ENSEMBLE

EUROPEAN COMMISSION

HORIZON 2020
H2020-ART-2016-2017/H2020-ART-2017-Two-Stages
GA No. 769115

ENSEMBLE

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

Deliverable No.	D2.6	
Deliverable Title	Functional specification for intelligent infrastructure - Strategic and Services Layers	
Dissemination level	Public	
Written By	Cecile VILLETTE, ALTAROAD	14-12-2018
	Franziska SCHMIDT, IFSTTAR	
Checked by	WP2 Leader, Alessandro Coda, CLEPA	22-11-2018

Approved by	Coordinator: Marika Hoedemaeker, TNO	14-12-2018
Status	Final, approved by EC	13-05-2020

Please refer to this document as:

Villette, C. (2018). *Functional specification for intelligent infrastructure - Strategic and Services Layers.* D2.6 of H2020 project ENSEMBLE, (platooningensemble.eu)

Disclaimer:

ENSEMBLE is co-funded by the European Commission, DG Research and Innovation, in the HORIZON 2020 Programme. The contents of this publication is the sole responsibility of the project partners involved in the present activity and do not necessarily represent the view of the European Commission and its services nor of any of the other consortium partners.

TABLE OF CONTENTS

Revision history

Version	Date	Author	Summary of changes	Status
0.1	17/08/2018	IFSTTAR	Draft structure of the deliverable	Prepared C.Villette
0.2	03/09/2018	IFSTTAR	Updated version of the deliverable	Prepared C.Villette
1	05/11/2018	IFSTTAR	Updated version of the deliverable	Prepared C.Villette
1.1	30/11/2018	IFSTTAR	Updated version of the deliverable with reviewer feedback	Prepared C.Villette / F. Schmidt
1.2	14/12/2018	IFSTTAR	Updated with agreement on scope for Level A demonstration	Prepared C.Villette / F. Schmidt
1.3	20/12/2018	IFSTTAR	Included final review comments	Prepared C.Villette / F. Schmidt
2.0	10/05/2020	IFSTTAR	Included comments EC	Prepared C.Villette / F. Schmidt
2.1	13/05/2020	CLEPA/TNO	Checked and approved	
2.2	25/05/2020	TNO	Removed the 'to be double checked by Boris' reference below Figure 3	
2.3	25/05/2020	CLEPA	Figure 1 Updated	

FIGURES

TABLES

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 realize 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 harmonization 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 document provides a non exhaustive overview of services to be provided by different actors interacting with multi-brand platoons, including (but not limited to) Infrastructure managers, authorities, truck OEMs, telematics providers, mapping solution providers, location-based service start-ups, etc.

By highlighting the diversity of the needs of the different stakeholders, including carriers, shippers, infrastructure managers and other innovation actors, the objective is to be able to provide the appropriate nature and to highlight the implied requirements on the Strategic and Service Layer in terms of functions and required data.

Regarding the Infrastructure / Authorities services, this document highlights the recommendation of architecture and APIs for the implementation during the ENSEMBLE project. Based on the learnings from the ongoing ENSEMBLE project, a later version of this same document will provide

recommendations for standardization across different types of infrastructure such as bridges, tunnels or toll gates.

Regarding the other services, such as Platoon coordination and location-based services, the architecture, functions and APIs will be described in Task 4.2.

2. INTRODUCTION

2.1. Background

The European Union’s road infrastructure has not been dimensioned to cope with important challenges. That means addressing the future societal needs, including an ageing population and expected increase in traffic congestion, as well as climate change. Without any action, this would lead lower service levels and higher economic costs, with decreased European competitiveness.

Initiatives performed across Europe are defining new requirements and functionalities for the intelligent infrastructure, in order to limit these impacts:

- Forever Open Road initiative by FERHL,
- *Route de 5ème Génération – R5G* (5th Generation of Roads, France),
- “*Die Straße des 21. Jahrhunderts”* (the Road of the 21st Century, Germany),
- SCOOP,
- the *Ferry Free E39 programme* (Norway),
- *Exploratory Advanced Research (EAR) Program* (USA).

These programs have already identified a consistent set of requirements for the infrastructure and vehicles to operate more efficiently on existing roads. Obviously, adoption time and challenges may differ depending on technologies and each country/region, because road users’ and road authorities’ demand are expected to develop at different paces. Still, some items remain consistent and, for their smooth integration in the European ecosystem, multi-brand platoons will benefit from being able to interact with this new generation of intelligent infrastructure.

Indeed, multi-brand platooning is positioning itself as one efficient way to transport goods and materials,improving overall delivery efficiency. Nevertheless multi-brand platoons could lead to accelerated wear or even have a damaging impact on infrastructure’s health compared to traditional trucks. The extent of this impact and its potential mitigation will be measured during the ENSEMBLE Project as part of WP4, and specifically Task 4.1, it is also critical to ensure that platoons can react to the inputs from Infrastructure and occasionally adapt to specific conditions.
Infrastructure is also able to send back to platoons redundant information and insight on possible treat that are out of the line of sight and meant to improve the safety of Platoons and third road users.

2.2. Aim

Regarding the point of view from Infrastructure owners/managers & Authorities, the goal is to facilitate the market uptake of multi-brand platoons that are compatible with existing infrastructure and its uses, and fully leverage the potential of the next generation of vehicle-to-infrastructure interaction to maximize safety and efficiency.

Regarding Platoon coordination and location-based services, the goal is to ensure a fair access to new opportunities created by Platooning to all parties and a transparent split of benefits.

The aim of this deliverable is to identify requirements for data exchanges, to support both interactions with the infrastructure and services offered by new and existing players.

More specifically, the objective of deliverable D2.6 is to provide the requirements for the cloud API to expose data sent by the road infrastructure for platoon information (position, speed, weight by axle, etc).

These requirements fulfil the use case #3.4.1 of D2.2 and are consistent with the service layer designed in T4.2.

A first version of this report is provided by November 2018; an update is planned at M30 (November 2020).

