Grant Agreement N°: 952189
Topic: ICT-53-2020

Next generation connectivity for enhanced, safe & efficient transport & logistics

D6.1: Description of enabling functions and their requirements

Revision: v.1.1

Work package	WP 6
Task	Task 6.1
Due date	30/11/2020
Submission date	24/12/2021 (resubmission after Interim Technical Review)
Deliverable lead	Be-Mobile
Version	1.1

Abstract

This document provides a detailed non-technical description of the WP6 enabling functions to be developed, validated and demonstrated within 5G Blueprint. For each enabling function, we provide an overview of the current state of the art; a description of the requirements of teleoperated transport on functionality; and a description of the functionalities that will be provided for this project. The main objective of this document is to create a clear understanding by all partners involved what these enabling functions are, and is therefore non-technical in nature, as a basis for the subsequent technical analysis that will be the subject of the next deliverable of WP6, being D6.2.

Keywords: “Enabling Functions”

Document Revision History

Version	Date	Description of change	List of contributor(s)
V0.1	01/11/2020	ToC	Joost Vandenbossche (Be-Mobile)
V0.2	10/11/2020	First draft	Joost Vandenbossche (Be-Mobile), Tom Van de Ven (Locatienet), Maarten van de Pas (Sweco), Siegfried Mercelis (imec), Martin Kralik (Roboauto), Sander Maas (Sentors), Wim Van den Broeck (R40)
V0.3	24/11/2020	Second draft and review	Karel Rural (HAN)
V0.4	24/11/2020	Final draft	Joost Vandenbossche (Be-Mobile)
V1.0	30/11/2020	Final version ready for submission	Wim Vandenberghe (MIW), Johann Marquez-Barja (imec)
V1.1	24/12/2021	Integrated improvements based on general project review after M10	Joost Vandenbossche (Be-Mobile), Wim Vandenberghe (MIW), Johann Marquez-Barja (imec)

Project co-funded by the European Commission under H2020-ICT-2018-20		
Nature of the deliverable:	R	
Dissemination Level		
PU	Public, fully open, e.g. web	√
CI	Classified, information as referred to in Commission Decision 2001/844/EC	
CO	Confidential to 5G-Blueprint project and Commission Services	

* R: Document, report (excluding the periodic and final reports)
DEM: Demonstrator, pilot, prototype, plan designs
DEC: Websites, patents filing, press & media actions, videos, etc.
OTHER: Software, technical diagram, etc

EXECUTIVE SUMMARY

The present document aims to provide a **description of the various enabling functions** that will be developed and validated in the context of the 5G-Blueprint project. We provide insights into the basic functionality that will be provided; into how these functionalities overcome the challenges posed by teleoperated transport (allowing to take advantages of some of its opportunities); and into how these functionalities to-be-developed differ from the functionalities that we know today.

The document's **main objective is to create a clear understanding by all partners involved what these enabling functions are** (and is therefore non-technical in nature). This then forms a fruitful basis for further exchanges, not only between WP6 and the technical WP's (WP4, WP5, and WP7), but also with WP3 and other non-technical partners involved in the project. Further, this document also serves as a launching platform for the more technical Tasks to be undertaken in WP6, which aim to assign clear roles, and define the functional and technical architecture behind the 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.

The functions discussed in this document enable teleoperation in two important ways. **First, they help to resolve key safety and security challenges** related to physically removing the operator from the vehicle: a teleoperator will not have the same situational awareness than an on-board operator, and the interaction between the operator and its environment is hindered. **Second, they help to unlock the business potential of teleoperated transport**. The business case for teleoperated transport lies in a more efficient use of scarce operators – transporting more with less. Some of the enabling functions developed in 5G-Blueprint are a first important step towards increasing operator efficiency, through providing better and up-to-date information, and reducing operator waiting times.

5G-Blueprint foresees in the development of 8 enabling functions:

- EF1 – Enhanced Awareness Dashboard foresees in clear and concise on-trip information about the situation on the road/waterway ahead to the teleoperator via a dashboard. This will present a consolidated view of all safety-related information to the teleoperator, increasing the teleoperator's situational awareness without creating information overload.
- EF2 – Vulnerable Road User Warnings provides warnings to teleoperators and vulnerable road users (e.g. pedestrians, or cyclists) about likely conflicts between teleoperated vehicles and vulnerable road users.
- EF3 – Time Slot Reservation ensures a conflict-less crossing of intersections by teleoperated vehicles by providing a time slot for "green-lighted" passage. This will reduce the likelihood of collisions on intersections, as well as ensure a smooth navigation of the intersection (which is especially important for truck platoons).
- EF4 – Distributed perception extends the perceptive range of the teleoperator (currently limited to camera's and sensors installed on the teleoperated vehicle) by making use of camera's and sensors on other vehicles or road-side or water-side units. This should lead to safer teleoperated transport.
- EF5 – Active collision avoidance provides safety measures which actively protect teleoperated vehicles from colliding with other road uses as an integral function capability of the teleoperation solution. This will further ensure the safe deployment of teleoperation in a production environment.
- EF6 – Container ID recognition provides the capability to identify the unique container ID number on shipping containers on the basis of camera images. This will allow for visual confirmation of the container ID in the absence of the truck/crane/barge operator, increasing efficiency and reducing the risk of errors.

- EF7 – ETA sharing provides real-time ETA and routing information to the teleoperator and other interested partners, as well as set up an exchange of data with terminal systems to dynamically organise the container pick-up or drop-off time at the terminal.
- EF8 – Scene Analytics foresees in a continuous monitoring (through IP cameras and sound sensors) and anomaly detection of several key areas relevant to teleoperation: inspection of the tele-operated vehicle (TOV) at the start and end of a trip, security breach of parked TOV, entry queue length at terminal, buffer parking occupancy, etc. This makes teleoperation safer and more efficient.

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ABBREVIATIONS

ACA	Anti-Collision Avoidance
CACC	Cooperative Adaptive Cruise Control
CAM	Cooperative Awareness Message
EF*x*	Enabling Function *x*
ETA	Estimated Time of Arrival
HMI	Human-Machine Interface
ISY	‘I saw you’ message
SGD	Safety Gateway Device
SRTI	Safety-Related Traffic Information
TAS	Truck Assignment System
TLC	Traffic Light Controller
TLEX	Traffic Light EXchange
TOV	Teleoperated Vehicle
UDAP	Urban Data Access Platform
VAM	VRU Awareness Message
VRU	Vulnerable Road User
WP4	Work Package 4
WP6	Work Package 6

1 INTRODUCTION

This document provides a non-technical description of the eight enabling functions that will be developed and validated within Work Package 6 (WP6) of the 5G Blueprint project. These descriptions serve as a starting point for the reader to understand the **basic functionalities** of these enabling functions and **how they can add value** to teleoperation (i.e. how they “enable” teleoperation).

