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D6.2: Functional architecture of enabling functions

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Abstract

This report provides a detailed functional description of the WP6 enabling functions and describes the in/outs, data streams and the partners involved in or affected by the enabling function. Furthermore, a detailed overview of the interoperability of the enabling functions by a functional and data flow architecture is given. These overviews make clear what data is used and what processing will be done with the data.

Keywords:

Enabling functions, functional architecture, data flow architecture

Document Revision History

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Disclaimer

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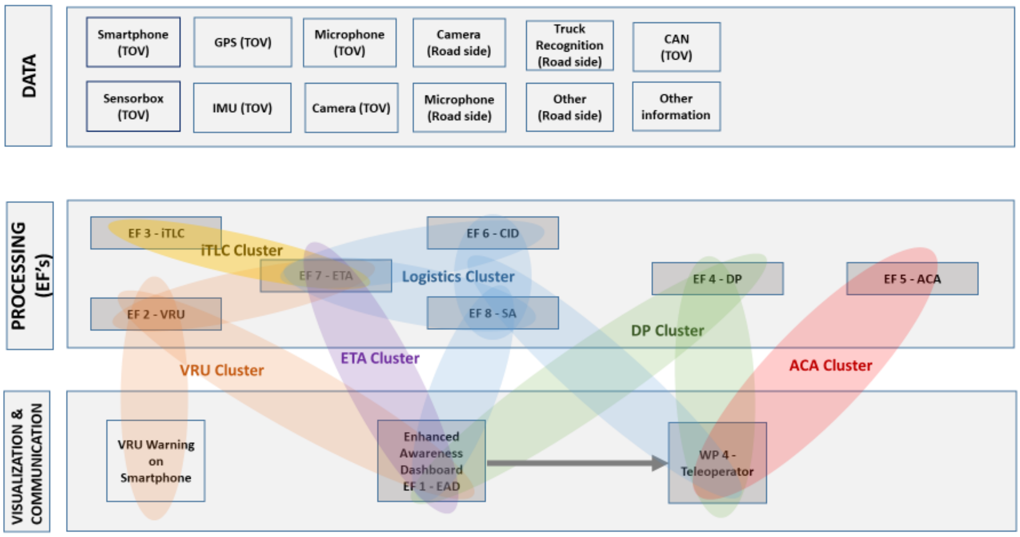
  DEM: Demonstrator, pilot, prototype, plan designs
  DEC: Websites, patents filing, press & media actions, videos, etc.
  OTHER: Software, technical diagram, etc

EXECUTIVE SUMMARY

Teleoperated transport poses unique challenges as the removal of the operator from the vehicle implies that (1) situational awareness of the operator is reduced; and that (2) interaction between operator and surrounding road users becomes 'virtual'. To guarantee the safety of teleoperated transport, both on private (port) premises and on public roads and across multiple countries, enabling functions are required. These enabling functions will process raw sensor data into useful information so that teleoperator transport is possible in a safe and cost-efficient way.

Functionally, we can distinguish between three layers, as shown in the below figure.



In the first "**Data Ingestion Layer**", raw data is collected from several sensors installed on the teleoperated vehicle (the "**TOV**") such as cameras, inertial measurement units, GPS, LiDAR and microphones and from external API's such as the Be-Mobile traffic API for the traffic situation based on Floating Car Data (FCD). For some enabling functions, data from sensors on the side of the road will also be collected. This could be data from CCTV's, Automatic Number Plate Recognition ("**ANPR**") cameras or microphones. In some cases, the raw data will be processed on the edge. The raw and/or pre-processed data will then be sent with the help of 5G towards the cloud.

The processing from raw data into useful information will be done in the second layer, the **"Processing Layer"**, by the enabling functions. We distinguish between **six clusters**, which are sets of processes and communication chains with a specific objective:

- **VRU cluster** (EF2 Vulnerable Road Users - **VRU**, EF1 Enhanced Awareness Dashboard - **EAD**, and EF7 ETA Sharing **ETA**): this cluster is aimed at warning Vulnerable Road Users ("VRU"s; pedestrians and cyclists) and teleoperators for potential VRU/TOV conflicts. Part of this cluster also involves communication back to the VRU via smartphone;
- **iTLC cluster** (EF3 Time slot reservation from iTLC - **iTLC** and EF7 ETA): the intelligent Traffic Light Controllers cluster aims to provide an appropriate time slot for green-lighted passage over an intersection to the teleoperated transport (ensuring smooth passage over the intersection, which is particularly relevant for teleoperated transport in platoons).
- **DP cluster** (EF4 Distributed Perception **DP** and EF1 EAD): the Distributed Perception cluster is aimed at providing an extended perceptive range to the remote teleoperator for making the appropriate decisions.
- **ACA cluster** (EF5 Active Collision Avoidance **ACA**): This cluster is aimed at providing Active Collision Avoidance tools to the teleoperated transport. As the cluster uses sensor

data and processes this into usable actions or warnings, the cluster is located in the processing layer and not directly in the data layer.

- **Logistics cluster** (EF6 Container ID recognition **CID**, EF7 ETA and EF8 Scene Analytics **SA**): This cluster is aimed at (i) streamlining tasks which would normally be carried out by operator on the ground and for which the remote teleoperator will require support; and at (ii) leveraging opportunities presented by teleoperation and the dataflow ensuing from it to increasing efficiency of (teleoperated) transport.
- **ETA cluster** (EF7 ETA and EF1 EAD): This cluster is aimed at providing detailed Estimated Times Of Arrival (ETAs) to the teleoperator and other interested parties. Inputs from other clusters will be used within this cluster; similarly, the output from this cluster will also be important for other clusters. This explains the central position of EF7 ETA in the architecture scheme.

The third layer, "**Visualization and Communication Layer**", involves the visualization and communication of the output of the various enabling functions to end-users (i.e. teleoperators, or vulnerable road users), other work packages and other interested parties. The output of many of the data processing clusters (but not necessarily all) will be consolidated by EF1 EAD into information that is relevant and usable by the teleoperator. Via EF1 and the displays used by WP4 clear and concise information on the advised speed, warnings, ETA and turn-by-turn navigation will be shown to the teleoperator via a heads-up display. In addition, a map-based view will be shown to the teleoperator via a secondary screen, offering more detailed information. For some EF's, such as EF4, EF5 and parts of the logistics cluster, some communication with WP4 and the teleoperator will take place directly (i.e. not via EF1 EAD).

For these different Enabling Functions, this report provides insights in the processes, data flows, and roles of each partner involved, including details about required in/outs, sequence diagrams, and user stories. This way, this report answers four questions:

- What can we functionally expect from the enabling functions?
- What inputs and outputs do each of these functions require?
- What role does each partner play in each of these functions?
- How are the enabling functions tied together?

This deliverable will be used as input, together with Deliverable D6.1 Description of enabling functions and their requirements" for designing the technical architecture, including a description of interfaces, secure communication protocols, hardware and software requirements. Technical questions that are still open will be tackled during the design phase of the architecture. This means that the investigation of the architectural dependencies from 5G functionalities is out of scope of this deliverable. This topic will be tackled later in D6.3.

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ABBREVIATIONS

ACA	Active Collision Avoidance
ACC	Adaptive cruise control
AEB	Advanced Emergency Breaking
ANPR	Automatic Number Plate Recognition
API	Application programming Interface
BIC	Bureau of International Containers
CACC	Cooperative Adaptive Cruise Control
CCTV	Closed-Circuit Tele-Vision
DTI	Delta Time until Impact
DTP	Delta T Paths
EBA	Emergency Breaking
EF	Enabling Function
EF1 EAD	Enabling Function 1: Enhanced Awareness Dashboard
EF2 VRU	Enabling Function 2: Vulnerable Road Users
EF3 iTLC	Enabling Function 3: Time slot reservation at iTLC
EF4 DP	Enabling Function 4: Distributed Perception
EF5 ACA	Enabling Function 5: Active Collision Avoidance
EF6 CID	Enabling Function 6: Container ID recognition
EF7 ETA	Enabling Function 7: ETA sharing
EF8 SA	Enabling Function 8: Scene Analytics
ELKS	Emergency Lane Keeping System
EAD	Enhanced Awareness Dashboard
ETA	Estimated Time of Arrival
ETSI	Europees Telecommunicatie en Standaardisatie Instituut
FCD	Floating Car Data
GNSS	Global Navigation Satellite System
HMI	Human Machine Interface
HUD	Heads-Up Display
HTTP	Hypertext Transfer Protocol
ISY	I Saw You message
iTLC	intelligent Traffic Light Controller
JSON	JavaScript Object Notation
LiDAR	Light Detection and Ranging
MQTT	Message Queuing Telemetry Transport
NDW	National Dataportaal Wegverkeer
REST	REpresentational State Transfer

SGD	Safety Gateway Device
SRTI	Safety-Related Traffic Information
TAS	Truck Assignment System
TOV	Tele-Operated Vehicle
TLC	Traffic Light Controller
V2I	Communication from Vehicle to Infrastructure
V2X	Communication from Vehicle to Everything
VRU	Vulnerable Road User
WAN	Wide Area Network
WGS 84	World Geodetic System 1984
WP	Work Package
XML	Extensible Markup Language

1 INTRODUCTION

As teleoperated transport poses unique challenges, enabling functions (“**EF**”s) are required. In order to perform teleoperated transport safely and cost-efficiently with EFs, it is important to have a good understanding of the functional details of the EFs. This will be the base for further development and implementation.

This document aims to inform the reader about the functional architecture for each enabling function, providing insights on (i) **what the enabling function will functionally do** (based on Deliverable “D6.1 Description of enabling functions and their requirement”); (ii) what **functional processes** are involved; (iii) what data is needed as **input**, and what data will constitute the **output** of the enabling function; and (iv) what **role** each partner involved in the enabling function will have. The second section of the document provides an overall data flow architecture, to give more insights in the connections and interactions between the different enabling functions. This means that the investigation of the architectural dependencies from 5G functionalities is out of scope of this deliverable. This topic will be tackled later in D6.3.

Section 2 presents the functional architecture for each enabling function (“EF”), covering four topics for each:

- Short description of the enabling function;
- Sequence diagrams setting out the functional processes;
- IN/OUT tables detailing input and output to the EF;
- Actor stories setting out the role of each partner involved in the EF.

Section 3 provides further details on the functional interoperability of EF’s, presenting the overarching functional architecture and the data flow architecture.

Section 4 concludes this document.

2 ARCHITECTURE AT EF LEVEL

2.1 EF1 EAD – Enhanced Awareness Dashboard

2.1.1 Short description

An "enhanced awareness dashboard" will be provided to the teleoperator on which three types of information will be displayed:

Speed advice. The starting point is the speed limit which will be taken on-board in real-time using in-vehicle signage of static and dynamic speed limits. Adjustments will also be made to reflect the limit at which the particular type of teleoperated vehicle ("**TOV**") can be expected to travel. The speed advice is then adjusted depending on Safety-Related Traffic Information ("**SRTI**"). This information can come from multiple sources:

- The standard SRTI feed (already operational by Be-Mobile today): this include warnings on obstacles, incidents, congestion ahead, emergency vehicles, roads in bad state, bridge openings, etc. Each of these events will trigger a particular advised adjustment in speed. For example, when the feed mentions an accident further up the road ahead, the teleoperator can be advised to gradually reduce its speed as the TOV approaches the accident.
- Warnings picked up from extended perceptive range (EF4 DP: Enabling Function 4: Distributed Perception) and the continuous monitoring of the TOV and its environment (EF8 SA: Enabling Function 8: Scene Analytics).
- Warnings on path conflicts with vulnerable road users ("VRU"s) (coming from EF2 VRU: Enabling Function 2: Vulnerable Road Users): Speed may be adjusted to reduce the likelihood of collision with a VRU.
- Time slot reservation at intersections equipped with intelligent Traffic Light Controllers ("**iTLC**") (coming from EF3 iTLC: Enabling Function 3: Time slot reservation at iTLC): Speed may be adjusted to ensure that the TOV makes the time slot. For example, it may well be that, at current speeds, the TOV will reach too early the time slot, causing unnecessary deceleration and acceleration. In that case, the advised speed will be adjusted downward.

The speed advice will be shown to the teleoperator along with the actual speed. Visual and/or auditive feedback will be presented to the teleoperator in case the actual speed surpasses the advised speed.

Warnings. The aforementioned warnings will also be presented to the teleoperator through succinct visuals (possibly along with auditive cues).

Navigation and routing features. Based on input received from the provider of the estimated time of arrival ("**ETA**") (EF7 ETA: Enabling Function 7: ETA sharing), the route will also be presented along with an ETA to the destination or a relevant intermediary point. The teleoperator will also be informed of any relevant potential delays picked up through EF8 SA.

In the back-end, the enabling function starts from a datahub in which all relevant data is collected in real-time, either directly from the vehicle (V2X) or infrastructure (I2X) or through a datahub operated by other partners (e.g. the EF8 SA provider). The data is then consolidated into information that is useful to the teleoperator, through the three aforementioned key pieces of data that will be presented to the teleoperator: Speed advice, relevant warnings and routing information.

The consolidated information may be displayed in two ways:

- **Heads-up-display (HUD):** This is a small widget directly in the line of sight of the teleoperator. This HUD will present only key operational information, that is: advised speed and current speed (based on GPS-speed); textual, symbolic warnings; and turn-by-turn navigation with ETA. This is illustrated in Figure 1 and in Figure 26 (on page 58).

- **Dynamic Map:** On a secondary screen, a real-time dynamic map with information on the route, long-distance obstacles, VRU's distribution perception and logistic optimization will be shown.

Figure 1: Teleoperation HUD (artist impression)

2.1.2 Sequence diagram

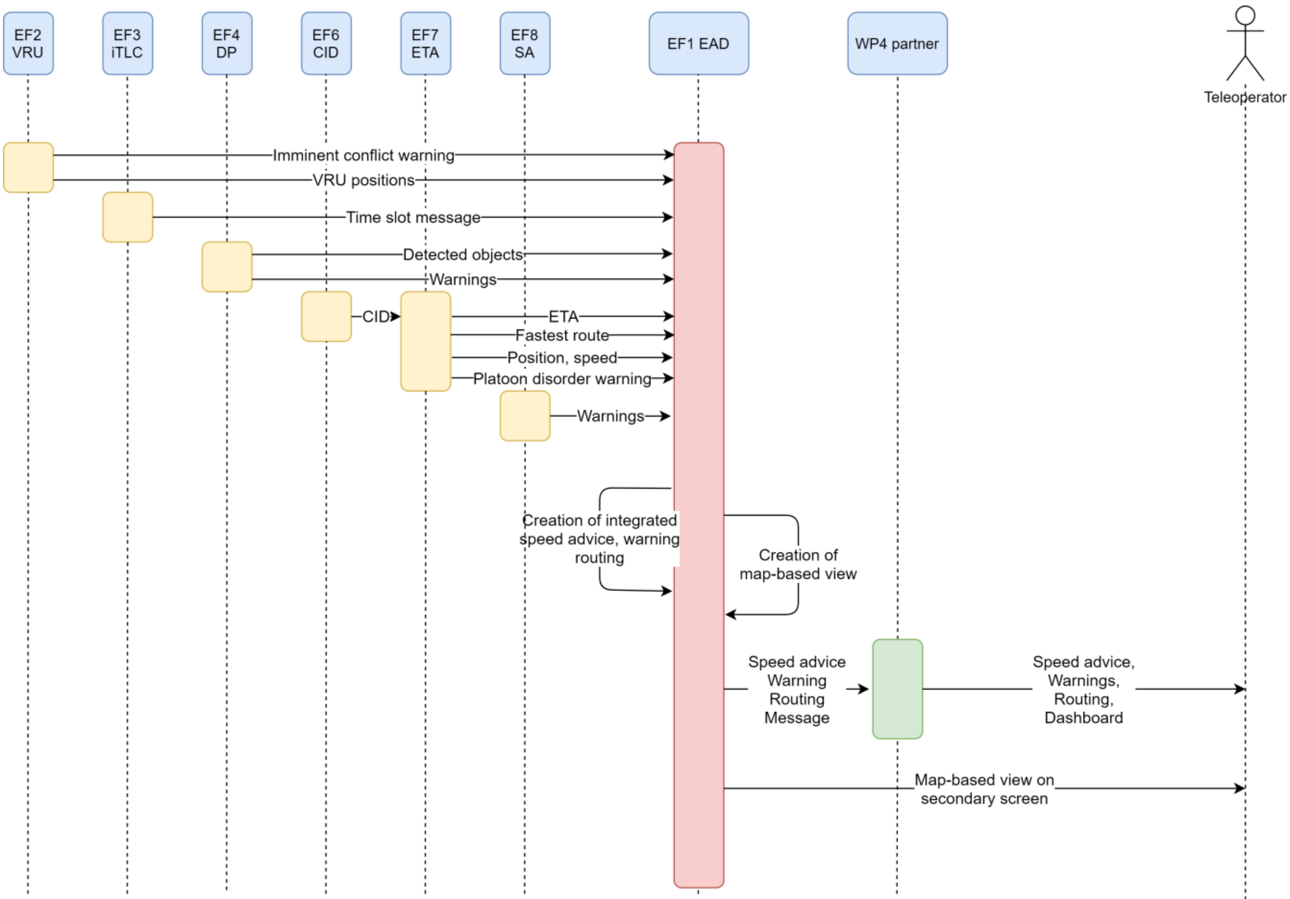

Figure 2: EF1 EAD Sequence Diagram

2.1.3 IN/OUT

Data Type	What	Planned input	Technical Requirements	Provider
SRTI	These vehicle-generated data, in addition to existing data streams, will facilitate more precise traffic Information for road users. This information takes the form of a warning or advice to the drivers in need of a road safety notification. By using DATEX II methodology the JSON and XML schemas could be generated easily and used by different partners in the project.	(temporary) Slippery roads Traffic incidents Objects on the roads (short-term) road works Wrong-way driver Reduced visibility (fog, smoke, ...) Roadblocks Hazardous weather situation (strong wind, heavy rain with reduced visibility) Emergency vehicles	Format: JSON or XML Protocol: Datex II Update frequency: 1 sec	Be-Mobile National Dataportaal Wegverkeer (NDW)
Speed, position, ETA, projected route	Data from the EF7 ETA provider to determine relevance of warnings (is it on the driver's route), determine speed advice, and communicate turn-by-turn navigation.	Current speed Position Current planned route with ETA, and turn-by-turn navigation		EF7 ETA
Static and dynamic map information	All calculation and visualisation of this EF will be done on a basemap. The start point for this basemap should be OSM so partners will be able to adjust or add map information easily in the basemap.	Streets (all road classes) divided into "segments" containing static information such as start and end coordinates, speed limit, length, restrictions, etc. Bicycle and pedestrian paths Crossroads, roundabouts Relevant parkings		Be-Mobile
Collision warning VRU's	Warnings on path conflicts with VRUs (coming from EF2): Speed may be adjusted to reduce the likelihood of collision with a VRU.	Collision warning Real-time GPS position of VRU (when warning is active) Location of collision VRU type	Format: WGS84 Update frequency: 1 sec when warning is active	EF2 VRU
Likely path	Of VRUs	Likely path of VRUs as a string of geographic coordinates	ETSI VAM	EF2 VRU
Time slot reservation	Information from the iTLC time slot provider such as the granted time slot will be necessary.	Feedback on request Timeslot reservation		EF3 iTLC
Shared world model (Map)	Provide a complete visualization of the surrounding environment that will used by different partners in the project to perform their functionalities.	Occupancy grid map	JSON/yaml	EF4 DP
Warnings picked up from extended perceptive range	Warnings picked up from extended perceptive range (EF4) and the continuous monitoring of the TOV and its environment (EF8)	Trigger/warning with information on potential hazard Camera image of hazard Location of hazard	Update frequency: 1 sec	EF4 DP EF8 SA
Platoon disorder warning	Based on input from EF6 CID, EF7 ETA will determine whether a platoon is in disorder, and signal this to EF1			EF7 ETA