2.3. Positioning within ENSEMBLE WP2 context

The deliverable D2.6 covers the part of requirements linked to the services and strategic layers. As the services are very dependent on the choice of future actors for implementation, the objective is not to describe them in an exhaustive way, but to give a first description of a generic scenario to identify data flows which are needed for actual delivery of these services.

This document introduces a first view of the strategic layer's functions and serves as a starting point for the initial specification of the interface to the tactical layer and the infrastructure. Task 4.2 will detail these layers and interfaces.

Finally, as part of WP4 (D4.1), the increased impact of platoons on the infrastructure versus traditionally spaced trucks will be determined, and the conditions under which this impact increases. D2.6 aims to set up the basis for a communication from the infrastructure to the Platoons to prevent this increased impact when the conditions for infrastructure damages or safety risks are met.

The outline of services used in this deliverable is following the architecture map defined for multi-brand platooning on the Figure 1 below:

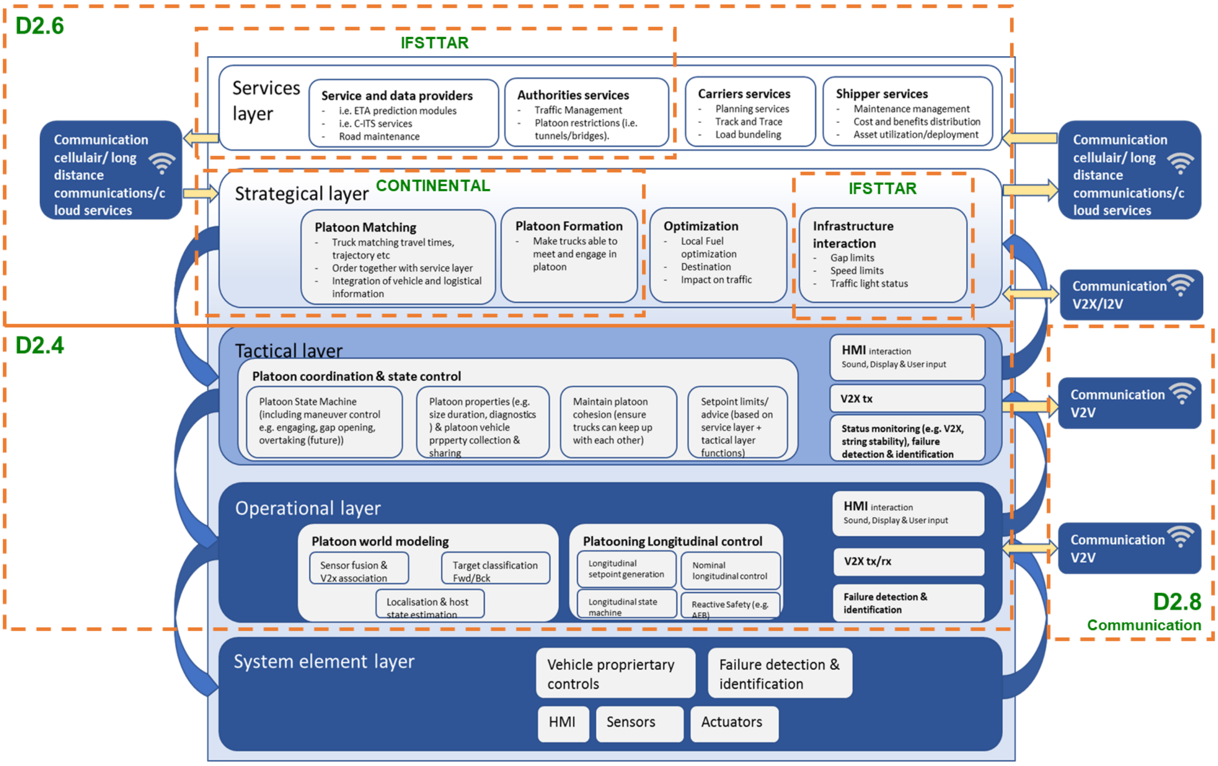

Figure 1: Layer Architecture for multi brand platooning

2.4. Structure of this report

This report is organized as follows:

- A background introduction on the concept of intelligent infrastructure and multi-brand platooning potential services,
- A non-exhaustive description of potential services to provide a basis for the requirements,
- A list of functions – and associated data - required to support the above listed services, with expected role of main stakeholders,
- A recommendation of the cloud API and Vehicle to Infrastructure (hereafter “V2I”) Interface for the implementation of the communication with infrastructure during the ENSEMBLE project,
- In the final version of this document in M30 of the ENSEMBLE project, a section on recommendation for the standardization of exchanges with the infrastructure will be appended.

3. DESCRIPTION OF THE NEW CHALLENGES

3.1. What is the intelligent infrastructure?

The next generation of roads will require high levels of adaptation, automation and resilience. The Forum of European Highway Research Laboratories (FEHRL (8)) is listing three elements that will define the next generation of roads as follows:

- **The Adaptable Road**: focusing on ways to allow road operators to respond in a flexible manner to changes in road users' demands and constraints;
- **The Automated Road**: focusing on the full integration of intelligent communication technology applications between the user, the vehicle, traffic management services and the road operations;
- **The Resilient Road**: focusing on ensuring service levels are maintained under extreme conditions (weather but also traffic conditions).

The key point regarding multi-brand platooning is the automated road aspect, on which we are focussing now and which includes:

- Comprehensive, interoperable communications systems linking road, driver, vehicle and the operators;
- Advanced vehicle and user guidance, speed control, management and direction guidance, including in-road guidance to manage traffic (Platoons in particular introduces specific challenges to merge in highways);
- Integrated traffic control, monitoring of traffic and road conditions to improve reliability and efficiency (Platoons, in particular, introduce specific challenges regarding dynamic loads on roads);
- Incident monitoring and automated response systems to reduce delays;
- Effective road tolling;
- Efficient electric vehicle power provision.

Road user: from consumer to participant

Future traffic management measures and information provision will become more personalised, with traffic management services able to provide direct information to (traffic) groups and individuals in the role of customers, while taking into account road conditions and other road users. Specifically for platoons, there is a challenge in making sure that platoons do not negatively affect other road users, in situations such as impeding highway entry/exit, or overtaking.

