Enabling cross-border tele-operated transport in the 5G Era: The 5G Blueprint approach

*Johann Marquez-Barja, *Seilendria A. Hadiwardoyo, *Vasilis Maglogiannis, *Dries Naudts, *Ingrid Moerman, *Peter Hellinckx, *Sofie Verbrugge, *Simon Delaere, †Wim Vandenberghe, ‡Eric Kenis, §Maria Chiara Campodonico, ¶Rakshith Kusumakar, ‖Job Meines, **Joost Vandenbossche

* *imec, University of Antwerp, Ghent University, Free University of Brussels*, Belgium

† *Ministerie van Infrastructuur en Waterstaat*, The Netherlands,

‡ *Departement Mobiliteit en Openbare Werken*, Belgium

§ *Martel Innovate*, Switzerland

¶ *V-Tron*, The Netherlands

‖ *KPN*, The Netherlands

** *Be-Mobile*, Belgium

***Abstract*—5G systems promise to enable autonomous vehicles by empowering road-, water-, and air-vehicles with ultra low latency communications and computing at edge in order to share and process data from multiple sensors. However, in order to realize such fully Connected and Automated Mobility (CAM) for cars, drones and vessels, a crucial intermediary step must be fully achieved: 5G-based tele-operated transport. In order to do so, the European project H2020 5G-Blueprint aims to design, test, and validate in real deployments a 5G-enabled tele-operated transport and its enabling functions in both a relevant and operational environment realised through cross-border trials on the road and on the water along 5G corridors in the Dutch and Belgian border area, resulting in a blueprint for future cooperation on 5G-enabled CAM between public, private and semi-private parties (e.g. ports), gaining new and innovative insights on the stringent particular requirements for safe CAM, on the architecture, on governance and relevant business models.**

***Index Terms*—tele-operated transport, 5G connectivity, logistics, vehicular communications**

I. Introduction

The transport sector in Belgium and the Netherlands currently faces a significant labour market shortage, with demand for truck drivers growing strongly in the last few years, while supply has not followed suit. In the Netherlands there were 4,900 job vacancies for truck drivers in Q1 of 2019 which did not get filled [1]. On average 41% of the Dutch transport companies indicate that shortage of labour market hinders the growth of their economic activities [2]. And in Belgium, similar shortages can be identified: according to Philippe Degraef, director of Febetra (federation of transporters), there were 6,000 truck driver vacancies ready to be filled in [3].

There is a clear need to find solutions in the short to medium run to help the sector overcome this structural personnel challenge. Measures to increase the attractiveness of the trucking (and shipping) profession would be warmly welcomed and would have a high business value.

Tele-operated trucks (and barges) constitute a solution to alleviate the shortage in professional truck drivers (and shippers) to a large extent in the short to medium run. On the supply side, driving a truck would become an innovative office job with employees acquiring new skills and working in shifts on the same truck. This would greatly increase attractiveness of the profession. Tele-operated trucks (and barges) will reduce shortage in unfilled vacancies, by making the profession more attractive due to a better work-life balance, and by keeping the number of drivers (and skippers) needed stable in case of increased economic activities due to more efficient use of their valuable time. Safety poses less of an issue for tele-operated driving (relative to L4/L5 automated driving) as it is guaranteed by a human that is still in control.

5G Blueprint[1] is an EU funded project with the aim to design and to validate a technical architecture, business and governance models for uninterrupted cross-border tele-operated transport based on 5G connectivity. The project's outcome should be usable as the blueprint for subsequent operational pan-European deployment of tele-operated transport solutions in the logistics sector and beyond. The objectives can be further broken down into technical, business, and regulatory objectives.

The main goal of this project is on the technical side to tailor and to implement the prototype of a tele-operated transport system. To do this, we will design and implement a 5G network for Connected and Automated Mobility (CAM) services. Since one of the goal is also to guarantee the safety of this system, we will implement the enabling functions to it. Finally, the proposed solution of having end-to-end tele-operated transport in real life scenario, including the cross-border conditions will be validated.

On the business side, the project aims to do a market analysis of 5G tele-operated transport, along with exploring the commercial possibilities. For that, we will analyze the position of possible role of tele-operated transport based on 5G. Then, we can investigate the market adoption. To further cope up with the regulations, this project will identify the regulatory issues regarding the deployment of cross-border tele-operated transport based on 5G connectivity, and identify recommended actions.

[1] http://www.5gblueprint.eu

The outcome of 5G Blueprint project, along with its technical demonstration and validation will be used as an input for profound analysis and definition of governance and business models. As such, the project will provide a blueprint for future cooperation on 5G-enabled CAM between public, private and semi-private parties (e.g. ports), gaining new and innovative insights on the very particular requirements for safe CAM, on the architecture, on governance and relevant business models.