Table 1 : INPUT data for EF1 EAD

Data Type	What	Proposed output	Technical Requirements	Consumer
EAD	The "enhanced awareness dashboard (EAD)" will be provided to the teleoperator on which three types of information will be displayed: - Warnings - Speed advice - Routing/navigation Dynamic speed advice containing the static speed limit into account adjusted by warnings, traffic situation, iTLC time slot reservation and warnings from EF2 VRU and EF4 DP.	Dashboard with: Dynamic speed advice (Km/u) Warnings Routing (waypoints and time to waypoint) Navigation instructions between the waypoints ETA	Format: JSON or XML Protocol: Datex II Update frequency: 1 sec	Roboauto
Map-based view	A map will be shown on a secondary screen available to the teleoperator. This map will present the route, along with relevant objects related to warnings, etc.	Mapviewer with real-time truck location and potential hazards		Teleoperator secondary screen

Table 2 : OUTPUT data for EF1 EAD

2.1.4 Actor stories

Function provider

As EF1 provider, I want to provide concise and clear information to the teleoperator related to the situation on the road ahead:

- In the first place, I will provide speed advice. I will start from the effective speed limit (dynamic or static). The speed advice is then adjusted depending on SRTI coming from standard feeds, or from input received from the warning providers (EF4 DP, and EF8 SA), VRU warning providers (EF2 VRU), and time slot provider, if relevant (EF3 iTLC via EF7 ETA).
- Secondly, I will also provide visuals showing relevant warnings. These warnings come from the different EF's and will be aggregated in a meaningful way.
- Finally, I will also show navigation and routing features, based on input received from the ETA provider (EF7 ETA). I will present the route along with an ETA to the destination or a relevant intermediary point. If relevant, I will also inform the teleoperator of the situation at the buffer parking ahead.

This information will be provided in the form of (i) a dashboard shown on the teleoperator's screen, and (ii) a map-based view on the teleoperator's secondary screen.

Providers of EF2 VRU, EF3 iTLC, EF4 DP, EF7 ETA, and EF8 SA will send the requested input to the EF1 EAD provider. This input will be the result of processes carried out in the context of my own enabling function.

WP4 partner

As a WP4 partner (more concretely, the provider of the teleoperator station, which will be Roboauto), I take in the information provided by the EF1 EAD function provider and present it on my teleoperation screen via a HUD. I give access to the EF1 EAD provider to a secondary screen on which the map-based view can be displayed.

Teleoperator

As a teleoperator, I would like to see information on my screen that can supplement my own observations while driving. This will increase safety of the teleoperated transport as well as my driving comfort. I will be able to see information on speed advice, warnings and routing on a dashboard presented on my screen, installed by WP4 Partner Roboauto , as well as in a map-based view on a secondary screen.

2.2 EF2 VRU – Vulnerable Road User Warnings

2.2.1 Short description

EF2 has a dual objective:

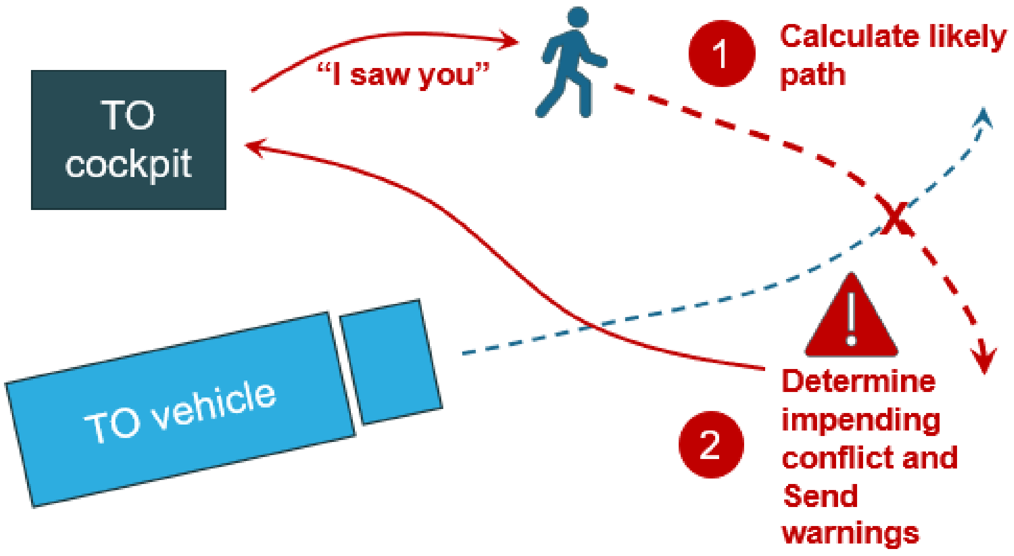

Figure 3: Objectives of EF2 VRU

First, it **calculates the likely path of all vulnerable road users** (VRU[1]) that participate in the service, based on data obtained from these VRUs and the topology of the surroundings. This likely path is then securely shared via an API with interested parties, such as the EF4 DP provider.

The likely path, over a 2 minutes horizon[2] (giving both VRU and teleoperator sufficient time to understand and counter any risk), will be derived from real-time sensory handset data, the environment (port area, road topology), the route planned by the VRU, the current and expected TLC states (when can the VRU cross the intersection), VRU type characteristics and individual VRU characteristics based on personal history. The likely path will be a string of [sequence number, latitude/longitude-pairs, timestamp, likelihood (value or class)] indicating the future path the VRU is expected to follow. The path can have multiple branches (indicated by a sub to the sequence number). The calculation of the likely path will happen through a combined process in the cloud and on the devices.

These strings will be shared (either V2X, via WAN or from hub-to-hub if likely paths are calculated in the cloud) with other parties in a predetermined format (e.g. a "CAM+", which takes the standard ETSI G5 CAM message and adds the likely path as a new element) in a map-agnostic way (so that the path is not tied to a particular basemap). These paths can then be plotted on a map, to augment information available to the teleoperator.

Second, EF2 VRU aims to **provide early warnings** (up to 2 minutes in advance [2]) to VRUs and

[1] In 5G-Blueprint, the term Vulnerable Road User is only intended to refer to cyclists or pedestrians. It is not intended to be interpreted in the definition given by the ITS Directive which also includes persons with disabilities or reduced mobility and orientation.

[2] Note that the validation of the appropriateness of the length of this time horizon is part of the research questions of this project. At the moment it is assumed that 2 minutes is the most appropriate length, but this is to be validated.

teleoperators about potential collisions between VRUs and TOVs. The likely paths of the relevant VRUs (the first objective of this function) are compared with the anticipated paths of the relevant TOVs (provided by the EF7 ETA provider, based on position and routing data and also shared via “CAM+” with the EF2 VRU provider). For each VRU-TOV combination, the probability of collision is calculated, as well as the type of collision. Based on the probability and the type, a (qualitative) threat level (from nil to very high) will be determined, based on the time-to-collision (short is higher) and the type of collision (e.g. lateral conflict is higher, then perpendicular, then frontal approach). This can be expressed in a linear function as visualised in the figure below. As measure for the type of collision the time difference between path intersections (delta t paths or **DTP**) is used, i.e. where paths intersect spatially DTP is the difference between the time at intersection of both paths. The time until impact (**DTI**) is the time until the intersection of the user’s own path minus now.

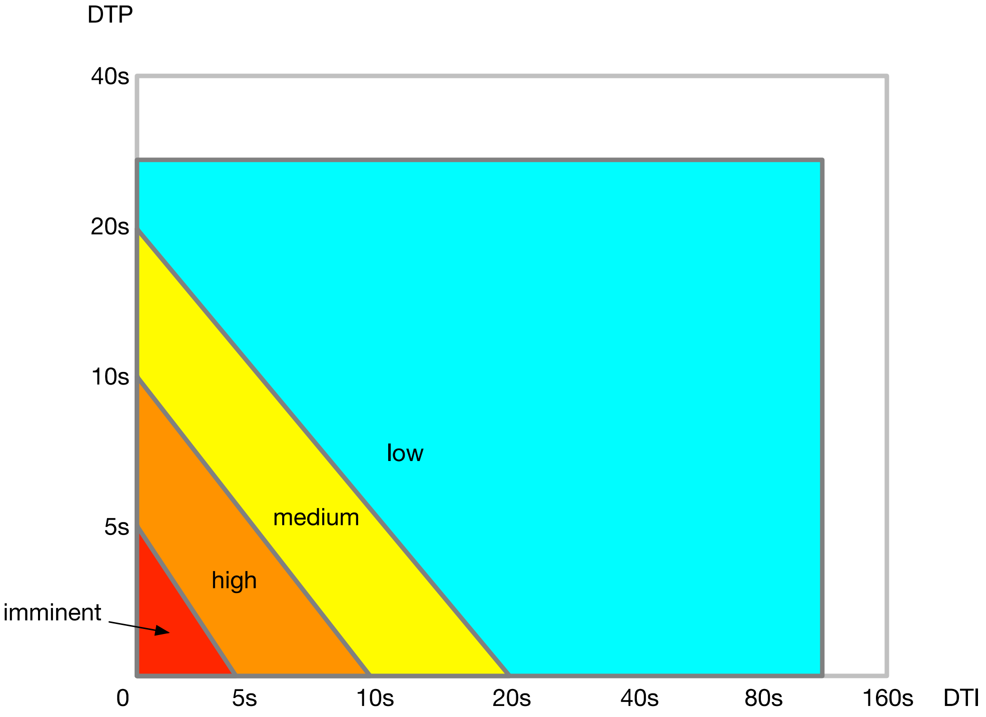

Figure 4: Classification of collisions

If there is a threat of collision, a warning will be sent out to the VRU through the application, using the appropriate available HMI options (visual (small-big, static-blinking), sound (soft-loud), vibration (slow-rapid)). They also receive advise on safe behaviour (e.g. ‘stay in cycle lane’, ‘adhere to TLC signs’). The relative position of TOVs is indicated on a map or using a schematic representation.

The EF2 VRU provider will also relay warnings on imminent and high collisions risks to the teleoperator of the relevant TOV through the EF1 EAD provider by publishing likely path messages to a central location. EF1 EAD will consolidate these warnings and consolidate them into into the consolidated advice presented to the teleoperator. Care will be taken to avoid overloading the teleoperator with too many warnings.

Teleoperators will be asked to acknowledge that they have seen a VRU (by manually marking individual VRUs as seen). This will result in an ISY to be sent to the VRU (via the application). The VRU will have the necessary information on TOV characteristics to be able to recognize the vehicle (e.g. ‘unmanned container pod’ or ‘articulated unmanned truck of transport company X’).

The function will be deployed with a 5G-wide area connection with cloud services (i.e. no V2X connections to TOVs or TLCs using short-range peer-to-peer connections). Either the relevant applications connect directly with a (or some) central data hub(s), or through a gateway built by the EF2 provider. Specific requirements for 5G will be low latency and high reliability of the 5G connections.

2.2.2 Sequence diagram

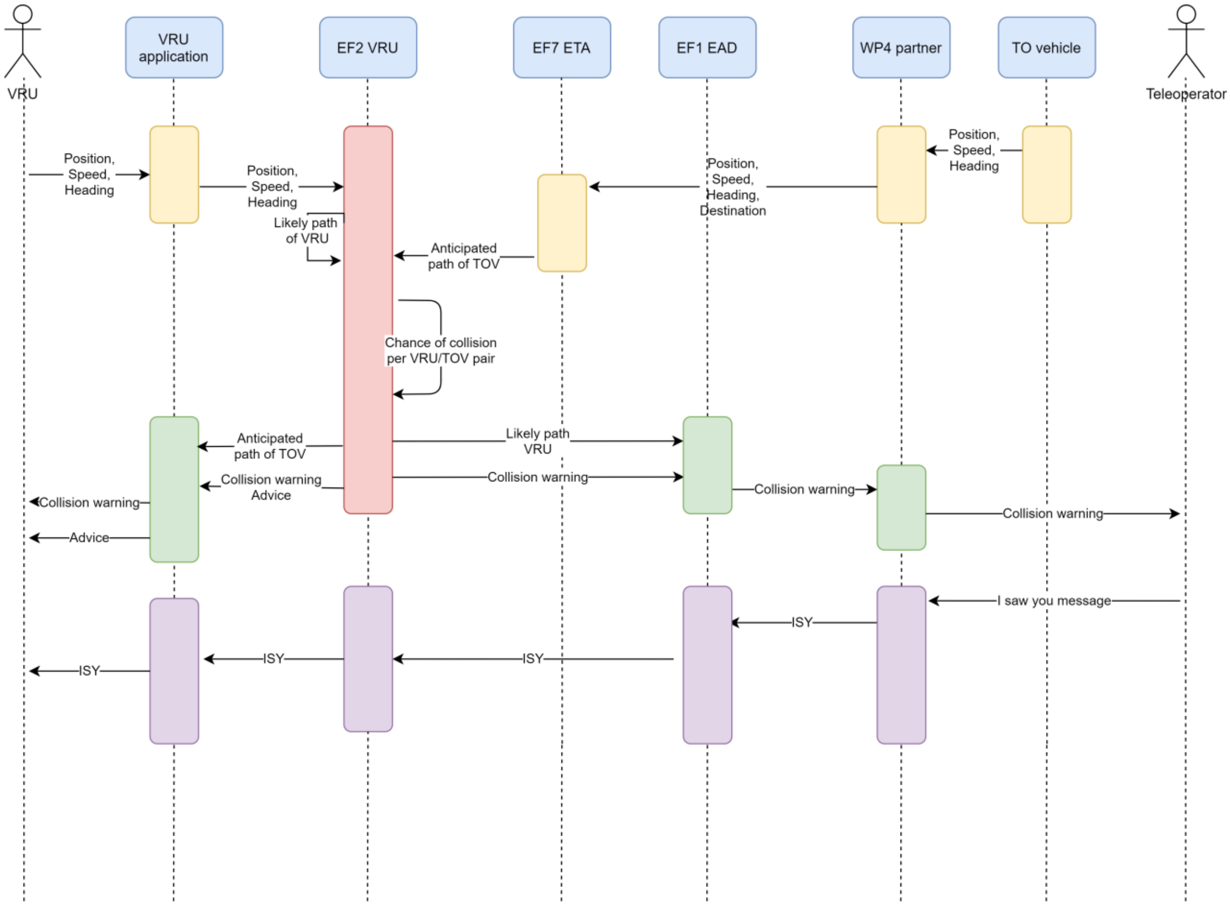

Figure 5: Sequence diagram EF2 VRU

2.2.3 IN/OUT

Data Type	What	Planned input	Technical Requirements	Provider
GNSS-data	Geographic position of VRU	Latitude, longitude	1Hz, accuracy 5m (HDOP)	Handset OS
Speed	Speed VRU	Speed	1Hz, accuracy 1 km/h	Handset OS
Acceleration	Acceleration VRU	acceleration	10 Hz, accuracy 1 m/s2	Handset OS
Heading	Heading VRU	heading	1 Hz, accuracy 1 degree	Handset OS
Digital map	Digital map of test areas	Center lines of roads, preferably separate centre lines for bicycle paths and sidewalks	Accuracy 1m for any position on line segments	OSM
Anticipated path TOV	The path the TOV is planned / is likely to follow	Set of geographic coordinates describing the path	ETSI VAM	WP4 through EF7 ETA
ISY	Confirmation of VRU awareness by TOV driver	Timestamp, TOV id, VRU ID	Contains user ID in anticipated path VRU and time stamp of manual confirmation	WP4 through EF1 EAD

Table 3: INPUT data for EF2 VRU

Data Type	What	Proposed output	Technical Requirements	Consumer
Likely path	Of VRUs	Likely path of VRUs as a string of geographic coordinates	ETSI VAM	EF1 EAD
Collision warning	Warning of imminent collision risk between a VRU and TOV	TOV ID, VRU ID, timestamp, time to collision		EF1 EAD Handset OS
I see you message	Confirmation of VRU awareness by TOV driver	Timestamp, TOV id, VRU ID	Contains user ID in anticipated path VRU and time stamp of manual confirmation	Handset OS

Table 4 : OUTPUT data for EF2 VRU

2.2.4 Actor stories

Function provider

As EF2 VRU provider, I want to provide warnings to the EF1 EAD provider and VRUs about impending path conflicts between TOVs and VRUs. These warnings should then be forwarded to teleoperators. I continuously (one cycle per second) collect the current position, speed and heading of VRU's from the VRU application. On the basis of this data, I calculate the anticipated path of the VRU. This will be a string of [sequence number, latitude/longitude-pairs, timestamp, likelihood (value or class)] indicating the future path the VRU is expected to follow. The path can have multiple branches (indicated by a sub to the sequence number).