In addition, the individual road users will themselves provide data that can be used for traffic management purposes, including information about origin, destination, objective of the journey and intended route. In addition to providing such information, in some cases anonymised, data is being collected based on location data from mobile phone companies and connected vehicles. By using this information, operators will provide tailored services to the specific road user.

The effectiveness of measures and services, therefore, is improved, leading to much higher user acceptance and appreciation of the service itself. The road user, however, must agree and being able to share specific (personal) information with service providers and the road operators. A new role of the future road user will be as participant in the management of our road systems as well as that of a customer.

It should be noted that this sharing of data allows for better or new services, but also should create win-win situations.Sharing data from a connected vehicle makes it possible, for example, to monitor the quality of the road surface, and therefore plan maintenance or repair actions when it is not sufficient anymore. Allocated time slots or dedicated lanes could also be provided to vehicles sharing data.

3.2. What are the key elements for validating infrastructure compatibility?

Current road infrastructure is designed by taking into account load models, which have been developed and calibrated using knowledge of existing traffic (volume of heavy traffic, type of trucks and their loadings) and taking into account uncertainties with safety margins (called safety factors). These margins are linked to the structure itself and its resistance, and to the loadings: indeed the infrastructure needs to be able to cope with the actual traffic - even if the structure is ageing, stringent weather conditions (cold/warm temperature, frost …), or specific constraints (e.g if some trucks are (slightly) overloaded).

The load models have been developed by assuming “normal” distances between trucks, which means generally distances higher than 50 meters. This explains that nowadays platooning is not allowed (everywhere) by the regulation. But if real-time, accurate information from the traffic is provided, for example by the trucks themselves through V2I, it could be possible to allow for lower safety margins. This principle is much advocated nowadays, for example by the COST1406 Value of information, OECD working group “Policies to extend the life of road assets” or the International Transport Forum.

The knowledge of the traffic needed to validate the compatibility between existing infrastructure and new types of them depends on the infrastructure elements to be considered: for example, the parameters impacting pavement wear are not the same used for the assessment of bridges.

For platooning, it would be helpful for the infrastructure managers to know they are able to assess the impact of platoons on the infrastructure and, consequently, issue dynamic recommendations for driving policies on specific zones of the network. To achieve this, they should have knowledge of the following parameters for each platoon and each truck of the given platoon, as it:

- Number of trucks within platoon and distance between trucks within the platoon,

- Axle loads,
- Distance between axles.

The objective is to be able to adapt the speed and inter-distance limits to the platoons in order to maximize the number of authorized platoons. This communication is the basis for a win-win situation, allowance for new types of traffic on one side and better assessment of traffic wear on the other.

The exact mechanisms for the collection and the exchange of this information has to be agreed between all parties. The road operators have expressed the need to be able to ban specific platoon configurations, if they are damaging the infrastructure or creating a safety concern.

3.3. What are the challenges around Platooning optimization and its requirements on the communication with infrastructure ?

Vehicle-to-infrastructure communications, either through roadside units or direct communication with a cloud service, is key to optimization schemes associated to truck platooning. Main aspects and stakes are shortly explained hereafter. The question answered in the section is how can the communication with infrastructure help to optimize Platooning.

The platooning service needs to provide value in order to maximize participation. It is important that carriers find it worthwhile to use the service, because the more they are, the higher the service will be valuable (club effect). This is due to the fact that it needs several vehicles to realize the value and, therefore, it requires coordination of them (either scheduled, or on the fly) and their routes. Matching is costly, as it puts additional constraints on vehicle operations for carriers, such as delaying departures or taking detours. On the other hand, the more carriers will practice platooning, the more vehicles will be able to candidate to get in platoons and the less costly platooning will be. Matching costs are expected to strongly decrease with market size.

This raises several optimization questions. One of them is the question of the technical compatibility between vehicles. Trucks are heterogeneous, and the difference in their characteristics will have an impact on the possibility to form platoons and their characteristics (inter-vehicle distance and speed, for example). A tradeoff has to be found between privileging technical similarities inside platoons (improving platoon performance but reducing the economic relevance of platooning) or allowing for platoons with heterogeneous vehicles (maximizing market size but probably raising technical issues). In order to further understand this issue, technical data is required on the relationship between platoon composition and platoon performance.

Another question is the platoon formation strategy. Scheduled platoons are essentially vehicles whose routes and timings are matched together. From an operation perspective, matching is a constraint, thus a cost. Carriers signing into a platooning service will not organize platooning themselves, except if platooning is reduced to their own fleets. This would probably strongly reduce the service's uptake, and probably remove the need for a commercial service altogether. In the case where the service allows platooning between several carriers, then the platooning strategy will be external to carriers. The options suggested by the platooning service to carriers will have to make sense from an economic standpoint: if the time loss and/or cost to participate to the platooning service consistently overcompensates the benefits, then expected participation will be low. In order to further investigate this issue, additional data on platooning formation strategy is needed, as well as on carrier costs.

An additional question is related to routing and infrastructure equipment. It may make sense to suggest to carriers to reroute their vehicles if the additional distance time and costs is balanced by the overall economic gain of using the service. This issue is particularly important if platooning is only possible on a sub-network of roads, because of technical constraints and/or the need to equip infrastructures. If it is technically required to equip infrastructures with communication devices to enable platooning, then the question of which part of network that should be equipped is also important, and closely related to the previous one. On this particular issue, communication cost data (fixed and variable) regarding infrastructure and vehicle equipment are required to be assessed.

4. DESCRIPTION OF THE POTENTIAL SERVICES FOR MULTI-BRAND PLATOONING INTRODUCTION

4.1. Service layer description

Service and data providers

Within the Services Layer various commercial parties can implement or develop supporting (data) models or algorithms that can possibly improve the efficiency or quality of one of the generic components from the Strategic Layer.

Example: a commercial ETA prediction tool that is used by the Platoon Matching service, or a tool optimizing fuel consumption.

Note: This is a very generic component as a placeholder for future commercial activities.