The document will later be supplemented by technical deliverables, explaining in more detail the functional and technical architecture behind these enabling functions, as well as how these enabling functions will be integrated into the Work Package 4 use-cases, and what the architectural dependencies from 5G functionalities are (D6.3).

The remainder of the document provides a description for each enabling function separately. The description consists of the following elements:

- Current State of the Art: How do the functionalities related to the enabling function exist today, and what are the key relevant drawbacks?
- Requirements from teleoperation: What requirements does teleoperated transport (i.e. the physical removal of the operator from the vehicle or barge) pose for the functionalities related to the enabling function? The approach is to provide a non-technical overview of these requirements. A cross-collaboration with WP4 to identify the specific use-case requirements is ongoing at this current early stage of the project (M3). Deliverable 6.2 will provide a more comprehensive and technical view on the requirements from these specific use-cases.
- Description of the enabling function: What will the functionality be that is provided by the enabling function?

2 EF1: ENHANCED AWARENESS DASHBOARD

Enabling Function 1 (**EF1**, led by Be-Mobile) foresees in providing clear and concise on-trip information about the situation on the road ahead to the teleoperator via a dashboard, with the aim to enhance the teleoperator's situational awareness.

The functionality provided should be seen as an advancement in the field of safety-related traffic information (**SRTI**) via C-ITS communication technology.

2.1 Current State of the Art

Today, a multitude of public and private feeds on SRTI have been developed in the Netherlands and Belgium, with agreements in place on the exchange and fair use of the information. Most notably, in the context of the Dutch Talking Traffic program, the Dutch authorities and industrial partners have cooperated to provide these SRTI feeds in real-time and directly in-car to road users.[1] Data exchange within Talking Traffic takes place using existing communication technologies. The following data is made available to road users in the context of Talking Traffic:

- In-vehicle signage: Information on traffic signs and variable message signs (**VMSs**) is shown in-vehicle. This includes speed limits, including dynamic speed limits. With respect to the latter it should be noted that protocols are in place (in both the Netherlands and Belgium) for the road operator to share information on dynamic speed limits displayed on VMS with navigation service providers who are then able to display these speed limits in the vehicle. Other types of information shown are lane configuration and overtaking restrictions for trucks.
- User-specific warnings on potentially dangerous situations and roadworks: Users are shown, in real-time and in-car, warnings on dangerous situations that are directly relevant for them, i.e. based on their current position, heading and route. These dangerous situations could be traffic accidents, the start of a traffic jam, bridge openings, obstacles on the road, ambulances, etc.
- Real-time information from traffic lights: Users are provided with, in-car and in real-time, the current status of the traffic lights on an intersection they are approaching. Status could be the current position (red/yellow/green) as well as the time-to-green and the time-to-red.
- Parking guidance information: Parking options are shown to users in the proximity of their destination. When the chosen parking is full, they are automatically redirected towards another parking.

These feeds are in essence uncoordinated. The end-users may be presented with a multitude of pieces of information without these being consolidated into one coherent and actionable advice. For example, the speed limit shown in-car may not reflect the proper speed advice if concurrently there is a warning for an accident further up the road.

2.2 Requirements from teleoperation

The removal of the operator from the vehicle has the risk of reducing situational awareness of the operator. Visual information conveyed by cameras may lack depth and sharpness and the camera system may create image distortions, such that it does not perfectly capture the combination of sensory perceptions of a driver on the road.

The reduced situational awareness thus creates a discomfort and safety risk:

[1] See www.talking-traffic.com

- The teleoperator will have to exert more effort than is usual to pick up on potentially dangerous events ahead. On top of that the perception that she/he may miss important cues, may give rise to additional stress.
- The reduced awareness and the added stress may lead to critical oversights in operation, leading to incidents and thus overall reduced safety.

Teleoperation thus calls for enhancing the awareness of the operator by providing relevant information during the transport. Allowing this for a more relaxed transport for the teleoperator: they can rely on technology to help guide them during operation.

SRTI feeds in their current form may contribute to enhancing this awareness, but also run the risk of ultimately being uninformative because of information overload (well-known paralysis by analysis). Information overload is a key concern for teleoperation. Distraction for the teleoperator while driving on public roads or private premises should be kept to a minimum. It is therefore important to provide the teleoperator with advice that is concise, intuitive to follow, and consistent.

Advances beyond the state of the art are thus required to (i) enhance awareness of the teleoperator; while (ii) reducing information overload.

At the same time, the current, standard SRTI feeds may miss relevant information that is available through the functionality of other EFs. Data collected through these EFs may provide a much clearer and relevant picture of the situation directly downstream from the Teleoperated Vehicle (TOV), and should at least be considered complimentary.

2.3 Description of the enabling function

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

1) **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 TOV can be expected to travel. The speed advice is then adjusted depending on SRTI. This information can come from multiple sources:

- The standard SRTI feed (already operational by Be-Mobile today): These include warnings on obstacles, traffic accidents, 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) and the continuous monitoring of the TOV and its environment (EF8).
- Warnings on potential path conflicts with VRU (coming from EF2), situations in which the path of the TOV and VRUs could intersect at some time in the future: Speed may be adjusted to reduce the likelihood of collision with a VRU.
- Time slot reservation (coming from EF3): 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.

  The speed advice will be shown to the teleoperator along with the actual speed. Visual and/or auditive and/or haptic (e.g. vibrations in the steering wheels, pedals or seat) feedback will be presented to the teleoperator in case the actual speed surpasses the advised speed.

2) **Warnings**. The aforementioned warnings will also be presented to the teleoperator

through succinct visuals (possibly along with auditive or haptic cues).

3) **Navigation and routing features**. Based on input received from the ETA provider (EF7), 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.