Simultaneously, I receive the current position, speed and heading, as well as the anticipated path of the moving TOVs in the test area from the EF7 ETA provider. The EF7 ETA provider has sourced this data in turn from WP4 Partner Roboauto (who collected it from sensors in the TOV). Anticipated paths of TO vehicles and VRU's are stored in the same format (ETSI G5 CAM+), such that the solution is map agnostic, making it possible to adopt it internationally through an update of the ETSI standard.

Next, I compare the anticipated paths of the VRU's with the anticipated paths of TOV's to determine the chance of a collision between each VRU and all TOVs, as well as the type of collision (e.g. approaching, front, aft, left, right, left-turn, right-turn (blind spot)). Based on the chance, and delta, and type of a potential collision, I will determine a threat level (from nil to very high) for each path intersection.

If the threat level for a particular TOV/VRU combination surpasses a threshold level as defined above:

- I inform or warn the VRU using the appropriate available HMI options (visual (small/big, static/blinking), sound (soft/loud), vibration (slow/rapid)), also providing advice on safe behaviour (e.g. 'stay in cycle lane', 'adhere to TLC signs', etc.).
- I inform or warn the EF1 EAD provider, providing the location and predicted timestamp of the potential collision, as well as the type of collision. I also send the EF1 EAD provider the IDs of the conflicting paths.

I will probably send about one path message per VRU every 10 seconds. The collision message frequency will depend on the number of potential collisions and hence will be much lower; a few per day per VRU. Anticipated maximum number of VRU participating in field trials is 10.

Finally, I may receive ISY from the EF1 EAD provider (who in turn received this from the WP4 provider and the teleoperator). I will present this message to the relevant VRU.

VRU

As a VRU, I would like to be warned of impending conflicts with TOVs. In case of an impending conflict, I would like to be notified that the teleoperator has seen me and is taking actions to avoid collision. I use an application provided by the EF2 VRU provider which continuously sends my real-time position (position, speed, heading) to the EF2 VRU provider.

I receive warnings from the EF2 VRU provider through the application (visual, sound, vibration) of an impending conflict with a TOV, as well as advise on safe behaviour.

I also receive an indication from the EF2 VRU provider through the application that the teleoperator has seen me and will take appropriate actions to avoid collision. I do not take any additional actions to avoid the conflict myself.

EF7 ETA provider

As EF7 ETA provider, I send the anticipated path of the TOV to the EF2 VRU provider on a continuous basis. The anticipated path will be based on the position, speed, heading and destination data received from the WP4 partner Roboauto that will collect data from the TOV. I also receive a continuous stream of TOV CAM+-messages from the WP4 provider. I make these messages available to the EF2 VRU provider in real-time.

EF1 EAD provider

As EF1 EAD provider I will forward any ISY message received from the WP4 provider to the EF2 VRU provider. I receive a continuous stream of VRU CAM+-messages from the EF2 VRU provider. I make these messages available to the WP4 provider in real-time via the map-based view on the secondary screen.

WP4 partner

As a WP4 partner (more concretely, the provider of the teleoperator station), I receive a collision warning from the EF1 EAD provider, as part of the general EF1 enhanced awareness dashboard. In case, the teleoperator sends back the ISY, I forward this on to the EF1 EAD provider.

Teleoperator

As teleoperator, I would like to be warned of impending conflicts between the TOV I am operating and VRU's. I receive warnings of such conflicts via the Enhanced Awareness Dashboard made available by the EF1 EAD provider via the screen of the WP4 partner. I am also able to see the position of VRU's in my surroundings on the map-based view on the secondary screen. When I see the VRU I have been warned for, I acknowledge this by pushing a button. This signal is then sent to the EF2 VRU provider (via the WP4 partner and the EF1 EAD provider).

2.3 EF3 iTLC – Time slot reservation from iTLCs

2.3.1 Short description

EF3 ensures conflict-less crossings for teleoperated transport at intersections with intelligent TLC's. Teleoperators can request a timeslot during which the TOV (and possibly, all TOVs part of the same platoon) is guaranteed a green-lighted passage over the intersection, without there being any possibility that conflicting traffic has green light at the same time. The teleoperator receives a time slot and an advised speed which ensures the time slot can be made. If the assigned time slot can no longer be made by the TOV (or any other TOV in the platoon), a new time slot is provided to the teleoperator.

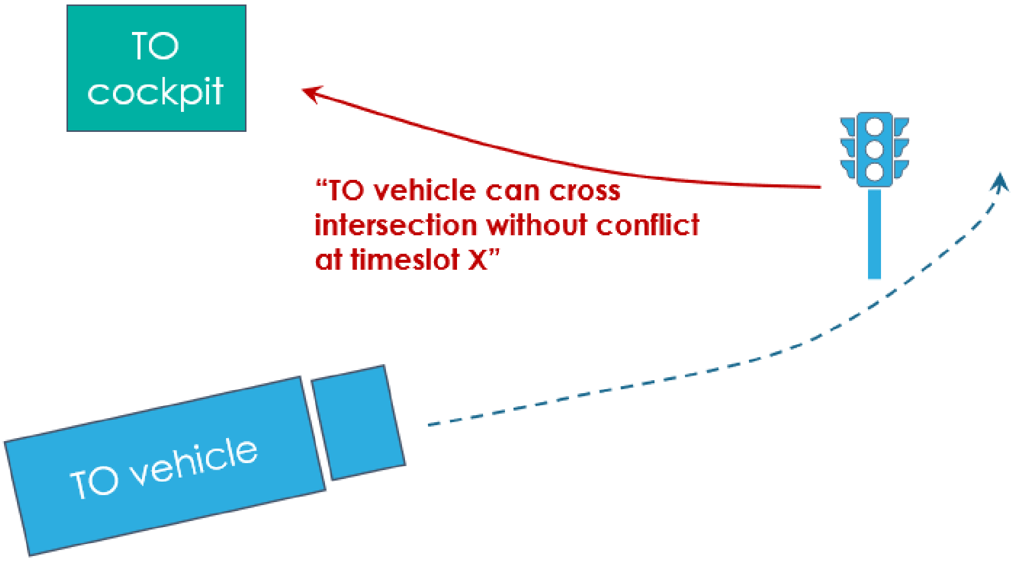

Figure 6: Objective of EF3 iTLC

The function provides two channels through which to request a time slot. The primary channel starts from a time slot request made by the EF7 ETA provider (based on the position of the TOV and the calculated route). When a TOV has an anticipated path that passes an intersection with intelligent TLCs within 2 minutes[2] of the current position, the EF7 ETA provider will begin continuously requesting a time slot, specifying the TOV's, the relevant intersection, its ETA and the desired direction. An indication of whether the TOV is part of a platoon will also be provided. Based on the various requests and the corresponding positions, the EF3 iTLC provider assigns time slots at the relevant intersections. Once the time slot is assigned, the involved teleoperators are informed of the time slot via the EF1 EAD dashboard. The dashboard also shows an advised speed which ensures that the time slot can be made (this advised speed will also take into account other factors affecting travel time to the intersection).

Based on the continuous stream of time slot requests, the EF3 iTLC provider will check whether the reserved time slot can be made, that is, whether the ETA provided in the request lies within the reserved time slot. If that is no longer the case, a new time slot will be assigned by the EF3 iTLC provider, based on ETA information at that time. The process repeats until the TOV (or the platoon) has safely cleared the intersection.

A secondary channel allows TOVs to request a timeslot via C-V2X with the roadside TLC hardware. As a TOV cannot accurately predict its own ETA, it requests the ETA to the TLC from the EF7 ETA provider. Once the TOV comes within range it requests a timeslot using this ETA and the same identification as the primary channel. The EF3 iTLC function will combine inputs from both channels to use the most recent request from the incoming channels. As such, changes in time slot reservation are communicated to EF7 irrespective of the origin of the request. This secondary channel allows the TOV to cancel the time slot reservation if it has to make an emergency stop due to connectivity issues.

2.3.2 Sequence diagram

2.3.2.1 Primary channel

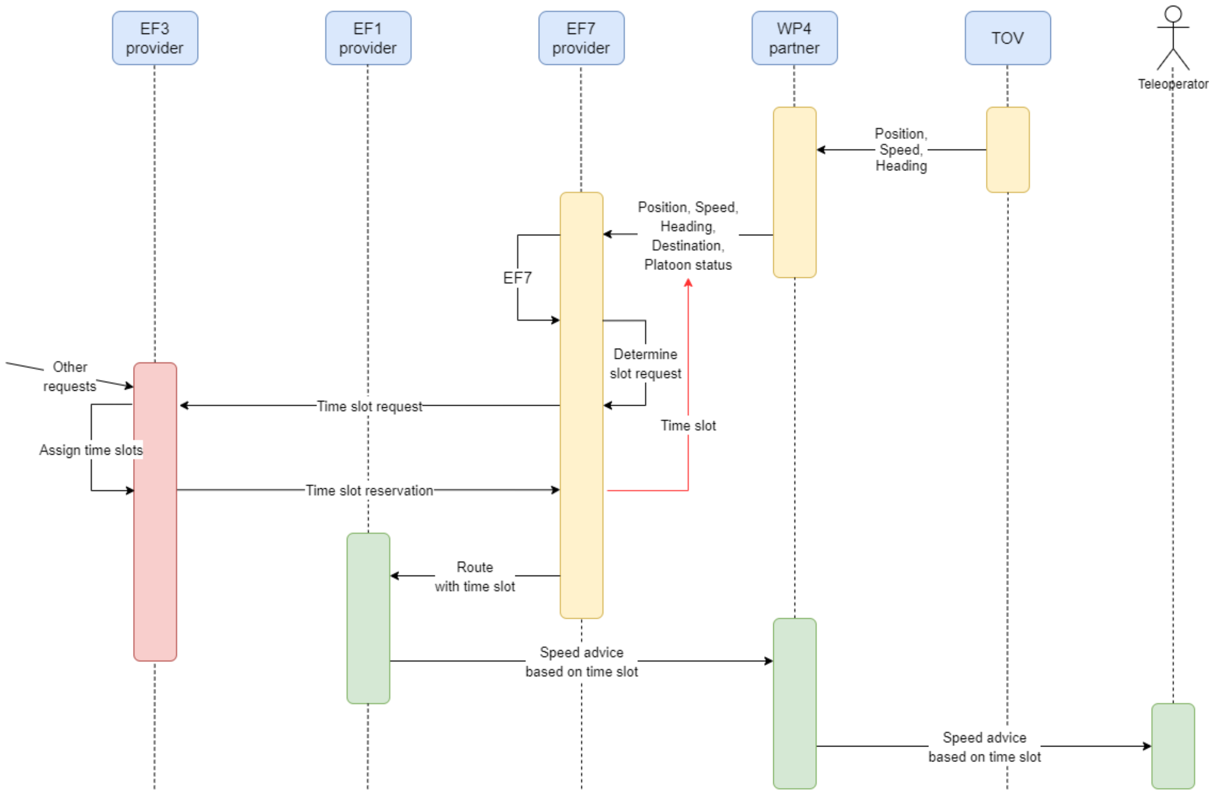

Figure 7: Sequence diagram EF3 iTLC - primary channel

2.3.2.2 Secondary channel

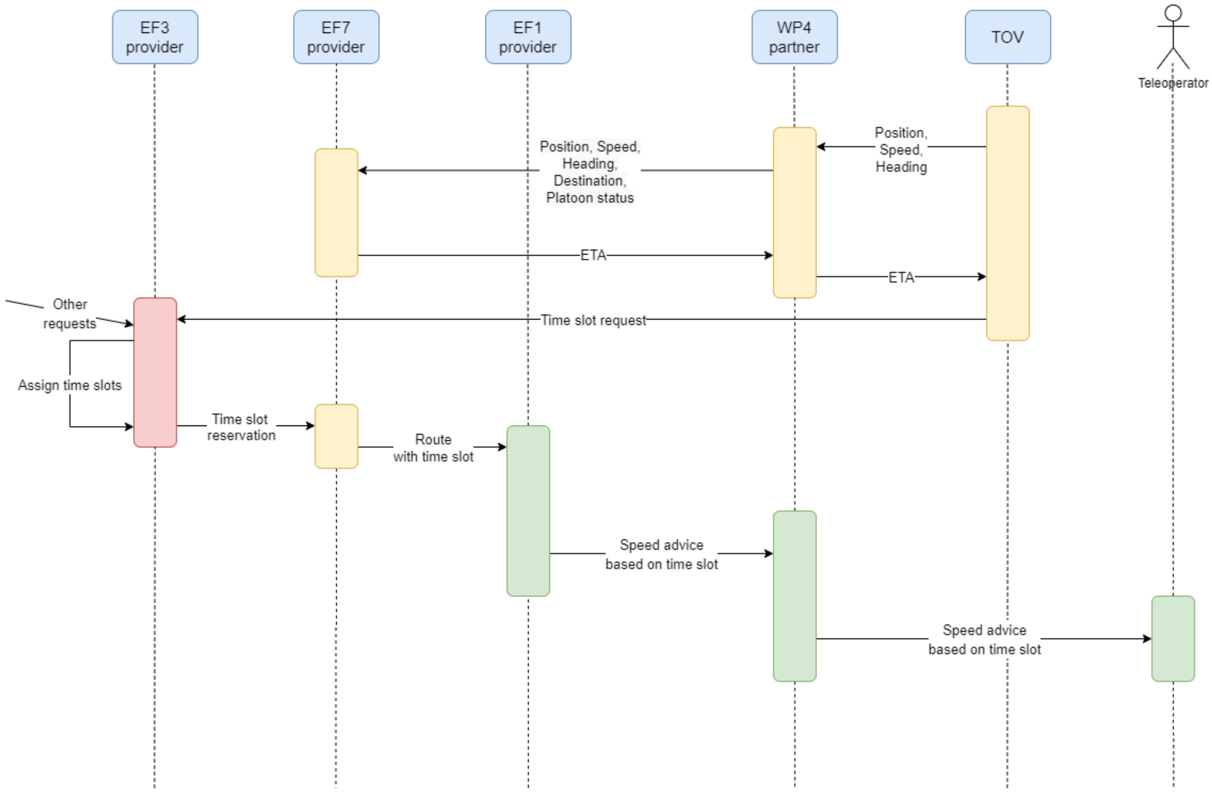

Figure 8: Sequence diagram EF3 iTLC - secondary channel

2.3.3 IN/OUT

Data Type	What	Planned input	Technical Requirements	Provider
Time slot request	A standardized priority request message, through which the TOV can request green.	Intersection ID Signal group ID Vehicle ID Request ID Request sequence ID ETA at stop line Platoon ID (if part of platoon)	Format: JSON/ASN.1 Protocol: ETSI SRM	EF7 ETA provider WP4 partner

Table 5: INPUT data for EF3 iTLC

Data Type	What	Proposed output	Technical Requirements	Consumer
Time slot reservation	An individualized time reservation message for the given intersection, signal group and vehicle. It guarantees a green phase for the requestor during the specified window in time and as such can be used to tailor a speed advice to the remote operator.	Intersection identifier Signal group identifier Vehicle identifier Start time of the window End time of the window	Format: JSON	EF7 ETA provider
Time slot request response	A response to the incoming request (updates), it denotes whether the request has been properly handled or not.	Intersection Identifier Signal group identifier Vehicle identifier Request identifier Request sequence identifier Request status	Format: JSON/ASN.1 UPER Protocol: ETSI SSM	EF7 ETA provider WP4 partner

Table 6: OUTPUT data for EF3 iTLC

2.3.4 Actor stories

Function provider

As EF3 iTLC provider, I want to provide accurate and reliable time slots for conflict-less crossing of intersections by TOV. The speed advice given by the EF1 provider will be based on the speed required to make the time slot. I receive time slot requests, containing ETA and platooning information from the EF7 ETA provider or via the TLC from the TOV itself. This information is pushed to me on a continuous basis from all TOVs who have an anticipated path that passes the relevant intersections. Simultaneously, I also receive time slot requests (or priority requests) from other road users (such as public transport or emergency vehicles). On the basis of these requests, and using the data provided, I accurately and optimally assign time slots for conflict-less crossing of the intersections. I communicate the reserved time slots to the EF7 ETA provider.

EF7 ETA provider

As EF7 ETA provider, I want to provide routing information to the teleoperator which is accurate, efficient, and incorporates time slots for conflict-less crossing of intersections by TOVs.