Road authorities services

The goal here is to describe for which roads platooning is allowed and which restrictions are relevant. Road authorities are understood as the road operators in charge of maintaining the road services in good conditions for all users. For example, they can be municipalities or highway managers. The leading authorities is of course the governments.

Within the Road Authorities Services, each of the road authorities can implement the network where platooning is allowed and under defined conditions. It is possible that future management principles will need to drive a more explicit interaction between goals for traffic flow and other societal goals, whereas they are primarily designed from a governmental perspective, at the moment. The Automated Road will require cooperation between public and private partners, and management principles are expected to reflect policy goals from both partners. Hence a combination of collective and individual goals and strategies will influence the management principles required to deliver the Automated Road.

Communication with the virtual truck (cloud to cloud):

- Authorization to platoon depending on platoon self-registration with the road authorities.
- Providing specific guidelines for platoons (adapted speed, lateral positioning, inter-distance, for e.g. adapted with the road surface) based (or not) on the platoon configuration (Number of vehicles, total weight of the trucks, axle configurations) to optimize infrastructure lifetime expectancy
- Providing safety information (weather, traffic patterns, infrastructure health)

- Allocate specific direction using traffic management (dynamic lane for prioritization, dynamic traffic lights, traffic light status)

Note: The data within this database can be overruled by the dynamic information from the real-time infrastructure interaction at the strategic layer.

Shipper services

Facilitate various components for shippers to trace their shipment and their transport conditions.

Example: a service providing a comparison of carriers based on reduction of CO_2 emissions or transportation time by leveraging platooning services. This would involve sharing of anonymised carrier data and is subject to regulation compliance.

Note: This service also provides a placeholder for future logistical concepts.

Carrier services

The objective is to facilitate and standardize the data from multiple carriers to facilitate an operational multi-brand, multi-fleet platooning service, whether the platoon leaves from a parking lot or meets on the way to the destination. By utilizing platooning the carrier can lower its operational cost (at least that is the assumption).

To get maximal benefit services need to:

- Maximize time in platoon (Matching),
- Introduce minimal new overhead (Easy management of multi-brand fleet e.g. set preferences in one location),
- Have platooning as a parameter in business planning (Correct information about platooning benefits),
- Efficient platoons (Optimization).

Example: a service providing a cost-benefit sharing (or incentivization) module to share the gains and costs of platooning between the various vehicles.

Note: This service also provides a placeholder for future logistical concepts (i.e. vehicle management).

4.2. Strategic layer description

Platoon Matching

The Platoon Matching functionality provides match candidates based on logistical or operational data based on matching concepts, depending on whether the platoon is set up before the vehicles leave their parking lot (Scheduled), or if they meet at predefined points once the first vehicles have already left (En-route), or if they can create platoons dynamically on the way (Ad-hoc). These terms will be further defined in T4.2.

1) A route can be described as the full trajectory between the vehicle origin and destination but can also be described as the route towards the next highway off-ramp.

2) For platooning additional information (i.e. trailer types, vehicle weights, freight types) are relevant, this information is used at the platooning service provider but are most likely not communicated towards the individual vehicles of the platoon.

3) This service can be integrated with various commercial components from the service layer (i.e. ETA predictors based on real-time data).

Platoon Formation

The Platoon Formation Functionality ensures that the vehicles from a suggested platoon (from the Platoon Matching component) are routed in such a way that the vehicles end up in range of V2V communication.

This service can integrate with various commercial components from the service layer (i.e. ETA predictors based on real-time data).

Optimization

The Platoon Optimization Component determines a system optimum platooning solution (target headway for each of the platoon candidate vehicles).

There is a dependency between the optimization and Platooning Matching components: for each platoon a suggested order is generated by the Platoon Formation component. However, the Optimization can suggest a re-ordering during the platoon execution.

Infrastructure interaction

To facilitate limits in dynamic road allowances based on real-time data (traffic conditions, traffic incidents, weather information etc), provide feedback and redundancy information from the infrastructure (lateral position, weight by axle, inter-distance) and to pre-register arriving platoons to RSU's (i.e. when vehicles are not (yet) in V2I range. The overall objective is to provide data from the infrastructure to keep platoons together as much as possible, and to keep all vehicles safe (platoons and vehicles surrounding them).

Communication by the roadside unit (immediate action scenario) - Examples:

- Providing dynamic guidelines based on weather conditions in case of weakened infrastructure by specific weather conditions or aging (e.g. Winter roads management) for a specific platoon with very high impact (vehicles with isolated single axles, etc).

- Providing dynamic guidelines based on infrastructure status on a specific zone (e.g. bridge) for specific platoon (e.g. high number of vehicles in platoon) to use a specific configuration (e.g. spread themselves laterally on the lane to avoid passing all exactly at the same point).

- Providing direct redundancy information from infrastructure for specific vehicles for the platoon to integrate as required (longitudinal and lateral displacement, trajectory, tire footprint).

- Provide safety warnings such as Emergency breaking ahead of the platoon outside of the line of sight.

- Detection of infraction of zone policy (e.g. Platoon maintained when reaching a bridge, overloaded truck) requiring platoon acknowledgement and dissolution. The final intention is to ensure safety for all users. For example, some platoons might be authorized on some bridges, rather than forbidding them all by default,

- Providing information about the surrounding traffic (RSU detection and warnings for vehicles coming on entry/exit ramps, incident management)

5. REQUIREMENTS AT THE SERVICE / STRATEGIC LAYER

5.1. Service layer functionalities

Functionality	On/ offboard	Input data	Output data	Why is the data needed?
Service and data providers	Off-board; Located in the cloud.	Platoon configuration, start and stop platooning points	Route plan, ETA, estimated fuel consumption…	Provide input for platoon matching
Authorities services	Off-board; Located in the cloud.	Map of the road network listing where platooning is allowed. This also include specific tunnels, bridges etc). This database should be generic and standard for Europe	Publicly available Platooning Database with GPS coordinates and limits (max. number of truck in a platoon, time windows in which platooning is allowed and/or restrictions in speed for platoons, etc)	Facilitate safe platooning and protect the road infrastructure
Shipper services	Off-board; Located in the cloud.	Various planning tools from various shipping companies	Standardized logistical data that can be integrated with the matching algorithms.	To facilitate multi-fleet platooning accross multiple shippers
Carrier services	Off-board, integrates the information from fleets towards platooning	Data from the platooning vehicles (i.e. driver, schedules, vehicle types, fuel consumption etc) and the main platooning KPI's to distribute the costs and	Standardized logistical data that can be integrated with the matching algorithms. Moreover this module provides the	To facilitate multi-fleet platooning accross multiple carriers and equally share the costs & benefits among the vehicles

	architecture.	benefits.		platooning.