II. 5G Blueprint Approach

Over the past years, several demonstrations, trials, and pilots of CAM use cases have been developed and executed. Vehicle-To-Everything (V2X) connectivity was typically foreseen by the incumbent ITS-G5 technology or existing mobile networks (4G/4G+) for connectivity purposes. Lately also Cellular Vehicle-To-Everything (CV2X) PC5 direct communication is being tested in trials in Europe as part of CONCORDA[2]. More recently, some CAM trials are being prepared using 5G network technology, as part of several H2020 projects, such as 5GCarmen[3], 5G-Mobix[4], 5GCroco[5], targeting higher level of automation of vehicles in cross border environments using 5G technology to meet the stringent requirements.

The overall concept of 5G Blueprint is to demonstrate and validate 5G-enabled tele-operated (i.e. remote-controlled) transport and its enabling functions in both a relevant and operational environment (TRL6 and TRL7), realised through (cross-border) trials on the road and on the water along 5G corridors in the Dutch and Belgian border area. We consider tele-operated transport (keeping the driver or shipper responsible for the control of the vehicle/barge but taking him/her physically out of the vehicle/barge) crucial as an intermediary step towards fully connected and automated mobility, constituting an innovative, but at the same time pragmatic, approach in relation to the classical evolution from L1 to L5 autonomous driving. The deployment of tele-operated transport (and additional innovations demonstrated in this proposal such as Cooperative Adaptive Cruise Control (CACC) and infrastructure-based docking) would already allow to realize the highest business value linked to CAM, i.e. a reduction in the number of drivers/shippers required per transport movement, while circumventing the need to address all corner cases in the absence of a human in charge which currently delays successful roll-out of L4/L5 autonomous driving. Tele-operated transport, its enabling functions and the resulting business opportunities are not possible without the use of low-latency, highly reliably, highly secure, high-bandwidth communication which only 5G can offer.

A. Use-cases

5G Blueprint will explore the following use cases:

- Automated Barge Control.
- Automated driver-in-loop docking functionality.

[2]https://ertico.com/concorda/
[3]https://5gcarmen.eu/
[4]https://www.5g-mobix.com/
[5]https://5gcroco.eu/

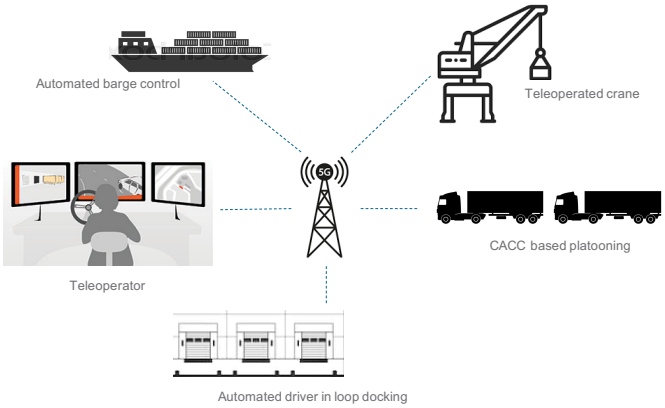

Fig. 1. 5G Blueprint Use Cases

- CACC based platooning.
- Remote take-over operations.

At the core of the project, there are two tele-operation use-cases (TRL7), on the road and on the water respectively. In the first use-case, yard truck and road-going vehicles will be equipped for remote-controlled operation, which is to be tested in a port environment as well as on sections of public road. In the second use-case, remote- controlled operations will be tested on a barge. On top of these use-cases additional CAM functionalities are developed with the aim to further increase efficiency of the teleoperators, (i) automated docking functionality in the port along with a tele-operable mobile harbour crane (TRL7); and (ii) CACC-based platooning (TRL7). Figure 1 illustrates the use cases. Moreover, these use cases will be validated and tested within the three different pilot sites for the 5G Blueprint project, such locations are strategic logistic-related sites located in Belgium and The Netherlands as can be observed in Figure 2.

B. Enabling functions

Safety is a critical enabler for the tele-operation of road vehicles, as the tele-operator must cope with the difficulty of perceiving his surroundings. Removing the driver from the vehicle or vessel has two important consequences which should be addressed to ensure a safe and smooth operation.