I receive, on a continuous basis and in real-time, the TOV's position, speed, heading and destination information from the WP4 partner, as well as information on the platoon status of the TOV (Is it part of a platoon? How many vehicles in the platoon? Where will the platoon dissolve? What is the TOV's position in the platoon?). I use this information, and other relevant data, to calculate the optimal route for the TOV towards its destination. The optimal route will be a series of coordinate/timestamp pairs which indicates the time at which the TOV is estimated to pass by a particular coordinate. On the basis of this optimal route, I determine whether a slot request needs to be made for a particular TOV. If that is the case, I send the EF3 iTLC provider a time slot request.

Upon receiving a time slot reservation from the EF3 iTLC provider, I take the assigned time slot in consideration when determining the optimal route for the TOV. Specifically, I will adjust the timestamps in the coordinate/timestamp pairs to reflect the timeslot.

Further, I send the optimal route (incorporating the time slot) to the EF1 EAD provider.

EF1 EAD provider

As EF1 EAD provider, I want to provide accurate speed advice to the teleoperator, as well as relevant information on upcoming crossings at intersections. I receive the optimal route (with a time slot) from the EF7 ETA provider. Based on that route and the time slot, I determine the speed that needs to be maintained to make the time slot. I send this speed advice to the WP4 partner.

Teleoperator

As a teleoperator, I want time slot reservations to ensure a smooth navigation of the intersections (i.e. without decelerations and accelerations, and without conflicts). If I operate a platoon of vehicles, I also want a time slot reservation to ensure that the entire platoon can cross the intersection in a continuous fashion. Via the WP4 partner, I receive speed advice which will ensure that the time slot can be made. I try to keep to that speed advice (insofar as the safety of the operation is not compromised).

2.4 EF4 DP – Distributed perception

2.4.1 Short description

EF 4 will provide an extended perceptive range to the remote teleoperator for making the appropriate decisions. A system of connected sensors on a distinct and diverse range of vehicles each with their limited field of view will be foreseen. The information gathered from these diverse sensors will be aggregated and fused into a global model (a "map") which will be used by the teleoperator for better decision making. For example: the internal sensors of a TOV will have data which will provide a localized (and incomplete) view of the environment. Other vehicles in the immediate environment may have a slightly different and complementary view of that same environment. By fusing the information available from within the TOV with the information collected by other vehicles in its vicinity, a consolidated view of the local environment can be created which is richer in terms of amount of information than the original view. Teleoperators will thus have more information on things happening further away from the TOV, enabling them to anticipate.

At least two use-cases will be demonstrated in the context of this project.

First in the context of CACC-based platooning, the fusion of maps generated based on data from each vehicle in the platoon will lead to a much richer view based on more information. As an example, we can consider the lead vehicle being controlled by the teleoperator, however, in case a vehicle starts to overtake from behind, the lead vehicle won't have any means to see this and thus it will limit the field-of-view of the teleoperator. If the vehicles at the back of the platoon can provide this information, then it will enhance the perceptive range of the teleoperator.

Second, in the context of automated truck docking, the fusion of maps generated based on data from various data sources on and around the truck, will allow the teleoperator to have a more complete view of the area while overseeing the docking manoeuvre. Today, non-teleoperated docking manoeuvres are limited in their flexibility as the approach angle is determined by what the operator sees; by extending that view, docking can be done more efficient and safer.

The fused "map" will be shared with the teleoperator as a layer on the map-based view shown on the secondary screen.

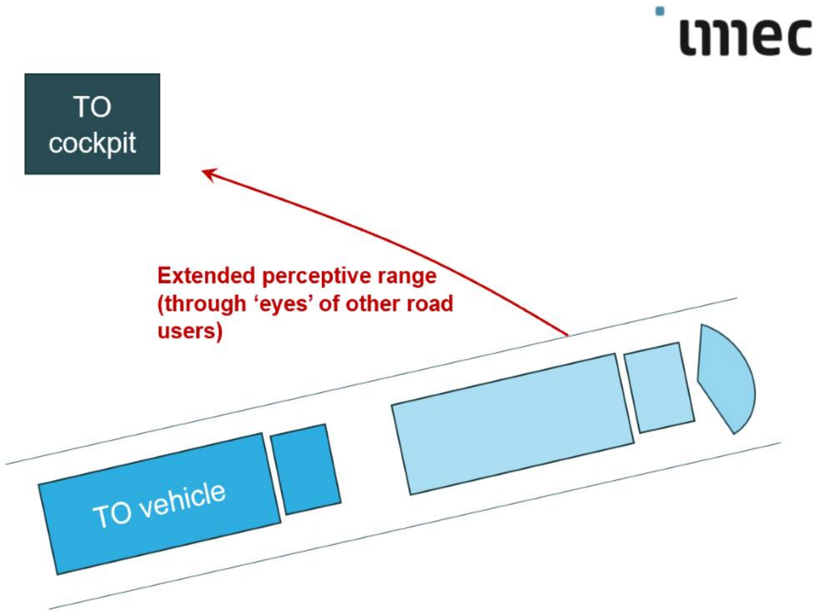

Figure 9: EF4 DP

Data exchange between the various vehicles will be decentralized using 5G technology. The shared world model is expected to be transmitted back to an imec cloud service where further fusion and post-processing of this data will take place. The TOV will be localized within the local versions of the map (either based on GPS signals, or, in case these are not reliable, based on the sensors mounted on the TOV). This location will then be used to fuse these locally generated maps. This results in a "map" which can be used by the teleoperator to enhance the awareness of the environment. Use of 5G connectivity will be needed to ensure reliability of the connection (for minimum dropouts), low latency (for real timeliness) and higher bandwidth (for large amounts of data for example: video and point cloud streams).

2.4.2 Sequence diagram

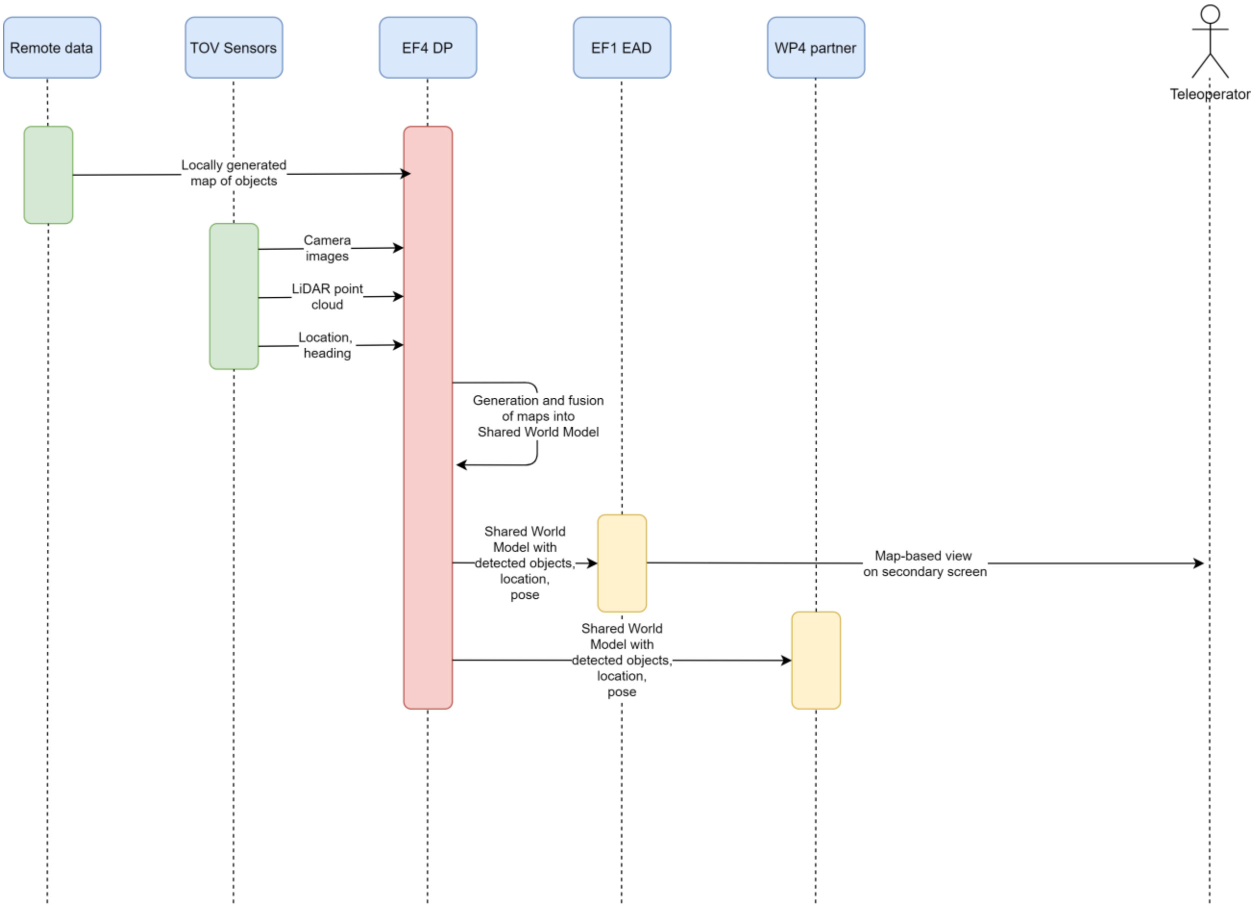

Figure 10: Sequence diagram for EF4 DP

2.4.3 IN/OUT

Data Type	What	Planned input	Technical Requirements	Provider
Camera images	Will act like an eye for the TOV perceiving the environment's landmarks and objects and will be used to perform object detection. By using depth estimation, semantic segmentation, visual SLAM (simultaneous localization and mapping). It will also act as a backup in case loss of connection with the LiDAR	Frames of the TOV's surroundings. Depth	Sensor type: Stereo camera Frequency: at least 30fps Format: png/jpeg	Onboard sensor (WP4 partner)
LiDAR Point cloud	Together fused with the camera images, this will provide and more accurate map and representation of the surroundings. It also surpasses the camera's performance during environmental variations like rain, fog, snow, shades, or low illumination.	Point cloud representing clusters of objects in surrounding.	Sensor type: Mechanical/Solid state Vertical resolution: at least 64 channels Horizontal field of view: 360 degrees Frequency: 10 Hz Format: las	Onboard sensor (WP4 partner)
GPS/IMU	Will be used along with the generated map to enhance the estimates poses and location on the map.	Current location based on a web mapping service Orientation and heading.	Stable connection 5G Frequency: atleast 10 Hz Format: json/yaml	Onboard sensor (WP4 partner)
Data from surrounding vehicles or fixed locations	Data from surrounding vehicles (or fixed locations) will be used to locally generate maps. These maps will then be fused with the map from the vehicle itself, providing a better visualization of the surrounding environment and reducing blind spots.	Global model (Map) Detected object's dimensions, location, speed, heading and time.	Frequency: at least 10Hz Format: json/yaml	Remote data i.e. neighbouring vehicles within a radius of at least 70m)

Table 7: INPUT data for EF4 DP

Data Type	What?	Proposed output	Technical Requirements	Consumer
Shared world model (Map)	Provide a complete visualization of the surrounding environment including detection of surrounding objects (vehicles, VRU's, etc.) that will used by different partners in the project to perform their functionalities.	Occupancy grid map	json/yaml	EF1 EAD provider WP4 partner
Location	In order to calculate the time to collision and to calculate the real-time route of the TOV, this EF will send the current location to the partners.	Location coordinates	json/yaml	EF1 EAD provider WP4 partner
Pose tracking	In order to receive warning on potential collisions/hazards this EF will send the current pose of the TOV.	Previous locations	json/yaml	EF1 EAD provider WP4 partner

Table 8: OUTPUT data for EF4 DP

2.4.4 Actor stories

Function provider

As function provider, I provide real-time dynamic situational awareness to the EF1 EAD provider and the WP4 partner on the basis of the distributed perception. I receive the perception data from onboard sensors including LiDAR, Camera, Radar, GNSS and IMU sensors. I fuse this data to create a common representation (dynamic map), taking also into account data from other vehicles or fixed locations. By merging these representations, I create a Shared World Model which is then shared, in the case of platooning via EF1 EAD, with the WP4 and eventually the teleoperator. The EFs and WP4 UCs can use this information to plan and act in a remote teleoperation scenario.

EF1 EAD Provider

I show this information in the form of a dynamic map on the secondary screen which is then used by the teleoperator to make better decisions while operating the vehicle.

WP4 partner

As WP4 partner (party providing the teleoperator station and/or the vehicular onboard units), for UCs 1, 2 and UC3, I send the extended perception information i.e the global model (Map) to the onboard control units for minimum level of autonomy. For example: in the CACC based platooning, the two cars will create a distributed perception model which will be useful for the chase car scenario. Furthermore, the local version of distributed perception system will also aid the local control in case of communication losses, thus the local copy of the perception system will aid the brief employment of semi-autonomy in case of delays or communication losses from control center towards the TOV.

Teleoperator

As a teleoperator, I would like to see information on my screen that can supplement my own observations while driving. This will increase safety of the teleoperated transport as well as my driving comfort. I want to see the movement, location and type of vehicles surrounding me, it is important for me to visualize all this information and therefore a dynamic map is useful for me.

2.5 EF5 ACA – Active Collision Avoidance

2.5.1 Short description

EF5 will provide the Active Collision Avoidance (ACA) extension to the TOV, mitigating hazardous situations associated with a possible loss of connection and with impaired perception of the environment. The benefit of EF5 is improved safety for the TOV, both to protect the vehicle itself and primarily to protect other (vulnerable) road users.

A sensor set containing Lidar, Radar, GNSS-INS and cameras will be installed on TOV. The task of this sensor system is to register obstacles on the TOV's route. The position GNSS-INS module will be used to locate the vehicle in a digital map that contains the planned path of the vehicle.

The data from the sensors will be processed in a dedicated computing unit designed for ACA. This unit will be interfaced with the teleoperation onboard unit and the vehicle interface using a safety gateway device (SGD). The safety gateway's task is to ensure a reliable and guaranteed data flow between the individual control units. In addition to the above responsibilities, SGD will check the current values of control commands from the operator and ensure that they are staying within the applicable range for immediate operating conditions. An example is a high-speed oversteering (lateral acceleration).The main safety features are:

- **Emergency braking in the event of a loss of connection (EBA):** The SGD monitors a heartbeat signal indicating the connection between the vehicle and the operator. If the heartbeat signal does not arrive within the time limit, the vehicle emergency stop procedure will be started.
- **Advanced emergency braking (AEB) system** which can automatically detect a potential forward collision and perform appropriate braking. AEB primarily uses a radar system to detect and track obstacles in the route of a teleoperated vehicle.
- **Adaptive cruise control (ACC) system** that automatically adjusts the vehicle speed to maintain a safe distance from vehicles ahead. The transmission possibilities of the network determine the safety distance in the context of teleoperation. For example, bandwidth significantly affects the driver's sight distance.
- **Emergency lane keeping system (ELKS)** which can ensure that the vehicle remains in the lane (pre-planned virtual track) in the event of a lost connection.

While these safety features are to some extent already available in existing commercial vehicle systems, they require significant adjustments for the following reasons:

- Existing systems do not take into account the situation that the driver is not in the vehicle.
- Existing systems do not take into account the state of the network as input for their function.
- Existing systems do not assume that the vehicle can be controlled by several driving systems with different priorities (driver on board, autonomous system, teleoperation, teleoperation combined with autonomous system).

The integrity of the connection between the Teleoperator Remote Station is ensured by the Heartbeat message that is transmitted by each entity every 25 milliseconds. The message contains its sequence number, the number of lost messages, the number of out-of-order or missing messages, and the timestamp of the last sent message. These attributes can be used for further diagnostics of the connection, as well as additional measures that can be taken to reflect the worsened quality of the connection. The most basic and the most important goal of the Heartbeat message is to signal that the ongoing connection is alive. In case no Heartbeat message with a greater sequence number is received within 500 milliseconds, the connection is closed.

In addition to the Heartbeat message controlling the connection integrity, the Teleoperation

Remote Station sends a Control Message every 20 milliseconds. The Control Message contains data that is used to control the TOV. In case a new Control Message is not received in 150 milliseconds from the last one, the TOV performs an emergency manoeuvre.

When connection between the teleoperator and the TOV is lost (and the vehicle is no longer being controlled via teleoperation), the Control Message not arriving within 150 milliseconds will trigger the EBA command first. However, this dual approach allows teleoperation to be also used as a supervising system. In such a case, Control Messages are not being sent from the TO Remote Station to the vehicle, unless the supervising Teleoperator decides to take over. The Heartbeat mechanism then serves to send the EBA command when the supervising Teleoperation system disconnects. The AEB system can be perceive as a natural extension of EBA that considers the situation around the vehicle, which the basic EBA system cannot.