Table 1: Overview of the service layer functionalities

5.2. Strategic layer functionalities

In the table below,

- parameters listed in italic are expected to be sent by / to the Tactical layer (to be refined in T4.2),
- The definition of the Vehicle's ID needs to be further defined to ensure consistency, but should at least secure that vehicles can be uniquely identified, whilst ensuring protection of personal data – so most likely not something that can directly be mapped to a license plate.

Functionality	On/ offboard	Input data	Output data	Why is the data needed?
Platoon Matching	On board for 'ad-hoc'. Off-board for other matching types.	**For ad-hoc matching**; *current vehicle location, next highway off-ramp.* For all nearby candidate vehicles (distance <500m): *current location, vehicle identifier, corresponding next highway off-ramps.* **For en-route :** *vehicle ids, current routes of all active vehicles (waypoints and corresponding ETA's)*.	Suggested platoon: array of vehicleIds, planned point (lon,lat) time in which the platoon is engaged, method in which the platoon is started (standstill/while driving), expected point at which the platoon is dissolved.	To communicate the startpoint of the platoon and the corresponding vehicleID's.

Platoon Formation	On board for 'ad-hoc'. Off-board for other matching types.	Platoon candidate from "Platoon Matching' component. See cell H2.	A detailed trajectory (lons, lats and ETA's) for each vehicle ID from the platoon candidate: the path from the current position of each vehicle towards the point where vehicle joins.	A generic white-label description is required to integrate with the various FMS and TMS systems
Optimization	For Level A platooning, can be done on-board. Later, off-board to include data e.g. road gradients, real-time traffic, etc.	Platoon candidates from "Platoon Matching' component. See above. Real-time data from the platooning vehicles to monitor current efficiency - *fuel consumption, vehicle configuration* (this data is derived from the 'platoon coordination and state control' from the tactical level.)	*Longitudinal and lateral targets and limits* for each vehicleID within the platoon	To optimize the performance of a platoon (in terms of fuel consumption and string stability)
Infrastructure interaction	Off-board	From platoon: *Vehicle number, types, tire configuration, weight, trajectory.* From infrastructure: road conditions and constraints, including temperature and humidity levels as available.	*A dynamic database (max. and min. speeds, max. and min timegaps*) for which the road allowances are available and early communication messages towards RSU units, as well as *zone policy coordinates*	Ensure safety for all vehicles. Optimize the cost function and risk level of the infrastructure (bridges, roads, tunnels)

Table 2: Overview of the strategic layer functionalities

5.3. Level A Platooning in the Ensemble project - Strategic layer requirements

The functionalities listed in the two previous sections are generic services that will be required in the next stages of Platooning. This section is focusing on the specific requirements to be implemented as part of Level A Platooning in the Ensemble project, and to be demonstrated either on the IDIADA test track or on the final live demonstration on open roads, depending on safety concerns and equipment availability.

Regarding min_time_delta, the objective is to manage a minimum space between the trucks to preserve infrastructure. The distance is best managed by the trucks as a combination of their speed and the time delta.
The majority of the ACC functionalities work with timegaps (and not distances), plus trucks drives at a constant speed drive. Therefore, it has been decided to prefer using the time gap instead of a distance.
The min distance is equal to = current max speed * min_time_delta

Table of requirements to address use case #3.4.1 of D2.2 :

Requirement Title	Description	Parameters	Actors involved	Barriers	Level A coverage
#1 – Ability to manage Zone policy publication	Ability to define policy based on zone (zone policy or geofencing)	• policy_area: array of GPS coordinates • platooning_authorized: boolean • max_speed: maximum speed • min_time_delta: minimum time in second between vehicles *//Optional for LEVEL A//* • *max_number: maximum number of vehicles platooning* • *lateral displacement : array of lateral displacements*	Platoon Infrastructure manager / Authorities	- the zone policy needs to be available on the C-ITS control centers 24h/7(redundancy, high availability) - The rules needs to be available for trucks that do not use a dynamic map, which is the reason for the V2I choice in the Ensemble project.	For Level A testing, implement support for V2I broadcast from a RSU at IDIADA No handshakes in the demo.

#2 – Ability to manage toll RSU position	Get the pre information on positioning of RSU & zone policy	• positioning of Toll RSU and power reduction zone policy (GPS coordinates)	Platoon Infrastructure manager / Authorities	- The zone policy needs to be clearly defined for safety purposes : information required to avoid emergency breaking at every toll - Could be included in infrastructure rules.	For Level A testing, implement support for V2I from RSU at IDIADA.
#3 – Ability to manage Zone policy update	Ability to adjust policy dynamically	• policy_area: array of GPS coordinates • platooning_authorized: boolean • max_speed: maximum speed • min_time_delta: minimum time in second between vehicles //Optional for LEVEL A// • max_number: maximum number of vehicles platooning • lateral displacement : array of lateral displacements	Platoon Infrastructure manager / Authorities	- A max time gap to implement the rule in the zone policy in case of an update (min, hours, days) needs to be defined > Further evolution can be studied for Level B & C with bidirectional communication with infrastructure.	For Level A testing, implement support for V2I from a RSU at IDIADA
#4 – Ability to manage Platoon configuration declaration	Ability to anticipate impact of specific platoons on infrastructure in current traffic and weather conditions.	//Inputs 2.8 platoonID: identifier for the platoon vehicleNumber: number of vehicles in platoon vehicleConfiguration: array of vehicles axle configuration maxWeightPerAxle: maximum weight per axle plannedInterdistance	Platoon system, infrastructure	Strong purpose needed : difficulty with GDPR to share information if not legally enforced There might not be the knowledge of axle loads for all trailers. There should only be requirements to the single vehicles.	Not implemented in Level A.