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 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 four ways:

- Via Heads-up Display: Key pieces of information are shown in the direct field of vision of the teleoperator. To avoid information overload, the shown information is limited to speed advice, a warning icon if applicable and turn-by-turn navigation.
- Via Map: Relevant information (including the route, but also warnings) are shown on a map. This map can be used as a secondary source of information by the teleoperator (similar to today's central console displays in today's high-end vehicles).
- Via the TOV's automated speed limiter: An integration can be made with the cruise control of the TOV, whereby the TOV's speed cannot exceed the advised speed provided by EF1.
- As augmented reality on top of camera images shown to the teleoperator: Several key pieces of information (such as VRU warnings) can be shown directly on the camera images by adding a virtual layer on top of these images.

The eventual choice of display will be clarified together with WP4 partners, and will be depending on the use case.

The proposed solution entails significant advances beyond the current state-of-the-art in SRTI provision: The SRTI provider will no longer be simply passing on the data to the end-user; rather, they will interpret, combine and consolidate various streams of SRTI and combine this into actionable and usable advice.

3 EF2: VULNERABLE ROAD USER WARNINGS

Enabling function 2 (EF2, led by Locatienet) foresees in providing warnings to teleoperators and vulnerable road users (VRU) about likely conflicts between these VRUs and TOVs. As per the ITS directive 2010/40/EU, VRUs are defined as "*non-motorised **road users**, such as pedestrians and cyclists as well as motor-cyclists and persons with disabilities or reduced mobility and orientation*".[2]

3.1 Current State of the Art

A wide range of R&D projects have focussed on the subject of VRUs:

- VRUITS[3] - provided evidence-based recommended practices on how VRUs can be integrated in Intelligent Transport Systems and on how HMI designs can be adapted to meet the needs of VRUs.
- ASPECCS[4], ADOSE[5] - focused on detecting the pedestrians and avoiding accidents by utilizing on-board sensors.
- SafeWay2School[6], Ko-Tag[7] – demonstrated the use of radio tags to warn human drivers for VRU presence.
- UDrive[8] – collected big data on accident, including accidents involving VRUs.
- C-Mobile[9] – demonstrated the use of co-operative technology for blind-spot detection.
- C-Roads[10] – established a platform, for authorities and road operators, to harmonise the deployment of cooperative intelligent transport systems across Europe.
- WATCH-OVER[11] - developed an integrated cooperative system to avoid road accidents that involve VRUs, using sensors and a dedicated VRU device.
- IMOVE[12] – Research program in Queensland, Australia for a safe integration of Connected and Automated Vehicles (CAV) into mixed urban traffic environment by observing and predicting CAVs and other road user interactions.

Some of the projects developed cooperative concepts similar to EF2, but none of these projects focused on:

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[2] https://ec.europa.eu/transport/themes/its/road/action_plan/its_and_vulnerable_road_users_en#:~:text=Vulnerable%20Road%20Users%20(VRU)%20are,or%20reduced%20mobility%20and%20orientation%22, last visited on 23/11/2020

[3] https://cordis.europa.eu/project/id/321586, last visited on 23/11/2020

[4] https://cordis.europa.eu/project/id/285106 , last visited on 23/11/2020

[5] https://cordis.europa.eu/article/id/89156-feature-stories-sensing-for-safety , last visited on 23/11/2020

[6] https://cordis.europa.eu/project/id/233967 , last visited on 23/11/2020

[7] https://trimis.ec.europa.eu/programme/cooperative-sensor-systems-and-cooperative-perception-systems-preventive-road-safety, last visited on 23/11/2020

[8] https://cordis.europa.eu/project/id/314050, last visited on 23/11/2020

[9] https://c-mobile-project.eu/, last visited on 23/11/2020

[10] https://www.c-roads.eu/platform.html, last visited on 23/11/2020

[11] http://www.watchover-eu.org/, last visited on 23/11/2020

[12] https://imoveaustralia.com/project/vru-and-cav-interactions/, last visited on 23/11/2020

- Interaction between VRUs and TOVs
- Deployment on 5G

In 5G Blueprint the concepts will be elaborated to allow a risk-based assessment of potential and imminent collision risks between VRUs and TOVs, and the exchange of current collision risks and sighting confirmation messages between VRUs and TOs. The project will demonstrate that these services can be implemented on 5G networks, and that these services work seamless cross-network and cross-border, providing the reliability and speed that is required for safety-related V2X services, to and for all road user types.

3.2 Requirements from teleoperation

The removal of the operator from the vehicle poses a double challenge towards VRUs.

First, as mentioned in Section 2.2., situational awareness of the teleoperator is likely reduced relative to that of an on-board driver. This may increase the probability that a teleoperator fails to spot a VRU further up in the camera's field of vision.

Second, interaction between the teleoperator and the VRU is hindered, as it is not possible to make eye contact. The VRU will as such not be sure that the teleoperator has seen him, and that the latter will take the appropriate measures to avoid collision (e.g. stop at a pedestrian crossing). This creates uncertainty for the VRU, leading to inefficiencies (i.e. both teleoperator and VRU losing time because they both wait for the other) and increased risk of collision (i.e. when the actions of the teleoperator and VRU are uncoordinated).

Detailed information on the position of VRUs for the teleoperator is required:

- Advance knowledge of potential and imminent conflicts with VRUs beyond the sensory horizon of the vehicle is needed, as a crucial safety precondition for teleoperated driving.
- A clear nearly real-time virtual view of VRUs in the immediate vicinity of the TOV will be needed as well. This will be useful for complex manoeuvres in areas where movements of VRUs and vehicles are not strictly separated (e.g. a docking facility in a warehouse). The teleoperator should be given assurance that no VRU is in his intended path, without having to constantly check for VRUs in the vicinity while doing the manoeuvre.

3.3 Description of the enabling function

EF2 has a dual objective:

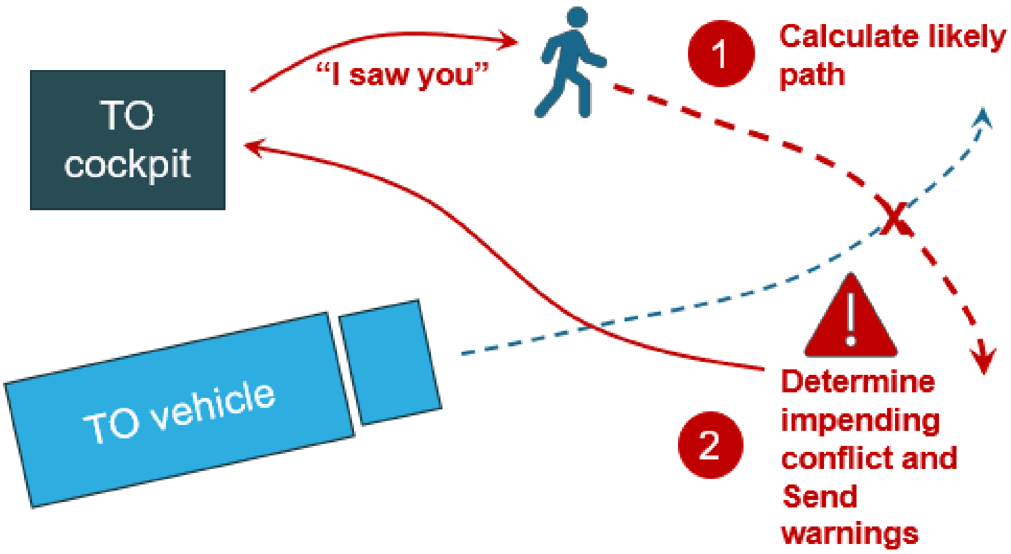

Figure 1: Schematic overview of EF2

First, it **calculates the likely path of all vulnerable road users** (VRU) 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 provider (who will integrate these paths into the TOV's extended perceptive range).

The likely path, calculated at various points over a 2 minute horizon, will be derived from real-time sensory handset data collected via an **application developed by Locatienet**, 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, or the new "VAM" message (VRU Awareness Message) that was recently standardize by ETSI13) 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 (by the EF4 provider), to augment information available to the teleoperator.

Second, EF2 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 provider, based on position and routing data and also shared via "CAM+" with the EF2 provider). For each VRU-TOV combination, the probability of collision is

13 https://www.etsi.org/newsroom/news/1852-2020-11-etsi-experts-complete-specifications-for-vulnerable-road-users

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).

If there is a threat of collision, a warning will be sent out to the VRU through the application. This means that the application has double role. On the one hand it is responsible to collect the current geospatial data of a VRU, therefore the application must at least capture current GPS, accelerometer, gyroscope and compass functions of the device on which the application is running. On the other hand, it is used to inform the VRU for imminent danger. This means that the application also needs to use the appropriate available HMI options (visual (small-big, static-blinking), sound (soft-loud), vibration (slow-rapid)). The VRU will also receive advise on safe behaviour (e.g. 'stay in cycle lane', 'adhere to TLC signs') through the application. And lastly, the relative position of TOVs will be indicated on a map or using a schematic representation, so also a mapbased view in the application will be required.

The EF2 provider will also relay these warnings to the teleoperator of the relevant TOV through the EF1 provider by publishing likely path messages to a central location.

Teleoperators will also 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 long-range (Uu) connection with cloud services (i.e. no V2X PC5 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 reliability of the 5G connections.

4 EF3: TIME SLOT RESERVATION

Enabling Function 3 (EF3, led by Sweco) ensures conflict-less crossings for teleoperated transport at intersections equipped with intelligent TLC's.

4.1 Current State of the Art

Intelligent Traffic Light Controllers (iTLCs) have been developed within the Netherlands as part of the Talking Traffic project[14]. These controllers consist of on-street hardware and controlling software (ITS application[15]). This software, through agreements on governance and data sharing protocols, can be deployed locally or remotely such as in the cloud. Moreover, by this separation of hardware and software via open standards, it is not required to purchase both systems from the same party, opening up the market for new methods of traffic light control.

Another aspect of the Talking Traffic project and the iTLCs is the sharing of data between vehicles, app users and the iTLCs through a centralized exchange (TLEX, to be replaced soon by UDAP). This allows for both optimised traffic control, proactive informing of road users on coming phase changes and the prioritisation of specific road user groups such as emergency vehicles, public transport and trucks. Although the concept of prioritising traffic is not new, EF3 will allow for much earlier priority requesting, will expand the audience of users which can request priority and will include real-time updates to the request based on calculated ETA of the requestor.

Although the mechanism for requesting priority does feature some form of feedback towards the requestor, no guarantees are made with regards to when these requests will be granted and as such these are poorly suited for automated vehicles. As such, the challenge is to increase alignment between vehicles and iTLCs, by developing individualised intersection passage reservation systems which assign and communicate a time slot to individual vehicles for uninterrupted crossing of the intersection.

4.2 Requirements from teleoperation

Given the particular nature of teleoperated transport – no physical presence of the driver – it is important that the TOV can navigate an intersection with as little disturbance as possible. Any disturbance (be it a sudden deceleration to stop for a red light, or a conflict with another road user) has negative implications on the overall safety of the transport.

EF3 guarantees conflict-less crossing, avoiding potential conflicts with other road users. In normal situations, conflicts can still arise at green lights, e.g. because the TOV turns right and has to give way to pedestrians crossing the road. The EF3 eliminates these conflicts by only giving green light to the signal group of the TOV (and other signal groups that do not come into conflict with the TOV).

In addition, with EF3, crossings become more predictable and manageable for teleoperators. The teleoperator will know 5 minutes in advance that the TOV will have a green-lighted passage. Speed can be adjusted to the time slot timeline and sudden decelerations or accelerations can be avoided. This should lead to faster travel times and lower fuel consumption.

A smooth navigation of the intersection is especially important for TOV platoons.

Platoons present an interesting business case for teleoperated driving: Transport starting from the same location can be combined into a single platoon for the first part of the trip, requiring only one teleoperator for the whole platoon; as the transport nears the destination, which may be

[14] https://www.talking-traffic.com/en/, last visited on 23/11/2020

[15] https://www.crow.nl/thema-s/verkeersmanagement/landelijke-ivri-standaarden , last visited on 23/11/2020

different for different trucks in the platoon, the platoon can be split up, assigning a different teleoperator to each TOV in the platoon.

During the operation of the platoon, it will be key that the platoon remains intact (the platoon integrity is maintained) and, more generally, that the impact of the platoon on the traffic context is kept at a minimum. Intersections present an interesting challenge in that respect, as these are the primary points where the platoon risks breaking up, and as a suboptimal crossing of the intersection (e.g. taking way more time than needed) can have detrimental effects on the traffic flow on that intersection during peak hours.

Systems should be put in place which ensure that platoons can be kept intact for the full length of the platoon route, including when crossing intersections. These systems should be set up in such a way that impact on surrounding traffic of the teleoperated Cooperative Adaptive Cruise Control (CACC) platoon is limited.

EF3 provides an elegant solution and should as such be seen as a crucial component to unlock the business case for teleoperated CACC platoons.