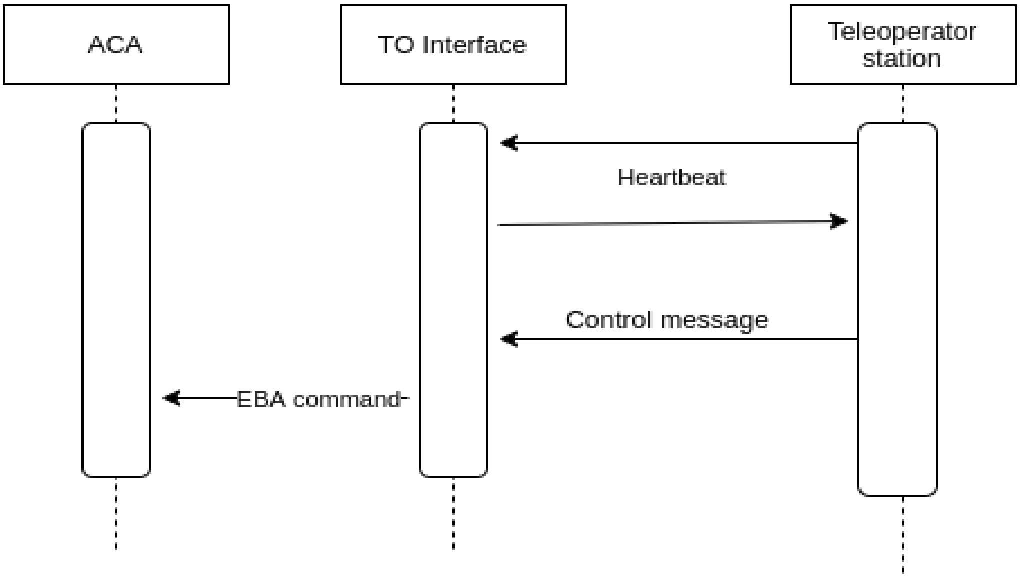

Figure 11: Connection between ACA and teleoperator station

Connection status is critical for all assistants mentioned under EF5. Another critical parameter is the available bandwidth, which is especially important for the ACC system. Thanks to this information, the ACC system can maintain a safe speed and distance from leading vehicles concerning safe sight distance.

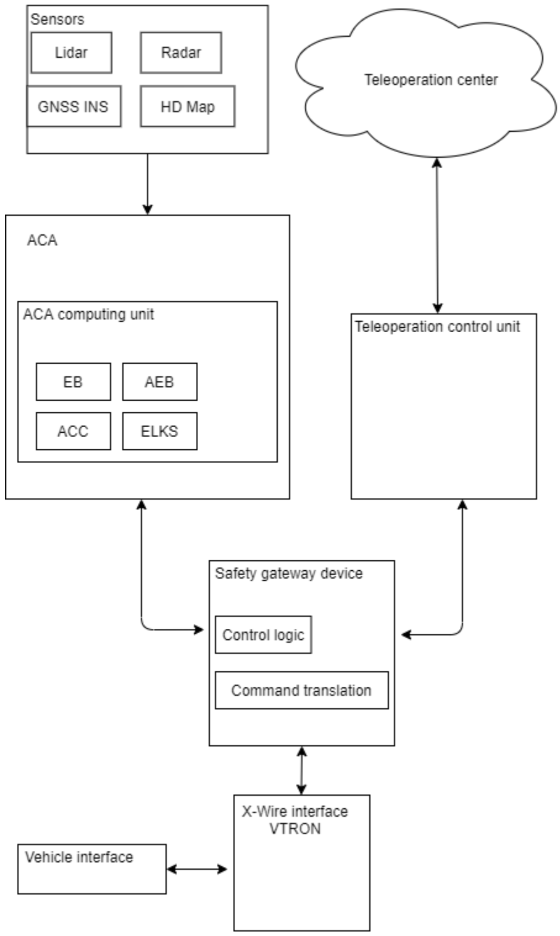

Figure 12: High-level architecture

2.5.2 Sequence diagram

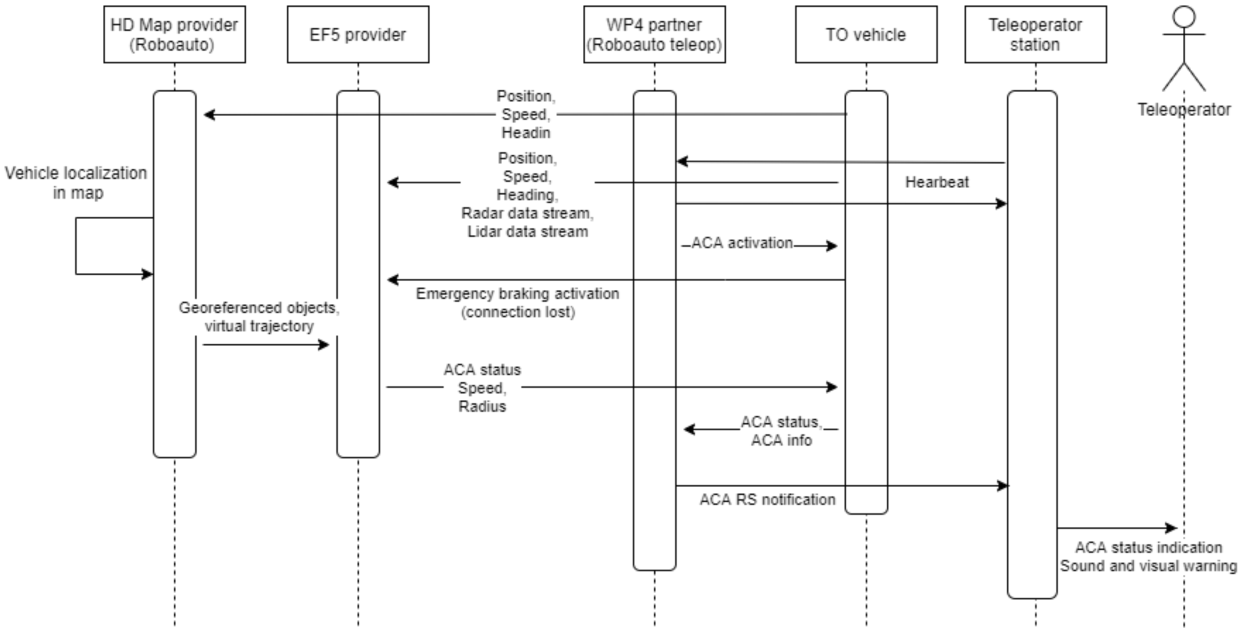

Figure 13: Sequence diagram for EF5 ACA

2.5.3 IN/OUT

Data Type	What	Planned input	Technical Requirements	Provider
Heartbeat	The Heartbeat signal running between TOV and Teleoperator station to indicate working connection.	sequence number, number of lost messages, number of out of order or missing messages, timestamp of last sent message	heartbeat is sent every 25ms, the time period between two consecutive heartbeats cannot exceed 500ms	WP4 partner (Roboauto)
Position and heading	Current position and orientation of the TOV provided by a GNSS/INS system	position, velocity, orientation	position is in WGS84 format	WP4 partner (Roboauto)
Speed info	Current TOV speed obtained from odometry data	current vehicle speed	speed is expressed in meters per second	WP4 partner (Roboauto)
Radar data stream	Objects detected by the TOV's on-board radar	object position, object size, object velocity, object reflectivity factor		WP4 partner (Roboauto)
Lidar data stream	Data from the TOV's on-board lidar	Point cloud data		WP4 partner (Roboauto)
EBA command	On-demand request for emergency braking issued upon connection loss or similar critical situations	Prompt for emergency braking to start		WP4 partner (Roboauto)
Map data	Trajectory that the TOV is expected to follow together with previously detected static objects along the path	Virtual trajectory, Georeferenced objects		WP4 partner (Roboauto)

Table 9: INPUT table for EF5 ACA

Data Type	What	Proposed output	Technical Requirements	Consumer
ACA status	Describes the current ACA status with respect to a detected possible collision	Collision immineence level, Emergency manoeuvre active/inactive		WP4 partner (Roboauto)
ACA data	Data used by the ACA to control the TOV	Speed and radius	Data is published only when an emergency maneuver is to be executed	WP4 partner (Roboauto)

Table 10: OUTPUT table for EF5 ACA

2.5.4 Actor stories

- As an EF5 provider, I want to offer a solution to improve the safety of TOV operations.
- As an EF5 provider, I want to provide a solution protecting VRUs hazards caused by loss or deterioration of TOV connectivity.
- As an EF5 provider, I want to compensate for the teleoperator's impaired situational awareness by providing an automatic system keeping a safe distance from the leading vehicle, based on available and predicted bandwidth.
- As an EF5 provider, I want to ensure that the teleoperated vehicle does not accidentally leave the planned trajectory when disconnection occurs, especially in the lateral direction.
- As a WP4 partner, I want to have a vehicle independent anti-collision system with an open interface. Such an interface allows me to expand an existing teleoperation plugin without interfering with the vehicle's CAS.
- As a WP4 partner, I need the CAS of the vehicle considering the possible loss of connection.
- As a WP4 partner, I need the onboard safety systems to take into account that the driver is not physically present in the vehicle. That means that the safety or assistance system should be adjusted in such a way that it does not require physical interaction with sensors in the vehicle (for example, hands on the steering wheel).

2.6 EF6 CID – Container ID recognition

2.6.1 Short description

EF6 provides the capability to identify shipping containers on video streams. Shipping containers are uniquely identified by using the so-called BIC code, which is globally standardized in ISO6346. The BIC code appears on all visible angles at any shipping container, some examples are shown in the figure below.

Side	Rear
	
Top	

Figure 14: BIC code on container

The recognized BIC code can directly be used for automation purposes, e.g. to automatically register this container as being arrived/departed or loaded/unloaded. Depending on decisions about the Human-Machine Interface design, it may also be presented to the teleoperator as an Augmented Reality application. This means that the recognized BIC code is shown in real-time as overlay on the video stream. This allows the teleoperator to gain an instant view on all the relevant information that is available from the planning software. The figures below give an illustration.

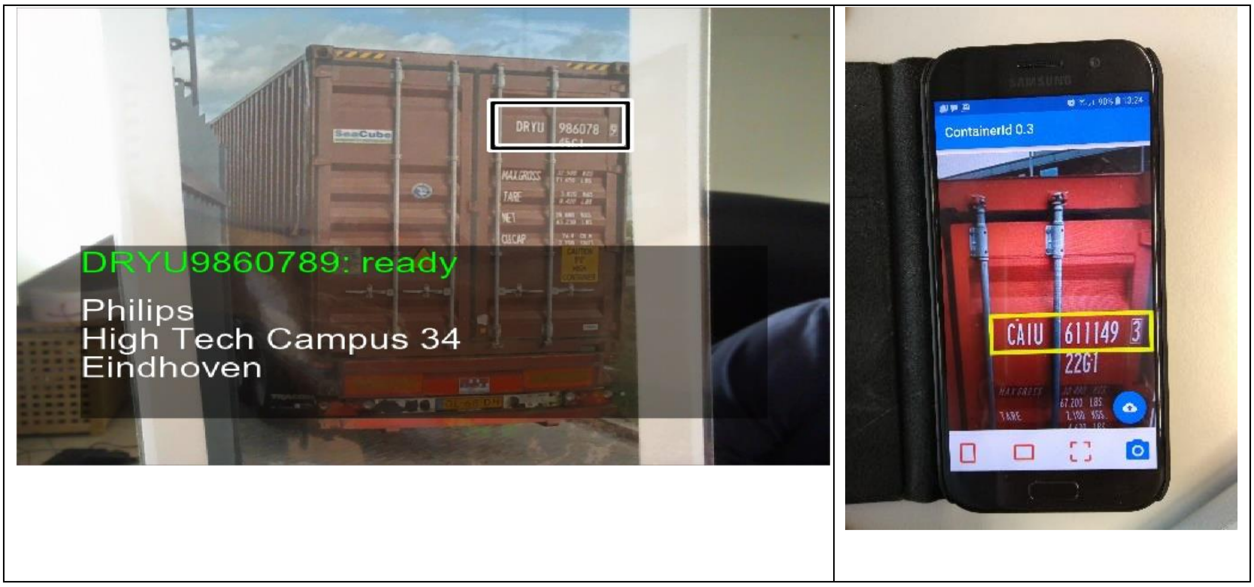

Figure 15: Container ID recognition with overlay

The container recognition software will be hosted on the platform used by the EF8 SA provider (the Nokia Scene Analytics Platform). The underlying image/video analysis takes a significant amount of processing power. By leveraging the low-latency and high bandwidth characteristics, 5G offers the ability to run deploy the processing "anywhere"[3]. This is a key advantage that 5G brings to the table: there is no need for powerful processing hardware that is physically connected to the camera. Because only a camera with a 5G modem is needed, this allows for more options in deployment (also in harsh environments), easier and inexpensive deployments (less hardware) and easier maintenance (both in software and hardware).

Figure 16: Picture of a reach stacker

The main use-case that is tested for this enabling function is to **facilitate the work of the crane or reach-stacker operator**. A recognition camera will be mounted on the spreader of a crane or reach-stacker (see Figure above). This will allow the operator to identify the container that was picked up from the quay or barge more easily.

The spreader is an extremely harsh environment for electronic devices, and this requires special cameras that withstand 50G forces. Today's state-of-the-art cameras are still analogue as they provide a low-latency video stream to the operator, and as they are more robust to failure over (short-range) wireless communication (when the line-of-sight is lost the video deteriorates though there is still image). These cameras are currently only used for viewing-only purposes on a display by the operator, but there is no further automatic recognition ability. The potential benefits of 5G would therefore not only allow automation, but also to apply more modern and better-quality image sensors, directly benefiting the operator's current tasks and the safety of personnel and truck drivers in the direct vicinity.

The advantage of this chosen main use-case is that once it is deployed, the methodology for other use cases is not expected to differ significantly, as long as a video stream is provided. This increases the business potential of all technical lessons learned in the project about this enabling function through this specific chosen use-case. Examples of such possible future evolutions / spin-offs are:

- The use-case for the crane or reach-stacker operator could be extended to include **Augmented Reality**. In this use-case the output of this enabling function would be combined with the camera-stream to generate an AR overlay on top of the camera images which the operator sees (such as the one shown in Figure 15 above).
- Support the **tracking of the container** on various parts of its journey (anywhere where it can be detected by a camera). For example, at the port entries and exits. This can support additional validation of the transport's position, allows a check that the right container is loaded onto the TOV (by comparing the TOV's GPS position with the timestamp and position of camera that identified the container), and can be used as part of a broader

[3] It is part of the research questions of this project to learn where this video processing can be performed best, taking both technical, economical and organisational characteristics into account (MEC, MNO core network, over-the-top cloud service, …).

logistic planning tool.

2.6.2 Sequence diagram (for main use-case)

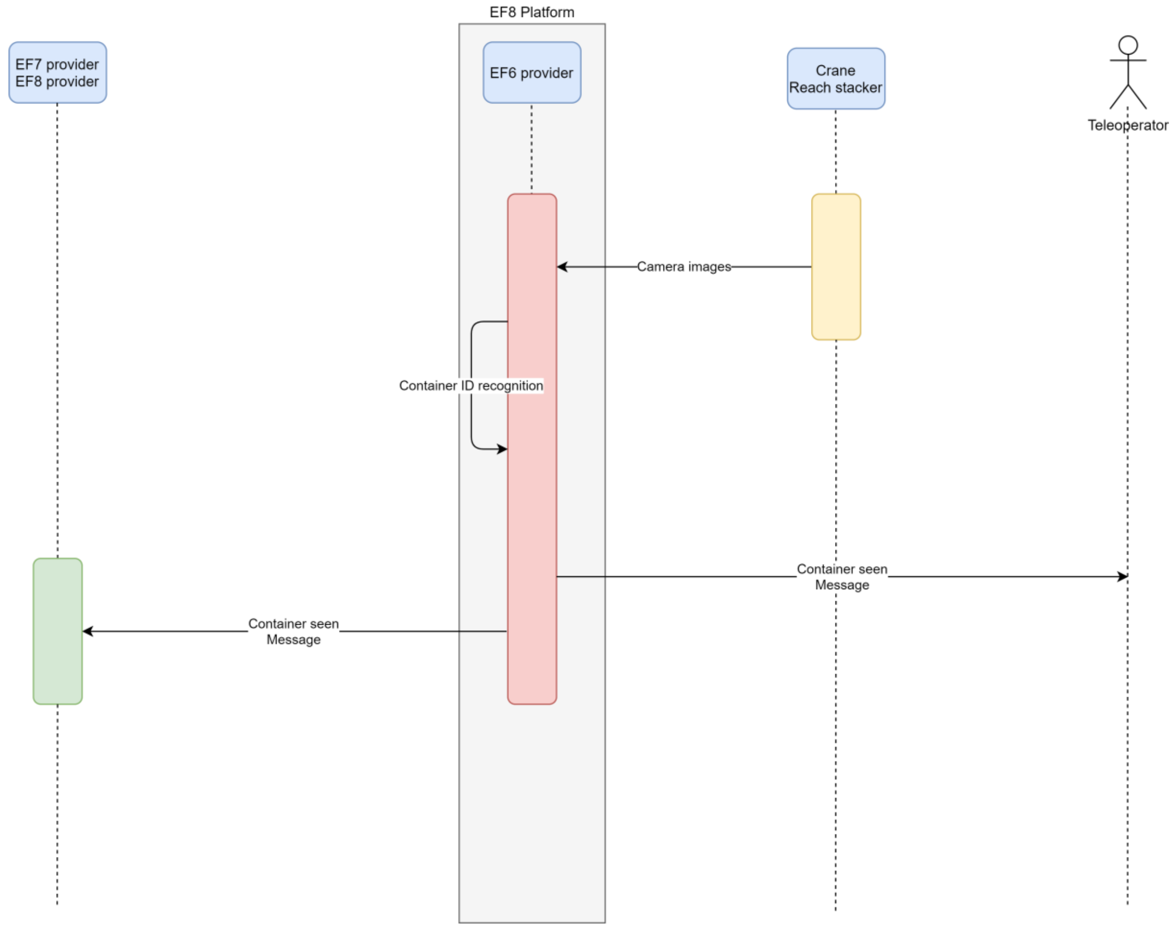

Figure 17: Sequence diagram for EF6 CID

2.6.3 IN/OUT

Data Type	What	Planned input	Technical Requirements	Provider
Video stream	Video-stream originating from crane or reach stacker	Readable BIC code (enough sharpness / light / minimal motion blur). Rule-of-thumb is that if a human can recognize the BIC code, so can the software.	Minimal resolution 640x480 pixels Preferred format H.264	Port Authority

Table 11: INPUT data for EF6 CID

Data Type	What	Proposed output	Technical Requirements	Consumer
Container Seen message	API push message providing the digitized version of the detected BIC	JSON message with the following contents: Video source (I.e. camera identifier) Coordinates for the location of the BIC Code in the as related to the original video Timestamp	Receiver must be capable to receive HTTP Post messages	EF7 ETA provider

Table 12: OUTPUT data for EF6 CID

2.6.4 Actor stories

Function provider

As EF6 provider, I want to provide digitized detections of BIC codes on containers, as seen on video streams received from cameras.