#5 – Ability to manage Targeted zone policy update based on infrastructure health	Based on the road sensor data, have the ability to adjust the speed limit for specific vehicles in real time.	• policy_area: array of GPS coordinates • platooning_authorized: boolean • max_speed: maximum speed • min_time_delta: minimum time in second between vehicles //Optional for LEVEL A// • max_number: maximum number of vehicles platooning • lateral displacement : array of lateral displacements	Platoon system, infrastructure	Regulation per country (speed, maximum weight, autorisation to pass bridges / tunnels / etc) Identification of Platoon ID	For Level A testing, implement support for V2I from a RSU at IDIADA

In addition to these requirements, we can also suggest to take the following items into account for later developments:

#6 – Ability to manage Toll management Adapt the power of emissions	Reduce the power of transmissions and properly adjust platoon configuration		Platoon Infrastructure manager / Authorities	Regulation Safety - avoid perturbation of toll management	For Level A testing, implement support for V2I from a RSU at IDIADA Prior to test track testing, IDIADA will propose a test for the mono brand platooning testing for toll gate handling and then it will be tested with multi brand in the end.

#6 – Ability to manage Standardized backend infrastructure (API)	//Level B and above // Specification of the off-board strategic layer to read out platooning data	we need a digital clone of the platoon "some-where in the could" all V2V values send to backend	platoon truck, back-end	There might be multiple OEM back-ends. Goal is to have a unified way of communicating	Not implemented in Level A, to be described as part of documentation of Ensemble project

6. DESCRIPTION OF THE CLOUD API AND V2I INTERFACE FOR THE IMPLEMENTATION OF THE COMMUNICATION WITH INFRASTRUCTURE DURING THE ENSEMBLE PROJECT.

6.1. Description of the V2I aspects for testing activities in ENSEMBLE

As listed in the introduction of this document, there are several objectives linked with the interactions between vehicles and infrastructure:

- Increased safety with redundant information from the infrastructure
- Improved traffic with dynamic, adapted recommendations to specific vehicle configuration and traffic conditions
- Optimized infrastructure management with adaptable driving conditions based on road and weather conditions.

ENSEMBLE project is paving the way to multi-brand truck platooning by defining relevant specifications and realizing first-time implementation. The outcome of the project is designed to allow agile deployment for progressive deployment of the concepts.

Test case description:

- Prior to the test, enter inputs on road composition and conditions in the system.
- Deploy a device that can detect the platoon configuration on the road ahead of a specific zone (distance to be agreed) with specific dimensioning constraints (bridge, tunnel, etc).
- Run the platoon over device.
- Send direct feedbacks from infrastructure on vehicle configuration, direction, lateral displacement, weight – data is available both in the cloud and through roadside units (V2I).
- Calculate of the road stress level and generation of a recommended max speed, min inter-distance, or lateral positioning recommendation for a specific zone, called zone policy. This is in line with the general trend that introduces the notion that regulation is dynamic and depends on traffic characteristics (in this case, platoon characteristics).
- Send dynamic update of zone policy towards the platoon – data is available both in the cloud and through roadside units (V2I).

- The platoon adjusts to the zone policy prior to the entering the specified zone.

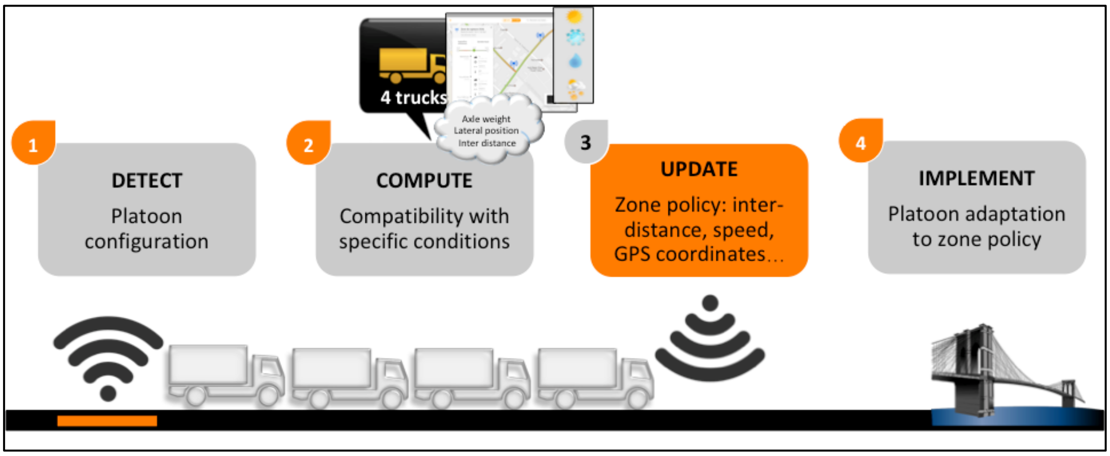

Figure 2: high level view of the dynamic zone-policy implementation use case

6.2. Example of architecture

The figure below is highlighting potential data exchanges with the OEM's ITS backend. Among these, road authorities appear both on the API site and on the V2x side.