4.3 Description of the enabling function

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 with a green-lighted passage over the intersection, without their 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.

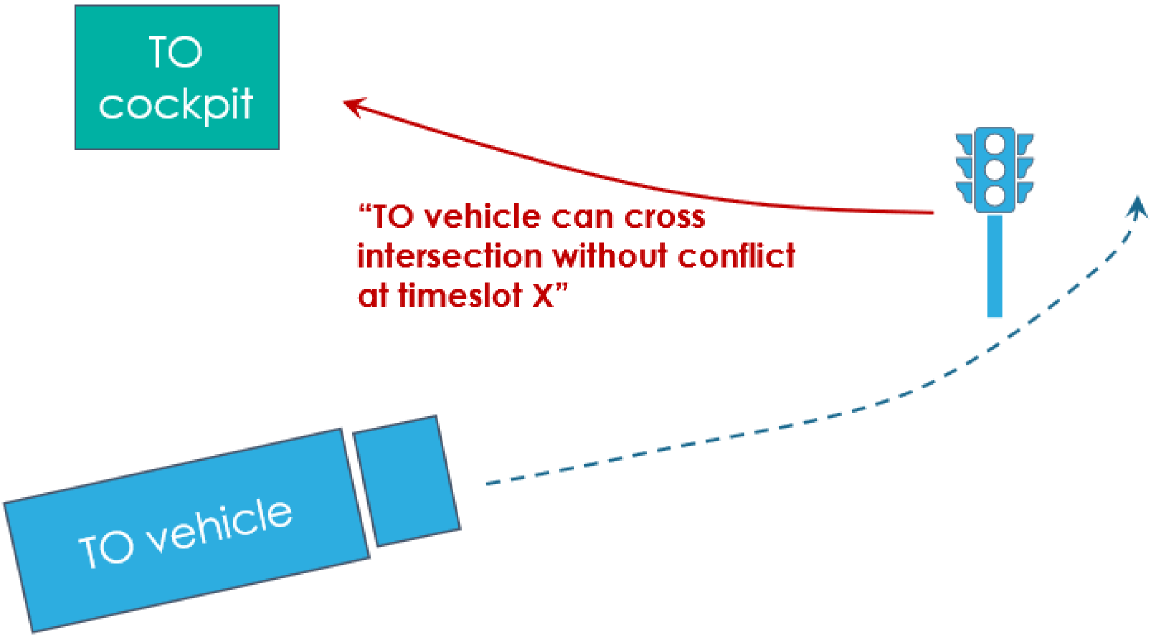

Figure 2: Schematic Overview of EF3

The function starts from a time slot request made by the EF1 provider (based on the position of the TOV and the route provided by the EF7 provider). When a TOV has an anticipated path that passes a intersection with intelligent TLCs within 2 minutes of the current position, the EF1 provider will share position, speed, heading and routing information from the TOV. 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 provider assigns time slots at the relevant intersections. The time slot reservation consists of at least the following:

- A start time
- An end time
- An intersection reference ID
- A vehicle ID
- A direction or signal group ID (the signal group being the collection of individual traffic lights who always receive the same signal across all red/green/orange phases of the TLC)

Once the time slot is assigned, the involved teleoperators are updated of the time slot via the EF1 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). The EF3 provider will check on a continuous basis whether the time slot can be made, that is, whether the speed necessary to make the time slot is below what is feasible (based on current traffic leading up to the intersection). If that is no longer the case, a new time slot will be assigned by the EF3 provider, based on position data at that time. The process repeats until the TOV (or the platoon) has safely cleared the intersection.

In order to guarantee low latency responses to requests and updates in time slot reservations, the traffic light controller application should ideally run as a close to the intersection as possible (on the edge).

5 EF4: DISTRIBUTED PERCEPTION

EF 4 (led by imec) will provide an **extended perceptive range** to the remote teleoperator for making the appropriate decisions.

5.1 Current State of the Art

Currently, remote teleoperation facilities rely on the sensors mounted on the vehicles for networked control. The main approach at the moment is to have a centralized location (remote control center) receiving the fused data from the vehicle being controlled, the data is then shared with the remote teleoperator for the control purposes. In the automotive industry, sensor fusion is used for a variety of applications, typically put under the denominator Advanced Driver Assistance Systems (ADAS). We can further classify ADAS applications, based on their intended use:

1. **Active Safety Sensors:** take active control of the vehicle (e.g. Electronic Stability Control). These systems extend the impact of the actions of a driver and reduce the negative effects of a slow human response.
2. **Cruising:** involves all features related to automated driving (e.g. lane keeping, auto chauffeur, adaptive cruise control, off-road cruise control, traffic jam assist)
3. **Manoeuvring:** all features related to assisting the driver (or taking over control) in confined spaces (e.g. automated parking)
4. **Vehicle Surrounding Sensors:** monitor the environment of the vehicle, supporting the driver in critical or dangerous situations (e.g. parking assist or lane change assistance)
5. **Human Machine Interfaces:** the basis for communication between humans and machines (e.g. visual information). Their main intent is increasing the level of comfort while driving and increasing safety by reducing distractions from road traffic.
6. **Safety Telematics Systems:** solutions for processing information via communication systems that enable V2V or V2X (e.g. navigation aids, traffic jan warnings, …). These applications are also aimed at increased comfort and safety.

In classical ADAS applications, sensor fusion is mostly based on internal vehicle data. When combined with external information ADAS can be further enhanced. The advent of connected driving brings sensor fusion technology one step further, paving the way towards distributed, collaborative intelligence, enabling applications such as collaborative adaptive cruise control, platooning, shared situational awareness (e.g., electronic horizon). In 5G-Blueprint, this will be used traffic hazard warnings furthermore, which will then be employed as an early warning system during the remote teleoperation.

5.2 Requirements for teleoperation

Remote teleoperation requires enhanced awareness on the part of the remote teleoperator mainly due to the reason that the driver in this case does not have direct view of the environment. On the contrary the operator uses the remote sensors to assess the operating environment. To increase the capacity of the remote teleoperator, dynamic situational awareness is highly significant. There is therefore a need for a dynamic view of the environment, ideally taking advantage of sensors mounted on other vehicles. This would solve the issue of reduced perception of the teleoperator.

In addition, there is a need for monitoring of the sensors mounted on the TOV, as malfunction could have significant negative consequences on operation in the absence of an on-board operator. Monitoring and graceful degradation systems should be put in place which provide a level of fault tolerance in the case of sensor and communication malfunction.