I receive raw video input streams (from camera's mounted to mobile equipment used for loading and unloading TOVs (i.e. cranes or reach-stackers) analyse these streams with our AI model(s) and send detections in digital format to interested EFs. The EFs receiving this information can then use this to enrich already available information or use the data within the detection to correlate with other available data and reach correlated conclusions.

I send container data received from fixed cameras and cameras mounted on mobile container-related equipment to EF8 SA and EF7 ETA.

EF8 SA provider

I receive digital detections for container BIC codes from the EF6 CID provider, which I can use to correlate against TOV cargo's to identify relevant TOVs. I am thus able to include information from other sources (fixed cameras and cameras mounted on equipment related to the loading and unloading of containers).

EF7 ETA provider

As EF7 provider, I want to enrich the data I receive from others (see relevant section below) with information from EF6 CID, which can be used to track the container when it lands in the port. This may trigger actions for logistic planning (such as informing the teleoperator, via EF1 EAD, about the cargo of a specific TOV).

Teleoperator (cargo)

As a teleoperator, I want to be informed what containers are (un)loaded on the teleoperated trucks I'm responsible for.

2.7 ETA – ETA Sharing

2.7.1 Short description

EF7 ETA foresees in providing two basic functionalities which will allow planners to dynamically schedule in teleoperators.

First, the estimated time of arrival ("**ETA**") of the teleoperated transport will be calculated on a continuous real-time basis. This ETA will be based on the fastest route from the current position of the TOV to a relevant waypoint, taking into account access restrictions for (teleoperated) heavy goods transport (such as dangerous goods zones, or environmental zones) and real-time traffic data. In addition, the ETA will take on board other data generated within the scope of the 5G-

Blueprint project, in particular those from other enabling functions. The ETA to the final destination will be sent towards EF1 EAD, together with the route and turn-by-turn navigation, and other interested partners (such as the logistic planner). EF 1 EAD will then display this information in a user friendly way.

Furthermore EF 7 will also calculate (intermediate) ETA's for important intermediate waypoints. The ETA to intermediate waypoints will be relevant for other enabling functions, in particular EF3 iTLC who needs this information to provide a timely timeslot reservation (though it may be useful for other EF's as well).

Data feeds will be set up to take into account at least (but not limited to) the following data streams:

- The assigned time slot on the intersections on the TOV's route (from EF3 iTLC). The ETA will take into account when the TOV is due to pass via the intersection.
- Relevant information from EF8 SA. If EF8 SA detects anomalies (such as abnormal waiting times at terminal gate) on the TOV's route, this will be taken into account for the calculation of the ETA.

Second, EF7 ETA foresees in a number of functionalities which assist logistic planners in ensuring a smooth and timely operating of the logistic transport. Functions may include:

- Establishing a connection with a terminal's Truck Assignment System (TAS). This system automatically assigns trucks to a pick-up or drop-off timeslot at a terminal. By making the coupling with the TAS, a dynamic assignment of pick-up/drop-off slots becomes possible. For example, the TAS may have assigned a pick-up timeslot for a particular transport at 10.00 to 10.15AM. This time slot is communicated to EF7 ETA which monitors continuously whether the transport is on schedule to make the 10AM time slot. If it is too early, the transport will be diverted to the buffer parking where the truck will wait until the ETA to the pick-up point corresponds to the 10 AM time slot. If the transport is too late, this is communicated to the TAS where a new time slot is provided.
- Providing transport triggers to the logistic planner. If a TOV or container (via EF6 CID) is detected somewhere, this information may be forwarded to the logistic planner or the teleoperation control centre, who may take a certain action. For example, when a container lands on a quay, the planner or control centre may want to assign a teleoperator or warn the teleoperator that she needs to go and pick up the container.

Please note that the at the time of writing this deliverable, the logistics partner for the Antwerp pilot site, which is the site where many of EF7's functionalities will be piloted, has just been changed. It is therefore needed to confirm the exact set of functionalities provided through EF7 ETA with that new partner. If that analysis would result in a delta of feasible functionalities for EF7 compared to what was written here, this will clearly be described in D6.3.

2.7.2 Sequence diagram

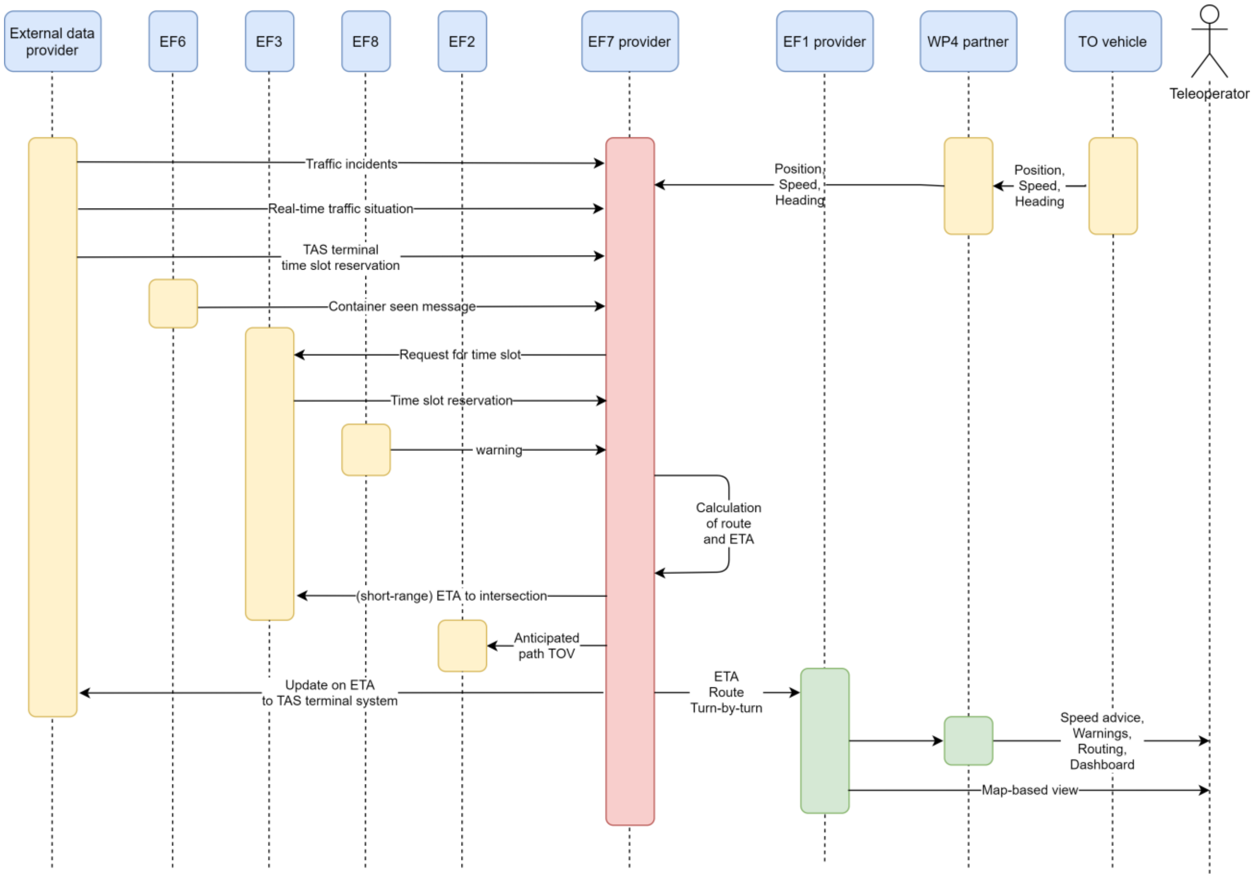

Figure 18: Sequence diagram for EF7 ETA

2.7.3 IN/OUT

Data Type	What?	Planned input	Technical Requirements	Provider
Position, heading TOV	The real-time position and heading of the TOV is needed for calculating the route, waypoints and ETA	Position Unique ID Heading	Position (x,y) in WGS 84 Update frequency: 1 sec	WP4 partner
SRTI	These vehicle-generated data, in addition to existing data streams, will facilitate more precise traffic Information for road users. This information takes the form of a warning or advice to the drivers in need of a road safety notification. By using DATEX II methodology the JSON and xml schemas could be generated easily and used by different partners in the project.	(temporary) Slippery roads Traffic incidents Objects on the roads (short-term) road works Wrong-way driver Reduced visibility (fog, smoke, ...) Roadblocks Hazardous weather situation (strong wind, heavy rain with reduced visibility) Emergency vehicles	Format: JSON or xml Protocol: Datex II Update frequency: 1 sec	Be-Mobile NDW
Traffic related information	Next to the SRTI-feed other more real-time information on the traffic situation is needed. This information consists minimally of following categories:	- Travel times - Delays or traffic jams - Traffic incidents	Format: Datex 2 Methodology: JSON or xml Update frequency: 1 min	Be-Mobile (as EF7 provider)
Time slot reservation	On the route of the TOV, it will be important to cross the intersection without losing time or stopping the vehicle/platoon. Also, for calculating the ETA information from the time slot provider will be necessary.	Feedback on request/prio Timeslot reservation	Format: WGS84 Update frequency: 1 sec when warning is active	EF3 iTLC
Container seen message	API push message providing the digitized version of the detected BIC	Video source (I.e. camera identifier) Coordinates for the location of the BIC Code in the as related to the original video Timestamp	JSON message via HTTP post	EF6 CID
TAS Time slot reservation	The destination of the TOV, could the ship yard or the terminal at the ship yard. Entering the yard is by a time slot, therefor it is important the check if the given time slot is still reachable on time. If the transport is too late, this is communicated to the TAS where a new time slot is provided.	Terminal time slot reservation		TAS system

Table 13: INPUT data for EF7 ETA

Data Type	What?	Proposed output?	Technical requirements	Consumer
ETA	The ETA of the teleoperated transport will be calculated on a continuous real-time basis and shared with the teleoperator (via the EF1 dashboard, showing also the route and turn-by-turn navigation) and other interested partners	Overall ETA	Update frequency: 5sec	EF1 EAD Logistic planner
Intermediate ETA	The calculated real-time ETA of the TOV towards a relevant waypoint.	ETA for every waypoint	Format: linestring (Geojson) in WGS 84 frequency: 15 sec , when route/ETA is changed.	EF3 iTLC, others
Turn by turn navigation	The route will be provided towards the teleoperator in turn-by-turn navigation instructions.	Linestring Text message with instructions Symbols (arrows) also need to be provided.		EF1 EAD provider
Route of the TOV	The calculated route of the TOV to the end destination or a relevant waypoint	Linestring with coordinates of the trajectory and ETA on the coordinates	Format: linestring (Geojson) in WGS 84 frequency: 15 sec and when route / ETA is changed.	EF2 VRU provider others
Approved TAS Time slot reservation	By making the coupling with the TAS, a dynamic assignment of pick-up/drop-off slots becomes possible. The TAS time slot is communicated to EF7 which monitors continuously whether the transport is on schedule to make the provided time slot.	Warnings		TAS system
Request for prio	A standardized priority request message, through which the TOV can request green.	Intersection ID Signal group ID Vehicle ID Request ID Request sequence ID ETA at stop line Platoon ID (if part of platoon)	Format: JSON/ASN.1 Protocol: ETSI SRM	EF7 ETA provider WP4 partner

Table 14:OUTPUT data for EF7 ETA

2.7.4 Actor stories

Function Provider

As EF7 provider, I want to provide concise and clear information related to the time of arrival and the progress of the TOV traject/route. In order to calculate a concise ETA, I would like to receive information on the traffic situation, potentially dangerous situations (traffic incidents, VRU warnings) and time slot reservations (at intersections or at terminals).

In the first place, I will provide an overall ETA calculated on a continuous real-time basis to the teleoperator. I will start from the position and heading provided by WP 4 and calculate the fastest route. The ETA from this route will be given towards interested partners and certainly with EF 1 EAD who will use it in their final visualization.

Furthermore, I will divide this route into waypoints and calculate an ETA for every waypoint. The intermediate waypoints will be relevant for other enabling functions, in particular EF 2 VRU and EF3 iTLC who needs this information to calculate potential collisions or provide a timely timeslot reservation (though it may be useful for other EF's as well).

Teleoperator

As a teleoperator, I would like to see ETA information on my HUD so that can supplement my own observations while driving. I would like to know the time of my arrival at my destination and also would like to follow up my route/ drive with the help of waypoints and their ETA's.

This will increase efficiency of the teleoperated transport as well as the planning for pick-up, delivery or time slot reservation.

EF 2: collision warning

As a VRU warning provider, I would like to receive the for me relevant waypoints and the ETA of that waypoint in real-time and on a continuous basis. I will send a warning on impending path conflicts between TOV and a VRU, in a predetermined format. These warnings contain information on the anticipated path of the VRU (coordinates plus timestamp) and the type of VRU.

EF 3: Time slot reservation

As a timeslot provider, I would like to receive a prio request for the for me relevant waypoints and the ETA of that waypoint in real-time and on a continuous basis, so that I can assign an appropriate time slot.

2.8 SA – Scene Analytics

2.8.1 Short description

EF8 foresees in a continuous monitoring of several key areas relevant to teleoperation, making teleoperation safer and more efficient. Key areas include the port terminal area, the buffer parking and the TOV itself. Monitoring will be done by processing real-time streams from multiple sources, detecting anomalies in real time. Used data sources are:

- Existing CCTV cameras with sound capabilities
- New to be installed sound detection equipment with geo-localization
- Other available real-time streams and additional external algorithms working on the same streams can be added at a later stage if deemed interesting.

Anomaly detection will take place in two phases:

First, in the learning phase, the EF8 provider will first learn the behaviour of the various sources under "normal" circumstances, by logging the streams during several weeks throughout the day. This will allow the provider to determine abnormal patterns. In the early stages it is crucial to learn the patterns and 'normal' behaviour unbiased and refrained from predetermined patterns. Once this start level is reached the anomalies coming from different streams will then get categorised and prioritised. Patterns will be captured by applying AI techniques on the various sources and on a combination of these sources. This last approach reduced the number of false positives drastically. At the end of this phase, we will have learned what normal visuals and sounds are and will be able to identify anomalies that are not related to the trucks themselves.

Second, in the deployed phase, the various streams will be processed and analysed to search for anomalous patterns. Whenever an anomaly is detected, this will be categorized and transmitted to the teleoperator. If the anomaly takes place off-trip (e.g. in case of a security breach when the TOV is parked), the information is sent straight to the teleoperation control centre where it is provided by way of report presented to the teleoperator at the start of the trip. If the anomaly takes place on-trip, the information is processed by the EF7 for updating the ETA and speed advice. EF7 will further distribute the warnings to the EF1 provider who will include the information in the enhanced awareness dashboard provided to the WP4 partner.

Use-cases include the following:

- Inspection of the TOV: Operators carry out inspection at the start and end of their trip. This inspection becomes more challenging in the physical absence of the teleoperator. The use-case therefore foresees in inspection of the truck by analysing and processing the streams available. Camera and sound streams may pick up on anomalies which point to for example (external or even internal) damage to the vehicle. Anomaly detection may also take place while driving.
- Security breach of the TOV: When the TOV is parked on the port premises or on a buffer parking, the state of the TOV can be continuously monitored. If a security breach is detected (e.g. an attempt to open the door), the EF can warn the teleoperation centre of the breach.
- Suboptimal operations: The continuous monitoring of the TOV's and key areas makes it also possible to detect parts of the transport itinerary that are not going as planned (i.e. that deviate from how the transport should normally go). For example, CCTV camera's at the entry gates of port terminals may pick up that the queue at a terminal entry is longer than typical. This may trigger a message to the teleoperator and to the EF7 provider that the arrival time of the payload will be delayed.

Other applications may be possible. The solution provided through EF8 is flexible in the sense that the monitoring of the key areas, and the development of algorithms processing the streams coming from these areas, may lead to new applications later on, illustrating the business potential of the technical lessons learned with this enabling function in the project.

