the Loop
DSRC	Dedicated Short-Range Communications
DDT	Dynamic driving task
EBS	Electronic brake system
ETSI	European Telecommunications Standards Institute
EU	European Union
FCW	Forward Collision Warning
FLC	Forward Looking Camera
FSC	Functional Safety Concept
GN	GeoNetworking
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
GUI	Graphical User Interface

Acronym / Abbreviation	Meaning
HARA	Hazard Analysis and Risk Assessment
HIL	Hardware-in-the-Loop
HMI	Human Machine Interface
HW	Hardware
I/O	Input/Output
IEEE	Institute of Electrical and Electronics Engineers
ISO	International Organization for Standardization
ITL	In-The_Loop
ITS	Intelligent Transport System
IVI	Infrastructure to Vehicle Information message
LDWS	Lane Departure Warning System
LKA	Lane Keeping Assist
LCA	Lane Centring Assist
LRR	Long Range Radar
LSG	Legal Safe Gap
MAP	MapData message
MIO	Most Important Object
MRR	Mid Range Radar
OS	Operating system
ODD	Operational Design Domain
OEM	Original Equipment Manufacturer
OOTL	Out-Of The-Loop
PAEB	Platooning Autonomous Emergency Braking
PMC	Platooning Mode Control
QM	Quality Management
rFMS	Remote FMS-Standard (FMS = fleet management system)
RSU	Road Side Unit
SA	Situation Awareness

Acronym / Abbreviation	Meaning
SAE	SAE International, formerly the Society of Automotive Engineers
SCH	Service Channel
SDO	Standard Developing Organisations
SIL	Software-in-the-Loop
SPAT	Signal Phase and Timing message
SRR	Short Range Radar
SW	Software
TC	Technical Committee
TOR	Take-Over Request
TOT	Take-Over Time
TTG	Target Time Gap
V2I	Vehicle to Infrastructure
V2V	Vehicle to Vehicle
V2X	Vehicle to any (where x equals either vehicle or infrastructure)
VDA	Verband der Automobilindustrie (German Association of the Automotive Industry)
WIFI	Wireless Fidelity
WLAN	Wireless Local Area Network
WP	Work Package