5.3 Description of the enabling function

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 remotely teleoperated truck 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.

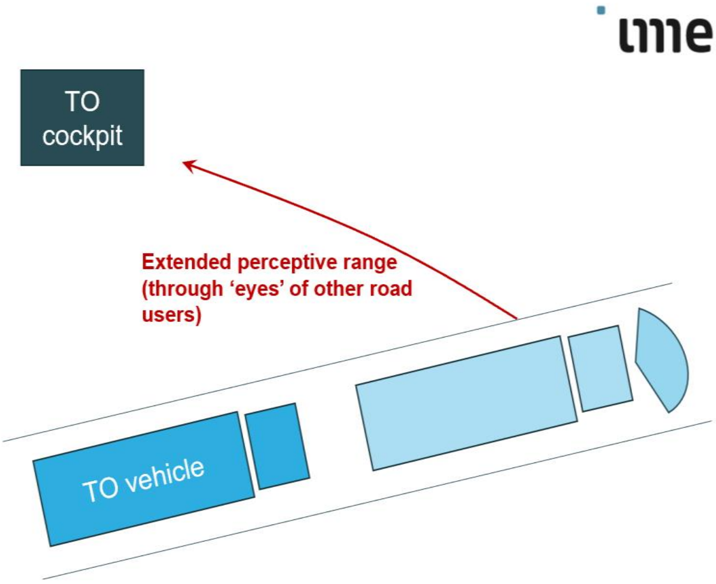

Figure 3: Schematic Overview of EF4

In addition, the EF also foresees in using the idea of graceful degradation with the shared situational awareness model that is envisioned. For this an early warning system will be provided to the remote teleoperator in the case of sensor malfunction. For example, by analysing the environmental context (e.g., weather, low visibility, ...) the reliability of certain driver assistance systems (lane keeping, etc.) can be assessed, providing insights into whether these systems are likely to fail. The insights can be used by the onboard control systems to determine whether these systems can be relied on for the vehicle to temporarily take over control from the remote teleoperator in case of momentary network interruptions or whether the vehicle should go into an emergency mode (e.g., slowing down, traffic indicators on). Data from multiple sources and sensors will be processed with reliability and quality in mind. Continuous predictions on these factors will be carried out in order to provide the relevant information to the teleoperators. By using this, the teleoperated trucks will have some sort of fault tolerance which is very useful in real life operations.

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. 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 e.g.: video and point cloud streams).

6 EF5: ACTIVE COLLISION AVOIDANCE

EF5 (led by Roboauto) provides safety measures to protect TOVs from colliding with other road users. An independent anti-collision add-on consisting of sensors (Radar, Lidar, Cameras) and a dedicated computing unit will be installed at the TOV. The functionality provided is essential for the safe deployment of teleoperation in a production environment.

6.1 Current State of the Art

Today's cars are equipped with multiple assistance systems whose purpose is to simplify driving a vehicle and minimize the risk of unreasonable harm.

Collision avoidance system (CAS) is sometimes referred to as a pre-crash system, forward-collision warning system, or collision mitigation system. We can find two basic variants in passenger vehicles. Both work on the same principle, monitoring the distance and sometimes speed of the leading vehicle and the instantaneous speed of the trailing vehicle. If the vehicles are too close, CAS will start the safety procedure. It can be a warning (in which case it is a passive system), or CAS activates emergency brakes (in which case it is an active approach). System implementations differ in the sensors. It most often uses radars, lidars, or stereo cameras.

The current trend is the increasing adoption of such systems. For example, in the European Union, the advanced Emergency Braking Systems and Lane Departure Warning Systems have been mandatory for heavy-duty vehicles since 2015.

An example of another critical assistance system is the lane keeping assistant (LKAS). LKAS unlike LDWS, actively aims to prevent unplanned lane departures. LKAS systems are the subject of constant research and development, especially concerning the reliability of lane detection.

Increasing demands on road safety show the need to use these systems also for vehicles equipped with teleoperation. Unfortunately, OEMs currently do not provide any official way to get access or interface with these systems. Moreover, there is a need to maintain a consistent HMI for the TOV operator across different vehicle types. These facts lead to a necessity to equip vehicles with third-party CAS technology compatible with the teleoperation solution, which is exactly the goal of EF5.

6.2 Requirements from teleoperation

Teleoperation can revolutionize worker mobility, has the potential to accelerate the deployment of autonomous vehicles, and should lead to increased safety for drivers and VRUs.

To harvest these benefits, it is necessary to thoroughly analyse and mitigate the risks associated with loss of connection.

A fatal situation can occur when the connection is lost or data transmission is significantly degraded. Another serious factor is the higher cognitive load and reduced situational awareness for the TOV operator. For these reasons, it is necessary to deploy assistance systems that compensate for it.

We can define following requirements for TOV.

- The TOV operator must be audibly warned of an imminent collision.
- The TOV operator sees the distance from the obstacle in the collision course.
- The TOV operator has a limited maximum speed according to the network (current latency, bandwidth) and environmental properties (weather conditions, traffic situation).
- The TOV must be able to maintain a minimum distance from the leading vehicle.
- The TOV must stop in the event of a loss of connection without colliding with the leading vehicle or VRU.

- The TOV may not leave the lane (“virtual track”) in case of a loss of connection.

6.3 Description of the enabling function

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.

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 oversteering at high speeds: the SGD will overrule the teleoperator’s steering commands in case it detects that the steering command is dangerous at current speeds. The SGD can hence be seen as the novel in-vehicle part of the ToD system that no longer only relays the commands from the remote operator to the vehicle drive-by-wire system (current state of the art), but now also interprets these commands, filters or improves them in case of safety concerns, or replaces them in a safe manner if the connectivity with the remote operator is lost.

The main safety features are:

- **Emergency braking in the event of a loss of connection**: 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.
- **Emergency lane keeping system (ELKS)** which can ensure that the vehicle remains in the lane (preplanned virtual track) in the event of a lost connection.

7 EF6: CONTAINER ID RECOGNITION

Enabling Function 6 (EF6, led by Sentors) provides the capability to identify shipping containers on video streams. There are two main reasons for introducing this function for teleoperation: allowing visual confirmation of the container ID without being physically present, and enabling efficiency and error reduction for visual confirmation through Augmented Reality.