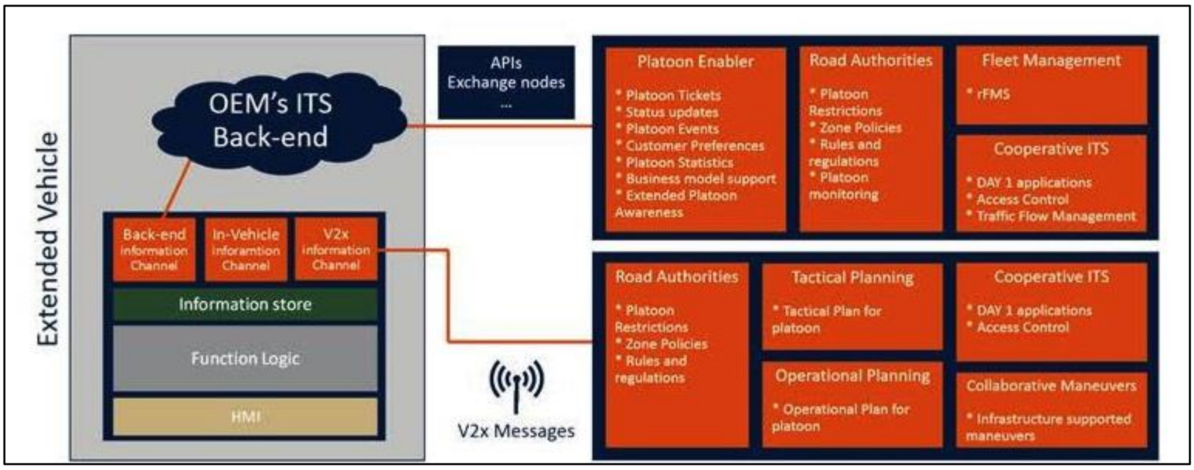

Figure 3: Example of the extended vehicle's interaction with Platoon and ITS information for platooning application

For our specific use case, both options can be implemented, depending on the ability for the platoon to call backed APIs in the cloud. This means that either :

- the trucks are communicating directly with the cloud set up by road authorities via local sites communication points such as road site units,

- or the trucks are communicating with their OEM's cloud and this one is in contact with the cloud set up by road authorities. In this situation, the OEM's cloud is "backed" by the cloud of road authorities (see picture below).

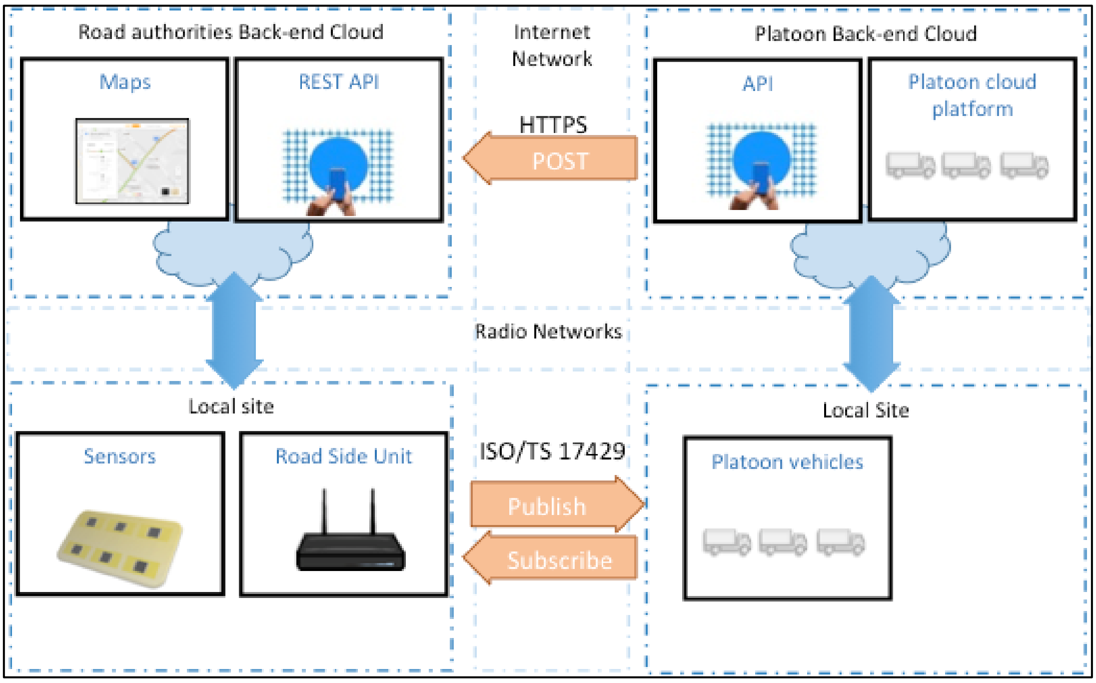

Figure 4: Proposition of implementation

V2I interaction using the ISO/TS 17429 norm and BACKED APIs in the cloud

6.3. Proposition for the Cloud API

The following table is a proposal for the format of the data available in the cloud and accessible via Backed API over HTTPS. Considering that these data needs to be exchanged either at the cloud level (service or strategic layer) and via V2I exchanges (tactical or operational layer), there is a strong likelihood that all these parameters would have to be exchanged at the strategic <> tactical layers interface.

METHOD	URL	BODY	ANSWER
POST	url/UBR/passage/	3 parameters in the body : • ubr_id • from : starting time for the passage list in unix time • to : ending time for the	Detection parameters: • @timestamp: passage time • temperature: mat temperature • speed: vehicle speed • total_mass: vehicle total mass

		passage list in unix time	• number_of_axletree: number of axles • axletree_mass: array of mass per axle • angle : passage angle • displacement : lateral displacement • wheel_width: array of vehicle wheel widths • time_delta: time from preceding vehicle • error: precision of the results
POST	url/UBR/policy/	2 parameters in the body : • ubr_id • @timestamp: passage time	Zone policy parameters : • policy_area: array of GPS coordinates • platooning_authorized: boolean • max_number: maximum number of vehicles platooning • max_speed: maximum vehicle speed • min_time_delta: minimum time in second between vehicles • lateral displacement : array of lateral displacements

Table 3: Overview of the cloud API for passage information and zone policy

6.4. Proposition for the V2I API

Requirements for the supporting standard:

- (Mandatory) Multi-usage: adaptable content to support different message format
- (Recommended) Multi-protocol: support for multiple radio networks
- (Recommended) Inter-operable: compatible with multiple smart mobility equipments and applications

Based on the lessons learnt from European initiatives on intelligent infrastructure and connected vehicles, below are recommendation to leverage collaborative ITS standards such as:

- [ISO 21217] (2014)
- CEN TC278 WG17
- [ISO/TS 17429] (2018)

Requirements for the Infrastructure to Vehicle (I2V) communication services:

Flow 1: From the vehicle to the infrastructure
Suggestion of standards: new message similar to CAM message, or ISO/TS 17429 (https://www.iso.org/standard/59727.html)

The CAM Message is often used today but might not be able to accommodate all parameters. The ISO/TS 17429 format is more recent but more flexible, by providing a common header and an adjustable content format.