2.8.2 Sequence diagram

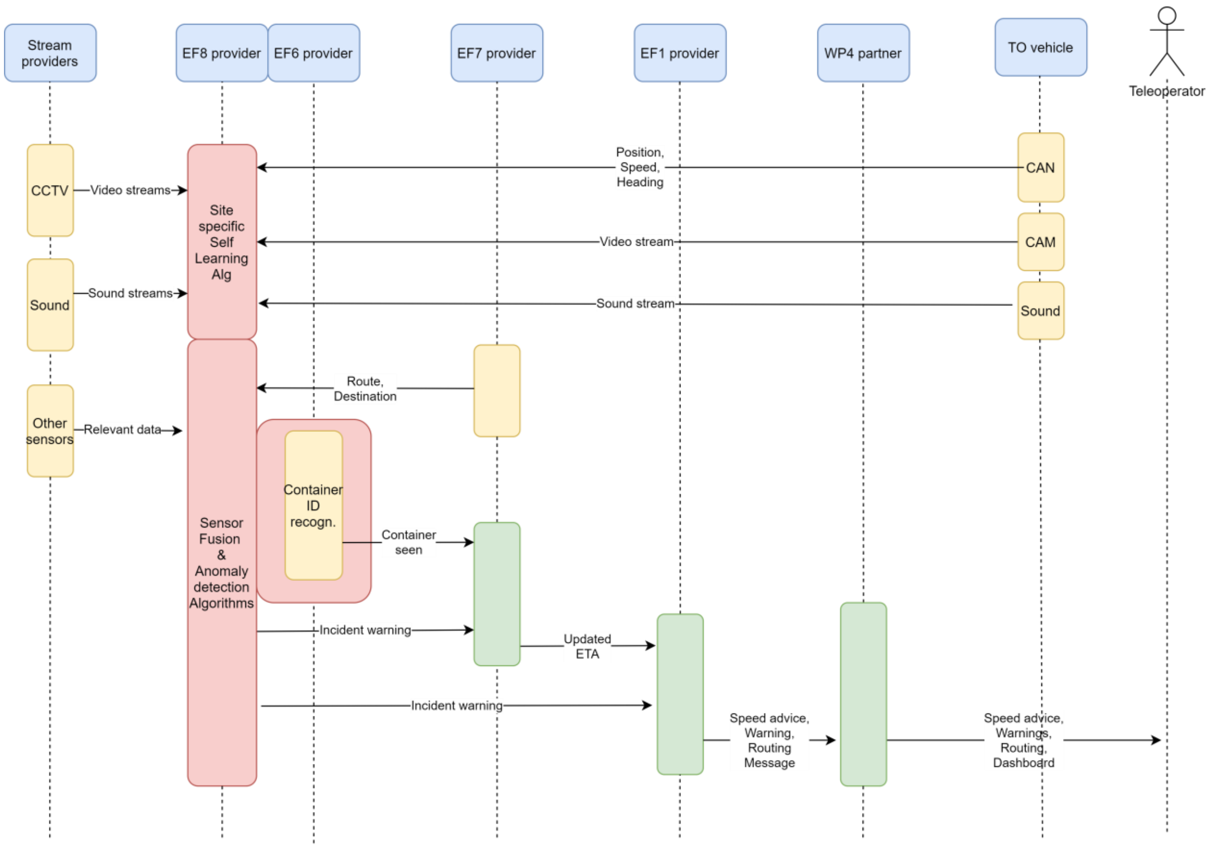

Figure 19: Sequence diagram for EF8 SA

2.8.3 IN/OUT

Data type	What?	Planned input	Technical requirements	Provider
Video from site	Video stream coming from CCTV camera's positioned at the location that needs to be monitored.	All CCTV camera's need to have sound integrated. A video therefore also transmit sound within the stream	RTSP stream made available through a public IP	Site owner
Sound from site	Sound detection device that provides streams of sound data at a specific location with frequency and decibel knowledge	Raw sound streams of every georefered location	Real time API directly from sound devise	EF8 SA
Video from truck	Video stream coming from dash camera onboard of the truck positioned at the location that needs to be monitored.	All CCTV camera's need to have sound integrated. A video therefore also transmit sound within the stream	RTSP stream made available through a public IP	Truck Owner or WP4

Sound from truck	Simplified sound detection device that provides streams of sound data at a specific location with frequency and decibel knowledge	Raw sound streams with indication of general direction	Real time API directly from sound devise	EF8 SA
CAN from truck	A permanent data stream made available from the CAN bus of the truck	Speed, GPS coordinates, other which is easily incorporated	Json, rtsp,	Truck Owner or WP4
Route and Destination	Update on the route of the TOV and the destination	coordinates	Json	EF7 ETA

Table 15: INPUT data for EF8

Data type	What?	Proposed output?	Technical requirements	Consumer
Anomalies prior to operations	Anomalies picked up (visual and auditive) prior to the start of operations. These are typically detected when the truck is standing still for a longer period in time)	- Trigger/warning with information on potential hazard - Camera image of hazard - Video footage with sound integrated - Location of anomaly - additional metadata such as object recognition, number plates, repeat offenders, ...	Triggers provided in realtime Update frequency other info : 10 sec	EF1
Warnings picked up from extended perceptive range	Anomalies picked up (visual and auditive) during operations of the truck. These are picked up from the continuous monitoring of the TOV and its environment where it has started or arrives (EF8)	- Trigger/warning with information on potential hazard - Camera image of hazard - Video footage with sound integrated is stored for later use. - Location of anomaly - additional metadata such as object recognition, number plates, available free parking spaces, ...	All information is provided in real time.	EF 1, EF7

Table 16: OUTPUT data for EF8 SA

2.8.4 Actor stories

EF8 SA provider

As EF8 SA provider, I would like to provide reliable and accurate information on incidents (i.e. abnormal events) on relevant parts of the TOV's trajectory, by applying artificial intelligence on a combination of several data streams on the Scene Analytics Platform.

In real-time, I take in all relevant data coming from the TOV, including but not limited to:

- Position, speed, GPS coordinates and heading;
- Live camera images;
- Live audio streams.

I also retrieve the current route and destination from the EF7 ETA provider and receive container ID information from the WP6 provider through his algorithm that will run on the same Scene analytics platform.

Finally, I also take in all other streams which may be relevant for me to detect anomalies. Sources may be other function providers (see below), or providers outside the core WP6 partners.

Using these data streams, I aim to first learn what normal behaviour is for video and sound and later detect anomalies on the platform which may point to "incidents" – events that are abnormal. These incidents will be transmitted to the EF7 ETA provider and the EF1 EAD provider.

EF7 ETA provider

As EF7 ETA provider, I provide the EF8 SA provider with a real-time update of the TOV's route and its destination. I receive updates on potential incidents on the TOV's route and update the ETA and/or route accordingly. I send the updated ETA and/or route to the EF1 EAD provider.

EF1 EAD provider

As EF1 EAD provider, I receive relevant event packages from the platform of the EF8 SA provider. These packages consist of meta data combined with video clips and sound clips. Based on these data, I decide what information will be deployed to the truck operator. The EF8 SA provider will initially send all the detected anomalies, but together with the operator of the TOV and the EF1 EAD provider an initial prioritisation will need to be done. Categories prior to start will be for example: security breach, for information only, to be verified prior to start, etc… During operations this will need to be categorised and prioritized during the initial learning phase at start of operations.

I also receive an updated ETA and route from the EF7 ETA provider.

I process these events, and updated ETA and route advice into an update of the speed advice, warning and routing message to be sent to the WP4 partner (who then pushes it to the dashboard of the teleoperator).

WP4 partner

I will allow equipment to be installed in the truck confinement to learn what normal sounds are whilst driving and standing still. These findings can then be used to identify in real time abnormal sound patterns like ambulance sirens etc. I also allow to share more general information regarding the opening of access points like barriers.

I receive an updated speed advice, warning and routing message from the EF1 provider and push this to the dashboard of the teleoperator.

Teleoperator

As a teleoperator, I am informed of every abnormal situation enhancing my situational awareness. I will be informed prior to starting the operations of any anomalies that have occurred prior to me starting and I will be informed of anomalies occurring during operations, through the dashboard.

Stream providers

Various providers may stream relevant data to the Scene Analytics Platform of the EF8 SA provider. These may include:

- EF2 provider (VRU interaction): I will put the real-time information of the VRU at the disposal of the EF8 provider. This either by API's or through more integration of the containerised algorithms onto the platform. The EF8 provider can then use this real time information to enhance the other detection algorithms running on the platform. For example, it could become necessary, when hazards are detected through EF2, other more performing algorithms can be used that require more processing power at the thime of a warning. By doing this, hazardous situations can be taken into account, thus improving capabilities.

- EF4 provider (Distributed perception): I will put the real time information of the real time data streams from the teleoperate truck and other nearby sources at the disposal of the R40 platform. This either by API's or through more integration of the containerised algorithms onto the platform. By doing this the hazardous situations can be taken into account thus improving the capabilities.
- EF6 provider (Container ID recognition): I can put the real time raw streams used for the real time container ID recognition at the disposal of the R40 platform. By doing this it can provide additional streams to be used by the Room40 algorithms and it would make it possible for me to run my containerized algorithm on the platform for future scaling if deemed an advantage.

3 INTEROPERABILITY OF EF'S

3.1 Functional architecture

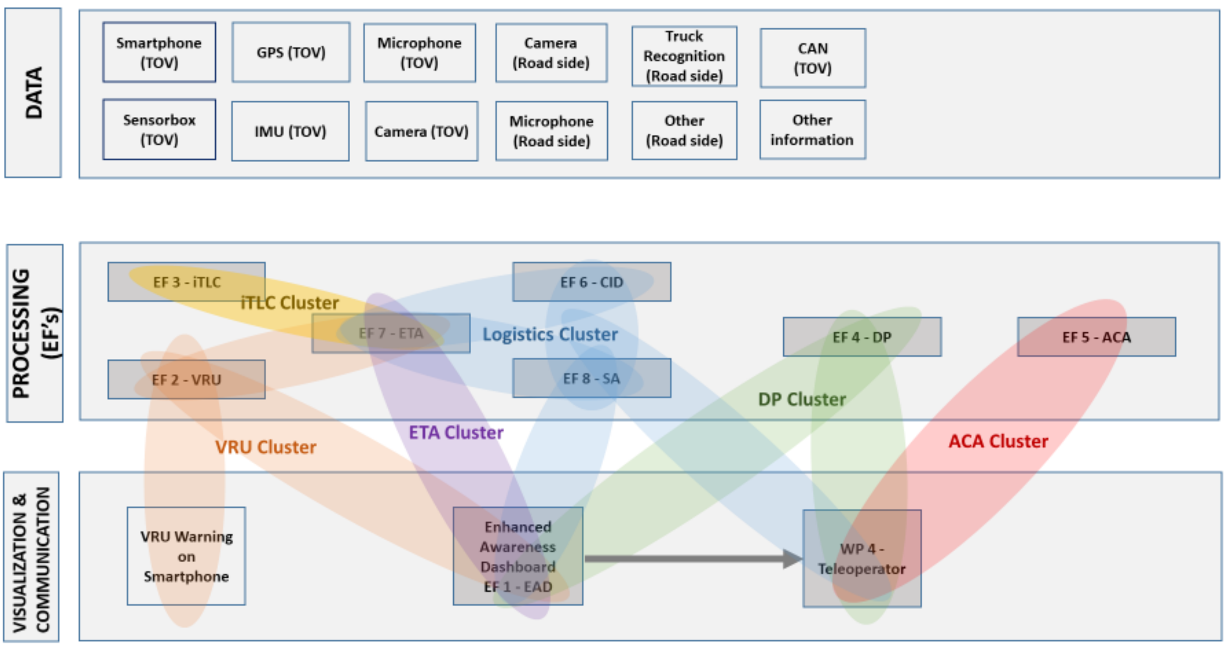

Figure 20: Functional architecture

The functional architecture of the EF's is divided in three layers. The first and top layer is the **data ingestion layer**. In this layer, raw data is collected from sensors (on and around) the TOV's and from external API's such as the Be-Mobile traffic API for the traffic situation based on FCD. The collected raw data will be stored and pre-processed. Once the raw data is made available it can be fetched by the partners involved in the enabling functions. The processing from raw data into useful information will be done in the second layer, **the processing layer** by the enabling functions. The second layer consists of 6 clusters, sets of processes and communication chains with a specific objective:

- **VRU cluster** (EF2, EF1, and EF7): This cluster is aimed at warning VRUs and teleoperators for potential VRU/TOV conflicts. Part of this cluster also involves communication back to the VRU via smartphone;
- **iTLC cluster** (EF3 and EF7): This cluster aims to provide an appropriate time slot to the tele-operated transport;
- **DP cluster** (EF4 and EF1): This cluster is aimed at providing an extended perceptive range to the remote teleoperator for making the appropriate decisions.
- **ACA cluster** (EF5): This cluster is aimed at providing active collision avoidance tools to the teleoperated transport.
- **Logistics cluster** (EF6, EF7 and EF8): This cluster is aimed at increasing efficiency of tele-operated transport.
- **ETA cluster** (EF7 and EF1): This cluster is aimed at providing detailed ETA estimates to the teleoperator and other interested parties. Inputs from other clusters will be used within this cluster; similarly, the output from this cluster will also be important for other clusters. This explains the central position of EF7 in the architecture scheme.

The output of many of these clusters will be consolidated directly (for ETA, VRU, logistics and DP) or indirectly (via ETA) in EF1 EAD, who will present the consolidated information to the teleoperator, via the HUD and a secondary screen. The **visualization and communication** to end-users (teleoperators, VRUs), other work packages and other interested parties will be done in the last layer. For some EF's, such as EF4, EF5 and parts of the logistics cluster, some communication with WP4 and the teleoperator will take place directly (i.e. not via EF1 EAD).

3.2 Data flow architecture

The data flow architecture presented here builds on the functional architecture, providing an overview of what data is used, and how the data flows between the various entities. Its aim is to provide a clear view on the interaction and interoperability between the partners involved in the different enabling functions.

3.2.1 Data Ingestion Layer

Raw data is collected from several TOV sensor such as camera's, IMU, GPS and microphones. If available, data from sensors on the side of the road will also be collected. This could be data from CCTVs, ANPRs or microphones[4]. In some cases, the raw data will be processed on the edge. The raw and/or pre-processed data will then be sent with the help of 5G towards the cloud. There, (further) processing will take place, after which enabling functions can use the data

Some of this data needs to be pre-processed or filtered before it can be used in the processing layer. For example: acceleration data can be distracted from the motion data received from the IMU. From this acceleration data sudden movements (lateral or transverse) can be filtered. In the processing layer these movements can be converted into warnings for the teleoperator.

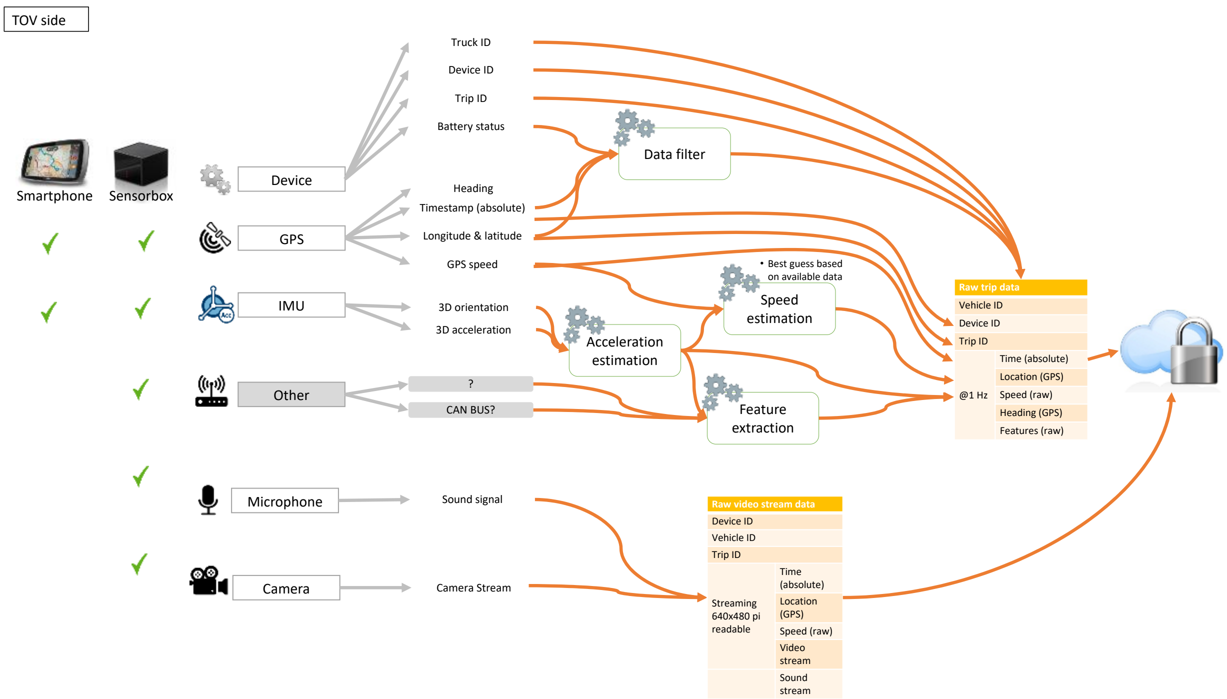

Figure 21: Sensors and data collected from TOV

[4] Note that for all these collected datasets, that solid agreements will be made regarding data management, including GDPR compliance. These agreements will be captured in the Data Management Plan (DMP) of the project. This DMP will be organised as a living document of which three different snapshots in time will be published at M6 (D2.2), M18 (D2.3) and M36 (D2.4).