7.1 Current State of the Art

Deepsea ports have been using container recognition systems for years in order to automatically register the arrival/departure of shipping containers, and to obtain images from potential damages to these containers. These systems rely on narrow gantries where the trucks pass through. The gantries are equipped with a multitude of cameras and lighting units from every corner. Some gantries also have a roof (canopy) in order to minimize the influence of adverse weather conditions. The container is filmed from every angle, and the resulting images are very similar in terms of lighting, distance and angle. This provides the ideal circumstances to robustly and reproducibly run image recognition software in order to register the container codes.

Besides these gantry systems, there are also software vendors on the market that offer Optical Character Recognition (OCR) that can be applied to shipping containers. In these cases, one or more camera systems are typically integrated at the truck gate. This requires a careful calibration since every installation is different.

The above systems are typically used at the outside interfaces of these ports: the truck gates and (in more recent years) the cranes. On the premises itself there are typically no other automated systems available. For example, the reach stacker driver that handles containers between the stacks and trucks, typically works from a planned list and has to manually search and enter the containers codes.

Note that such automated systems are typically deployed at seaports that handle thousands of containers per day. The scale of their operations can justify the investment in terms of infrastructure and services. The majority of smaller container ports, on the other hand, such as barge terminals and empty depots, are still relying on manual actions for container recognition used for validating the container and for damage reporting. In that situation, for example, the operator takes a photo by using his/her smartphone, or visually checks the container ID.

7.2 Requirements from teleoperation

As stated before, there are two main reasons to introduce a container ID recognition function for teleoperation.

First, visual confirmation of the container ID is still required

Teleoperation poses a particular challenge for portside activities where containers are handled. Validating that the correct container is handled can only be done visibly, as containers do not contain track & trace sensors. Also, the inspection for damages can only be done visually. As the teleoperator is no longer physically present, he/she is no longer able to visually identify the relevant container. Instead, the teleoperator will either have to perform the identification on the basis of the received camera images, which may be a difficult task, or rely on persons on the ground.

The need for visual confirmation may undermine the rationale and business case for teleoperation. Partly because visual confirmation on the basis of camera images requires additional time. But, more importantly, also because a container handling action typically marks a handover to another company in the supply chain, for example from a barge container terminal to a trucking company. A physical handover also means a hand-over in responsibility and accountability in terms of timely delivery and damages to the container and its goods. When the operator is not able to meet these current business practises, it would imply that the current handling and signing-off process would need adjustments as well. This potentially provides an additional barrier to the roll-out of teleoperated driving.

This enabling function offers an elegant solution to that challenge, in that it actively assists the teleoperator in identifying the container in real-time. This allows the teleoperator to focus on teleoperation itself, while avoiding the mistake of a wrong pick up or miss out on obvious damages.

Second, Augmented Reality would enable efficiency and error reduction for visual confirmation.

It is time-consuming and error-prone to manually write down and compare the BIC codes to the planned lists. This already holds true for current container handling operations, but even more if the teleoperator is not physically present. In particular, a teleoperator may handle various equipment at different sites quickly after each other, and even in parallel when some vehicles are parked and/or driving in autonomous mode.

This is where EF6 steps in, by providing automatic container identification that can be used to show the teleoperator an Augmented Reality overlay on the video stream. This way, relevant additional information from the planning can be presented to the teleoperator. This limits the handling time and reduces manual errors in checking a number of key elements, such as:

- whether the container is part of today's load/unload list
- destination address (customer) for this container
- owner of the container (shipping line)
- potential reported damages earlier in the chain

7.3 Description of the enabling function

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 appears on all visible angles at any shipping container, some examples are shown in the figure below.

<table>
<tr><td>Side

</td><td rowspan="2">Rear</td></tr>
<tr><td>Top

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

Figure 4: Illustration of a container's BIC

The recognized BIC code can 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.

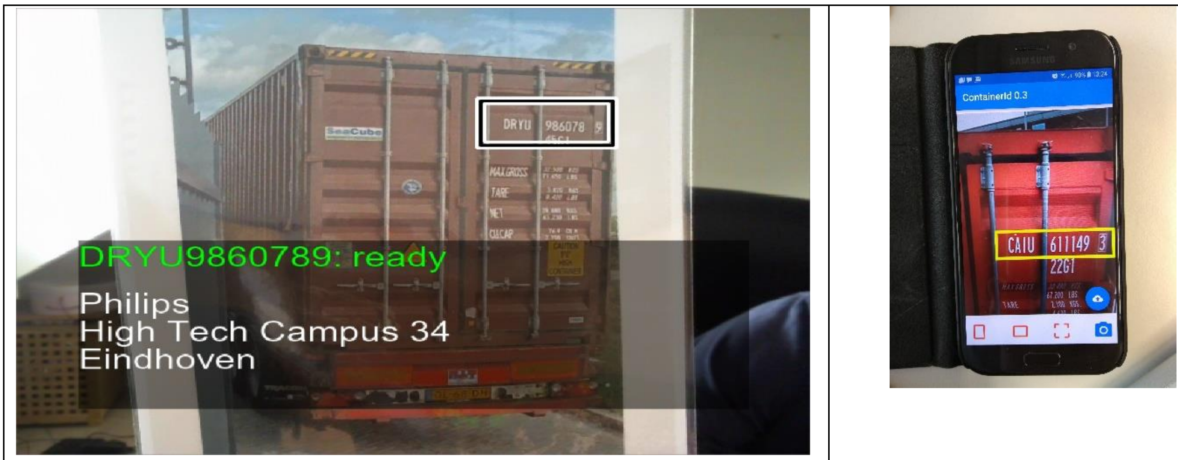

Figure 5: Illustration of container ID recognition

The container recognition software will be hosted on the platform used by the EF8 provider (the Nokia Scene Analytics Platform). The underlying image/video analysis takes a significant amount of processing power. By levering the low-latency and high bandwidth characteristics, 5G offers the ability to run deploy the processing “anywhere”. 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).

The video streams can come from various sources. During the course of the project the exact location will be determined. Relevant possibilities include camera's positioned:

- Near the port entry/exit gate that monitor the TOV
- Onboard the TOV itself
- Onboard a non-TOV vehicle on the port's premises, from which the camera stream is offered to the teleoperator. An example of such a vehicle could be a reach stacker, see the figure below.

The recognized BIC containers are pushed via a REST-based API to EF7 (ETA sharing) and the planning software. Eventually the results are presented via the EF1 Enhanced Awareness HMI that is shown to the teleoperator.