Platoon declaration:
platoonID: identifier for the platoon
vehicleNumber: number of vehicles in platoon
vehicleConfiguration: array of vehicles axle configuration
maxWeightPerAxle: maximum weight per axle

Flow 2: From the infrastructure to the vehicle
Suggestion of standards: SAM message (ETSI TS 102 894) or ISO/TS 17429 (https://www.iso.org/standard/59727.html)
The SAM Message is often used today and can broadcast the information but it will not be able to make it personalized for one type of vehicles. The ISO/TS 17429 format is more recent but more flexible, and allows interacting with specific vehicles.

Zone policy parameters:
policy_area: array of GPS coordinates
platooning_authorized: boolean
max_number: maximum number of vehicles platooning
max_speed: maximum vehicle speed
min_time_delta: minimum time in second between vehicles
lateral displacement : array of lateral displacements

7. SUMMARY AND CONCLUSION

Context :

The European Union’s road infrastructure has not been dimensioned to cope with important challenges. That means addressing the future societal needs, including an ageing population and expected increase in traffic congestion, as well as climate change. Without any action, this would lead lower service levels and higher economic costs, with decreased European competitiveness. Innovative measures such as intelligent and dynamic infrastructure are being tested by several complementing initiatives across Europe. They introduce the notion of dynamic road regulation based on vehicle configuration in general and platoon configuration specifically.

Platoon & Infrastructure:

Platooning introduces a specific impact on infrastructure such as increased stress levels due to the reduced inter-distance, making infrastructure such as bridges especially vulnerable. On a protective side, in order to get buy-in from infrastructure managers to authorize platoons, the taking into account of areas with specific rules is critical. On a value added side, the infrastructure can provide safety recommendation to the platoons based on the current state of the infrastructure such as recommended speed and inter-distance.

Beyond infrastructure interactions and services, multi-brand platoons will introduce new potential services. For these services to be made available, logical functions have been identified, both at the service and strategic layers, to support the definition of the interface between the strategic and tactical layers.

In this deliverable, the following bullet points have been addressed :

- Provided context information on the background for infrastructure communication purposes, with the aim to improve infrastructure durability and vehicle safety,
- Provided the service layer functionalities that will be the base of the service layer designed in T4.2.
- Addressed how platoon and infrastructure should communicate in use cases specific to platooning, for example in use case #3.4.1 of D2.2 with the transmission of recommendation of speed and inter-distance on specific sections of the infrastructure, and listed other cases where V2I and I2V communications could be relevant (e.g. toll gates).

- Clarified required parameters and information to be transmitted as part of the messages
- Provided some example of communication architecture between different entities to cover for different scenarios based on OEM and road authorities preferences.

This document highlights the requirements for multi-brand platooning to be compatible with those new intelligent infrastructures, via cloud interfaces and V2I interfaces. To be future proof and minimize the deployment effort both on the infrastructure and OEM sides, the standard used for the V2I interactions should be multi-usage, multi-protocol, inter-operable. Based on lessons learnt from other European project, such standards exist and are listed as suggestions for the implementation of a POC within the Ensemble project.

Next steps :

- Implementation of the requirements to support the test of use case #3.4.1 of D2.2
-
- Task 4.2 of the ENSEMBLE Project will further address the service layerUpdate of the D2.6 documents with lessons learnt from the test of use case #3.4.1 at the IDIADA test facilities and documentation of recommended standards in D2.7 by Q4 2020.

8. BIBLIOGRAPHY

On intelligent infrastructure:

SCOOP@F, C-ROADS France and InterCor (2017). French C-ITS use cases catalog

FERHL Forever Open Road initiative (2018). A roadmap for research.

Route de 5ème Génération – R5G (5th Generation of Roads, France),

“Die Straße des 21. Jahrhunderts” (the Road of the 21st Century, Germany),

The Ferry Free E39 programme (Norway) ,

Exploratory Advanced Research (EAR) Program (USA).

On intelligent infrastructure:

Reference Architecture for communication « ITS station » (ISO 21217)

ISO TC 204 WG16 / WG17 / WG18 (http://its-standards.info)

CEN TC 278 WG17 (Urban ITS)

France (AFNOR) : GC ITS / CN16

ETSI – Normalisation – Final Joint Mandate M453 Report
http://www.etsi.org/images/fles/technologies/Final_Joint_Mandate_M453_Report_2013-07-15.pdf

C-ITS Platorm (Commission Européenne) - htps://ec.europa.eu/transport/themes/its/c-its_en

9. APPENDIX A. GLOSSARY

9.1. Definitions

Term	Definition
Convoy	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
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.
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.
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 design	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,

Term	Definition
domain)	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.
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 decides to disengage from the platoon itself or is requested by another member of the platoon to do so. When conditions are met the ego-vehicle starts to increase the gap between the trucks to a safe non-platooning gap. The disengaging is completed when the gap is large enough (e.g. time gap of 1.5 seconds, which is depends on the operational safety based on vehicle dynamics and human reaction times is given). A.k.a. leave platoon

Term	Definition
Platoon dissolve	All trucks are disengaging the platoon at the same time. A.k.a. decoupling, a.k.a. disassemble.
Platoon engaging	Using wireless communication (V2V), the Platoon Candidate sends an engaging request. When conditions are met the system starts to decrease the time gap between the trucks to the platooning time gap. A.k.a. join platoon
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 on the fly, scheduled or a mixture of both. 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	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
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

Term	Definition
	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.
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	Description of system properties. Details of how the requirements shall be implemented at system level
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).

9.2. 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
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
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