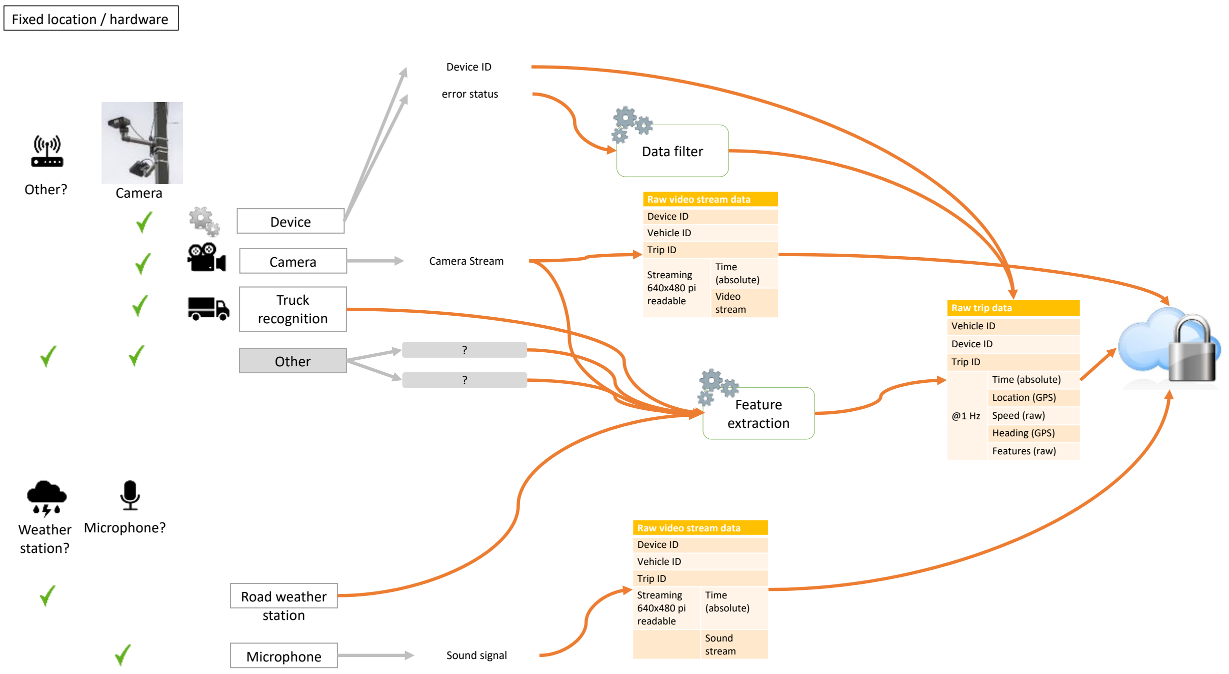

Figure 22: Sensors and data collected from other hardware and fixed locations

3.2.2 Processing layer

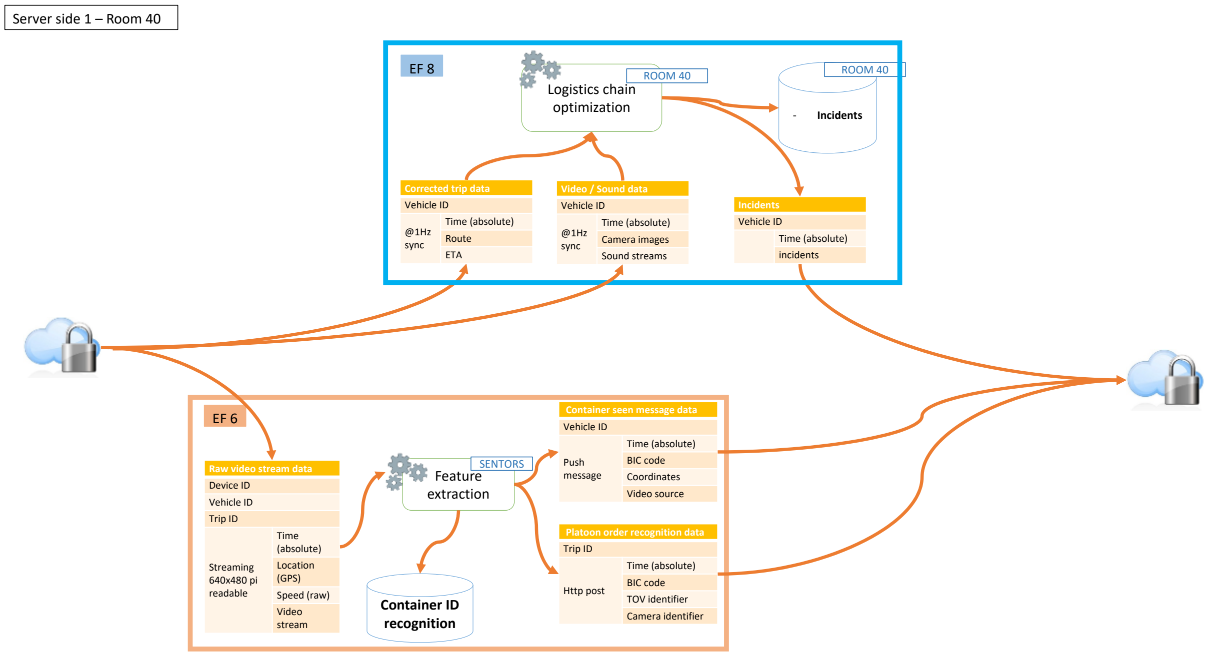

Figure 23: Data processing by EF8 SA and EF6 CID

Room 40, as EF8 SA provider, will collect per vehicle ID route information with the ETA of the TOV, timestamp, streaming information such as camera images and sound. By combining this information, they will detect anomalies (visual and auditive). These anomalies (incidents) will be sent towards Be-Mobile (EF7 ETA and EF 1 EAD) so the ETA can be changed, and the anomalies can be communicated to the teleoperator.

On the same platform the container ID's will be checked on the video stream. The recognized BIC containers are pushed via a REST-based API to EF7 ETA and the planning software.

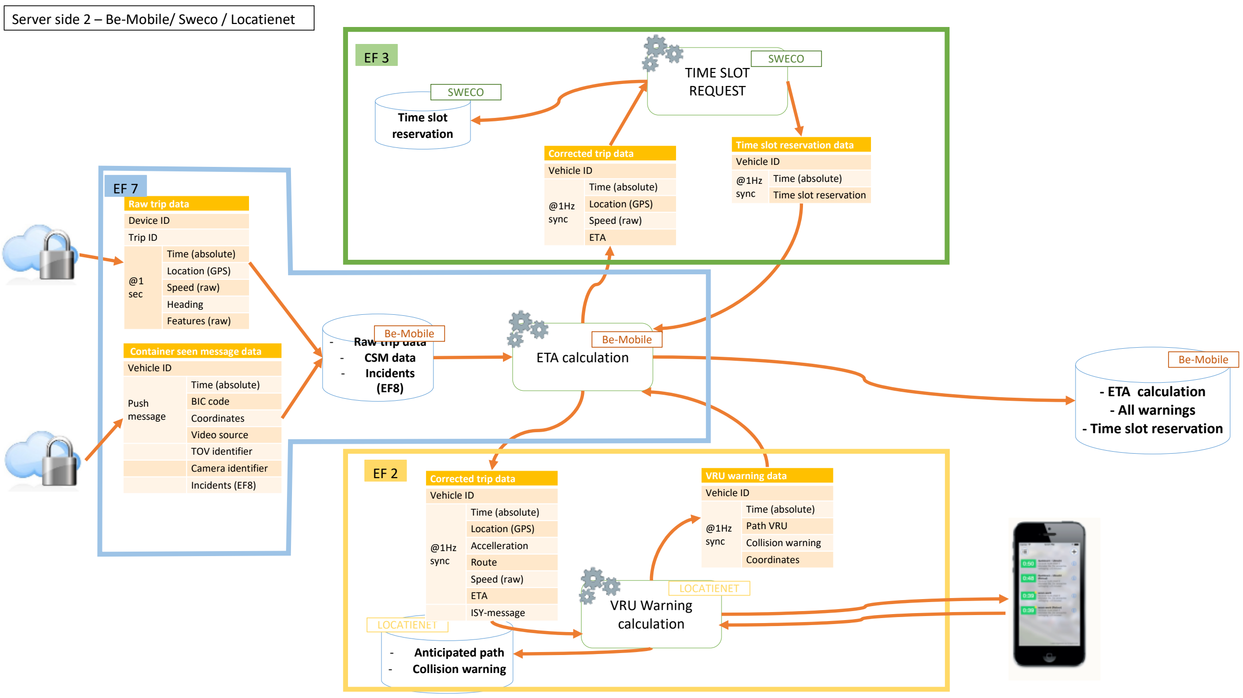

Figure 24: Data processing by EF2 VRU, EF3 iTLC and EF7 ETA

Be-Mobile (as EF 7 ETA provider) will collect speed, heading and the position from the onboard GPS unit in order to calculate the ETA of the TOV. The ETA of the teleoperated transport will be calculated on a continuous real-time basis and shared with the teleoperator (via the EF1 EAD dashboard, showing also the route and turn-by-turn navigation) and other interested partners. This ETA will be based on the fastest route from the current position, speed and heading of the TOV to the point of destination. Furthermore, dynamic information from other EF's will also be taken into account. The route of the TOV will also be divided into waypoints. For each waypoint an ETA will also be calculated. These intermediate ETAs will be used by EF2 VRU to calculate more accurate potential collision or by EF3 iTLC to assign a time slot.

Information taken into account for calculating the ETA:

- The standard SRTI feed (Be-Mobile)
- Warnings picked up from extended perceptive range (EF4 DP) and the continuous monitoring of the TOV and its environment (EF8 SA).
- Warnings on path conflicts with VRUs (coming from EF2 VRU): EF2 VRU aims to provide early warnings (up to 2 minutes in advance) to VRUs and teleoperators about potential collisions between VRUs and TOVs. The likely paths of the relevant VRUs (the first objective of this function) are compared with the anticipated paths of the relevant TOVs (provided by the EF7 ETA provider, based on position and routing data and also shared via "CAM+" with the EF2 VRU provider). Speed may be adjusted to reduce the likelihood of collision with a VRU.
- Time slot reservation (coming from EF3 iTLC): Be-Mobile will also request a time slot with Sweco (EF3 iTLC) in order to cross the intersection without losing time or stopping the vehicle/platoon. When the request is granted, speed may be adjusted to ensure that the TOV makes the time slot. For example, it may well be that, at current speeds, the TOV will be too early for the time slot, causing unnecessary deceleration and acceleration. In that case, the advised speed will be adjusted downward.

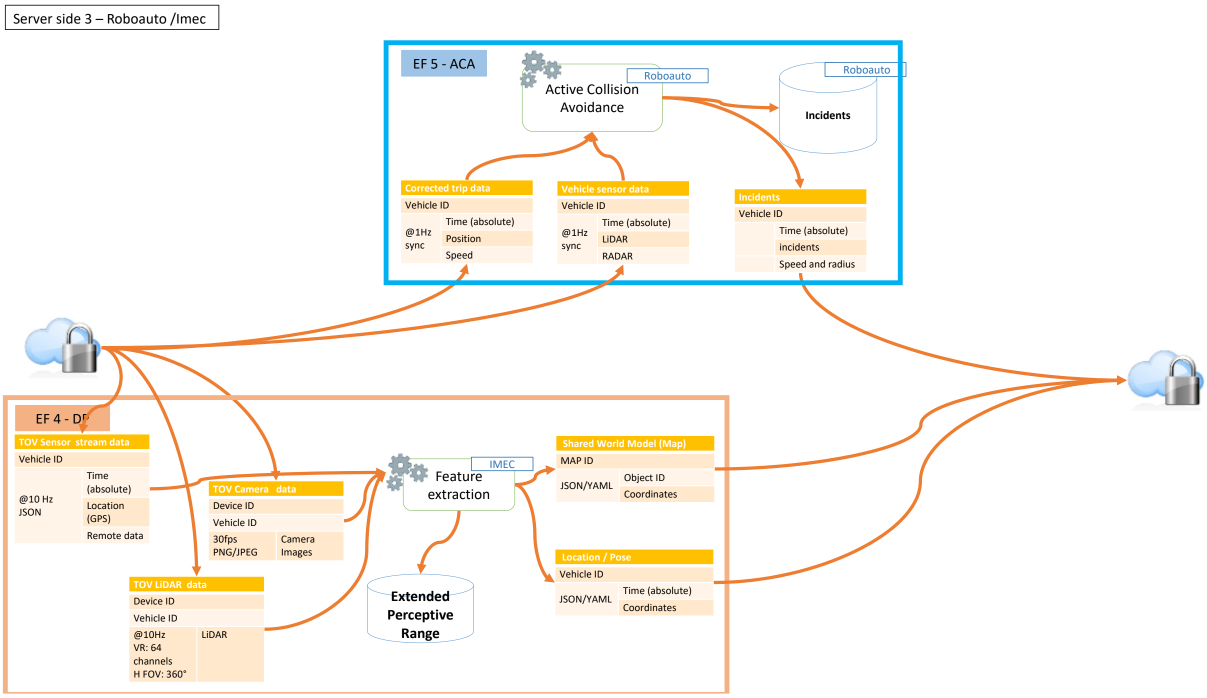

Figure 25: Visualisation and communication

Roboauto (EF5- ACA) will provide the active collision avoidance (ACA) extension to the TOV, mitigating hazardous situations associated with a possible loss of connection and with impaired perception of the environment. A sensor set containing Lidar, Radar, GNSS-INS and cameras will be installed on TOV. The task of this sensor system is to register obstacles on the TOV's route. The position GNSS-INS module will be used to locate the vehicle in a digital map that contains the planned path of the vehicle. The data from the sensors will be processed in a dedicated computing unit designed for ACA. Once an obstacle (ex. incident or take over) is detected a message/alert is sent towards the teleoperator.

IMEC (EF 4 – DP) will provide an extended perceptive range to the remote teleoperator for making the appropriate decisions. A system of connected sensors on a distinct and diverse range of vehicles each with their limited field of view will be foreseen. The information gathered from these diverse sensors will be aggregated and fused into a global model (a "map") which will be sent towards Be-Mobile (EF1 – EAD) and used by the teleoperator for better decision making.

3.2.3 Visualisation and communication layer

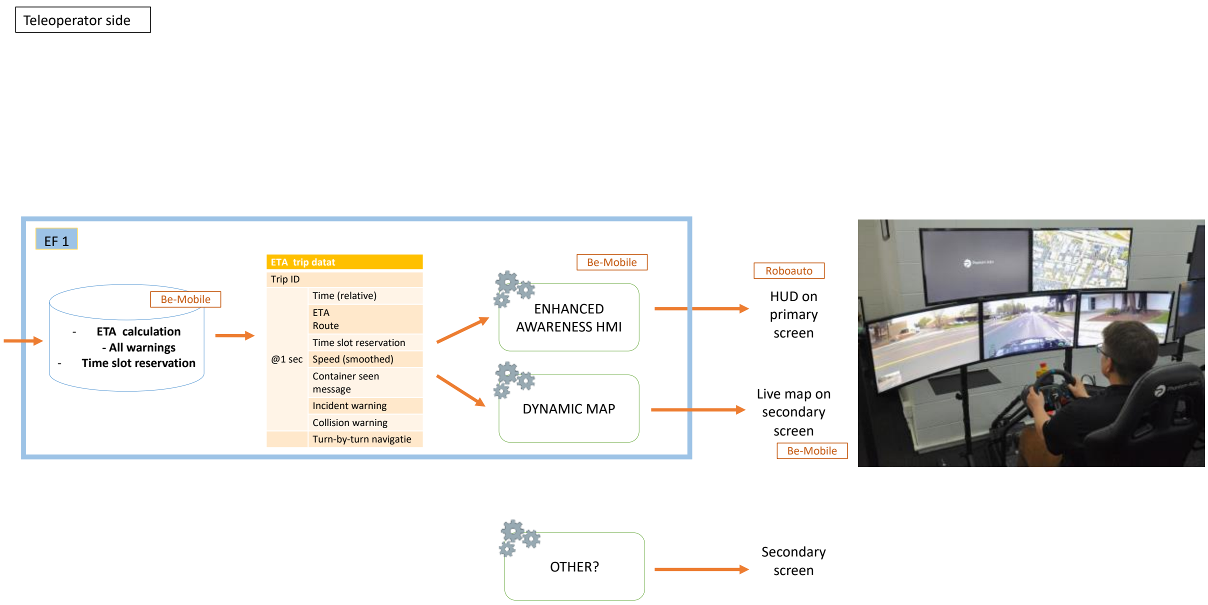

Figure 26: Visualisation and communication

Be-Mobile (EF1 EAD) will collect all information from EF7 ETA or other EFs and visualize all the information in an “enhanced awareness dashboard” on which three types of information will be displayed:

Speed advice. The speed advice will be shown to the teleoperator along with the actual speed. Visual and/or auditive feedback will be presented to the teleoperator in case the actual speed surpasses the advised speed.

Warnings. The aforementioned warnings will also be presented to the teleoperator through succinct visuals (possibly along with auditive cues).

Navigation and routing features. Based on input received from the ETA provider (EF7 ETA), the route will also be presented along with an ETA to the destination or a relevant intermediary point. The teleoperator will also be informed of any relevant potential delays picked up through EF8 SA.

The consolidated information may be displayed in two ways:

- **Heads-up-display (HUD)**: This is basically a small widget directly in the line of sight of the teleoperator. This HUD would present only key operation, that is: advice speed vs current speed (based on GPS-speed); textual, symbolic warnings; and turn-by-turn navigation with ETA. If the information is limited to a few datapoints, this could be integrated in the teleoperator dashboard by Roboauto.
- **Dynamic Map**: On a secondary screen, a real-time dynamic map with information on the route, long-distance obstacles, VRU’s distribution perception and logistic optimization will be shown.

Part of the secondary screen can also be used by other EF’s (such as EF4, EF5 and the logistics cluster) for the visualization of additional components.

4 CONCLUSIONS

This report provides a detailed functional description of the WP6 enabling functions and describes the in/outs, sequence diagrams, user stories, data streams and the partners involved in or affected by the enabling function. Furthermore, a detailed overview of the interoperability of the enabling functions by a functional and data flow architecture is given. These overviews make clear what data is used and what processing will be done with the data.

The report answers four questions:

- What can we functionally expect from the enabling functions?
- What inputs and outputs do each of these functions require?
- What role does each partner play in each of these functions?
- How are the enabling functions tied together?

This deliverable will be used as input, together with Deliverable D6.1 Description of enabling functions and their requirements" for designing the technical architecture, including a description of interfaces, secure communication protocols, hardware and software requirements. Technical questions that are still open will be tackled during the design phase of the architecture.