8 EF7: ETA SHARING

Enabling Function 7 (EF7, led by Be-Mobile) aims to provide real-time ETA to the teleoperator and other interested partners, routing information, as well as set up an exchange of data with terminal systems to dynamically organise the container pick-up or drop-off time at the terminal.

8.1 Current State of the Art

The estimation of travel times on the basis of routing algorithms and real-time traffic data is by now well-established. However, these systems are, at present, not properly integrated with other relevant sources of data specific to the teleoperated transport (or other types of “special transport”). For example, to estimate the travel time over a particular intersection, the algorithm will take the average travel time over that intersection for all road users (or focusing on one particular well-identified group such as trucks); it does not take into account that the TOV may have a time slot within which it can pass the intersection uninterrupted. Similarly, the ETA will stop at the terminal entrance, without accounting for potential waiting times at that entrance.

The ETA EF solution which will be developed in this project will be more sophisticated in that it will take on board all data relevant to the estimation.

In addition, current fleet management tools (of which ETA calculation is a part) are still far off from being integrated into the IT systems used by terminals. Important synergies between these fleet management tools and terminal IT systems therefore remain underdeveloped.

8.2 Requirements from teleoperation

Teleoperated transport presents a compelling business case by which logistic cost savings can be made via a more efficient deployment of the operator. At several points during the transport, on-board operators face unnecessary waiting times (for example at terminal gates, or on buffer parkings). Teleoperation would make it possible for the operator to be assigned to a different transport. If the waiting time is over, another teleoperator can be assigned to the transport (this could, for example, be someone who has specific accreditation to drive TOV’s on terminal premises).

In order for this business case to materialize, precise information needs to be available on (i) the ETA of the teleoperated transport at key points (such as the buffer parking, terminal entry, or the container pick-up or drop-off spot in the terminal); and on (ii) when (and where) the container can be picked up or dropped off. This would enable the teleoperation planner to dynamically schedule in teleoperators, while maintaining the efficient flow of the transport operation.

8.3 Description of the enabling function

EF7 foresees in providing at least two (and likely three) basic functionalities which will allow planners to dynamically schedule in teleoperators.

First, 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. This ETA will be based on the fastest route from the current position of the TOV to the point of destination, 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. 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). The ETA will take into account when the TOV is due to pass via the intersection.
- Relevant information from EF8. If EF8 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, the function foresees 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 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.

Third, it may also be possible to connect EF7 with more advanced terminal systems (such as the Terminal Operating System). This may make it possible to provide "private yard navigation" services, where the teleoperator is not only shown the route towards the terminal entry, but also receives turn-by-turn navigation on the port premises. The chosen route, and corresponding ETA, to the particular pick-up point, may then also be determined by feedback from other enabling functions (e.g. anomalies detected on port premises).

9 EF8: SCENE ANALYTICS

Enabling Function 8 (EF8, led by Room40) foresees in a continuous monitoring of several key areas relevant to teleoperation in the transport and logistic context, making teleoperation safer and more efficient (in avoiding unnecessary operator waiting times, and reducing travel times).

9.1 Current State of the Art

The Internet of Things (IoT) is transforming how businesses operate—whether it's offering new services, enabling new business models, providing a safer environment, optimizing Industry 4.0, providing insights, or making decisions on behalf of people. Network-connected cameras are one of the largest producers of IoT data, and they have the potential to be one of the most insightful – if we can extract analytics about the scenes the cameras are supervising. Furthermore, as the cost of the cameras goes down, their ubiquity goes up—and prioritizing which scenes/events are needed for human review is a big challenge.

This is precisely the challenge that needs to be addressed. Computer vision (CV) technology and machine learning (ML) techniques should determine scenes of interest and produce metadata about what the cameras are monitoring. Some of these algorithms work in real time to provide situational intelligence to a scene. Some of the algorithms work periodically to provide business intelligence. A centralised design increases the amount of time users spend looking at live streams.

Current systems provide the following functionalities:

- Video management systems (VMS) manage cameras, record footage and/or view video streams.
- Traditional security video analytics vendors (some of this software is embedded within the cameras themselves) have a set of standard security and surveillance algorithms focused solely on campus security scenes.
- Most emerging video analytics capabilities are coming from public cloud suppliers. They have released tools and building blocks for a customized video analytics solution. However, these building blocks require an enterprise to build the solution themselves.
- Reduced flexibility to the deployment of the video analytics processing.
- Lack of a flexible environment to add more streaming algorithms based on industry need without creating an entire video analytics application.
- Not possible to enable "sensor fusion" whereby other IoT sensors can trigger video events, and scene metadata can be combined to perform higher-level analytics. Currently the combination of sound sensors and video camera's is just starting to become a valuable solution.

The philosophy behind EF8 is that IP cameras and sound sensors are really intelligent IoT sensors, which can derive complex context through anomaly detection on the video and audio streams. They are not just viewing windows into the physical world — which has been the focus of the current state of the art.

9.2 Requirements from teleoperation

Teleoperation will require support for tasks related to the transport that would normally require a physical presence of the operator (or other on-the-ground crew). Examples of such tasks include the pre- or post-trip inspection of the truck, monitoring of the safety of the truck when parked. In order to preserve the business case for teleoperation, functions will have to be developed which can take over these tasks, further eliminating the need for an operator to be physically present in the vehicle.

Other requirements mentioned for previous enabling functions also apply: situational awareness will have to be enhanced to make transport safer and more efficient.

9.3 Description of the enabling function

As expressed above, EF8 foresees in a continuous monitoring of several key areas relevant to teleoperation in the transport and logistic context, 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. The processing will be executed by edge computing, that's why the data fusion does not happen in the TO centre itself. The used data sources are:

- CCTV camera's
- 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 amount 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 certain anomalies that are not related to the trucks..

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 EF1 provider and included in the enhanced awareness dashboard provided to the WP4 Partner Roboauto, who control the displays to show in the TOV centre.

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 as the project progresses.

10 CONCLUSION

This document provided a non-technical description of the eight enabling functions that will be developed and validated within Work Package 6 (WP6) of the 5G Blueprint project. These descriptions serve as a starting point for the reader to understand the basic functionalities of these enabling functions and how they can add value to teleoperation (i.e. how they “enable” teleoperation).

The document will serve as the basis for subsequent technical deliverables, explaining in more detail the functional and technical architecture behind these enabling functions, as well as how these enabling functions will be integrated into the Work Package 4 use-cases.