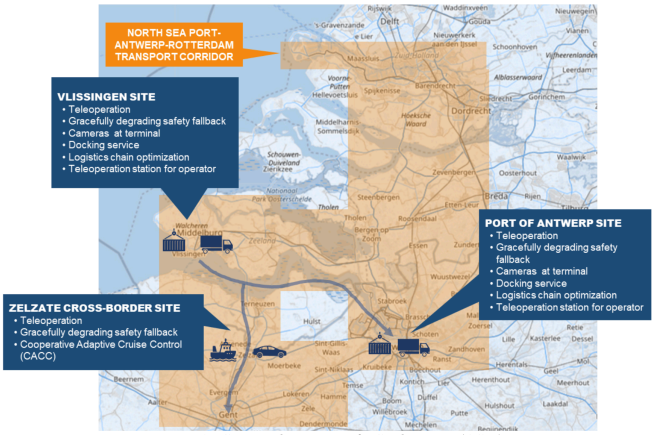

Fig. 2. Pilot sites

First, the situational awareness of the tele-operator is likely reduced relative to that of an on-board driver due to the lack of perception of acceleration and vehicle tilt. Visual information conveyed by cameras may lack depth and sharpness and the camera system may create image distortion, such that it does not perfectly capture the combination of sensory perceptions of a driver on the road. The main challenge, therefore, is to find an adequate replacement for lost sensory perceptions, primarily through appropriate visual and sound augmentation. Second, as no driver is physically present (except as a fallback in the context of the pilot) interaction between the driver and other road users (e.g. eye contact) is hindered.

Some Enabling Functions that will be added to support the use cases are as follows:

- Enhanced awareness Human Machine Interface (HMI).
- Vulnerable Road User (VRU) interaction.
- Time slot reservation at intersection.
- Distributed perception.
- Active collision avoidance.
- Container ID Recognition.
- Estimated Time of Arrival (ETA) sharing.
- Logistic chain optimization.

C. 5G Connectivity

Within 5G Blueprint, we want to exceed the limits of current 5G roll-outs, by implementing, deploying and evaluating the newest 5G features as enablers towards a full ecosystem for highly advanced CAM use cases, such as tele-operated operation of vehicles and vessels. Cross border challenges will be tackled in terms of 5G network design and implementation on the field to reduce outage time when performing handovers between Mobile Network Operator (MNO) networks across the border, continuously fulfilling the service requirements. 5G-NR CV2X Release 16 will play an important role in realizing the challenging requirements of advanced CAM use cases. 3GPP Release 16 is still under development and it is expected to be frozen by the first quarter of 2020.

3GPP Release 16 targets enhancements of the 5G features that have been standardized in 3GPP Release 15 and expansion of 5G with new features. Release 16 aims to provide higher throughput, higher reliability, lower latency and wideband ranging and positioning for enabling autonomous driving use cases, using 5G-NR CV2X both long- and short-range communication. Hence, based on the scalable OFDM-based air interface, 5G-NR CV2X is expected to efficiently use diverse spectrum bands for different use cases, leveraging wideband carrier support to deliver higher data rates. The self-contained slot structure with immediate feedback allows ultra-reliable low latency communications. Additionally, advanced 5G channel coding target to enhance the reliability of CV2X system, while larger number of antennas aim to deliver higher data rate and increase the communication range.

The Release 16 features above combined with other 3GPP features such as network slicing, Multi-access Edge Computing (MEC), Network function virtualization (NFV), Service Based Architecture (SBA) will be considered for the 5G Blueprint network architecture for the realization of the defined use cases. The designed 5G network will be evaluated in realistic conditions at the different trial locations. This will result in well-defined recommendations towards MNOs and other stakeholders in the ecosystem to support these contemporary challenging use cases.

As 5G-NR CV2X supports both long- and short-range communication, 5G Blueprint will examine whether hybrid communication can be used to enhance specific CAM use cases. Furthermore, regarding the short-range communication, coexistence between CV2X (PC5) and the other ITS system, namely ITS-G5 will be studied. Finally, the use of public/private fiber infrastructure in a 5G landscape will be technically investigated, targeting the reduce of deployment and operational costs of 5G networks.

D. Business and Governance models

An important part of the project will focus on developing a blueprint for future 5G-enabled CAM business cases, by identifying workable business and governance models. Many stakeholders from many different backgrounds (private, public, semi-public) will be part of the CAM ecosystem and it is important to proactively identify the ways in which they can cooperate and compete within the ecosystem so as to generate the intended beneficial effects of CAM (and tele-operated transport in particular) for everyone involved (public authorities, port authorities, data providers, service providers, logistic companies and road users).

A business model analysis will therefore be carried out, assessing questions related to the control and distribution of the assets and rents within the ecosystem, the interoperability of different vendor solutions, the distribution of computing power and data, the value proposition offered to prospective customers and the revenue models associated with each model. The analysis will be techno-economic in nature, measuring the associated economic costs, benefits and allocation models for the different architectures, business cases and stakeholders. Additionally, a value network analysis will help understand the roles and responsibilities of different public and private stakeholders, also plotting the flow of goods, information and money between the actors. The analyses will put particular focus on specific challenges involved in the studied settings: for instance, cross-border CAM services along the Flemish-Dutch corridor will most likely require the involvement of multiple mobile network operators, raising the issue of seamless cross-border roaming obligations and agreements.

Further, governance strategies will be researched. Governance will be needed to assure the necessary roles and responsibilities are filled and stakeholder coordination is sustained. Based on these analyses, the project aims to provide recommendations on optimal business and governance models for different organizational and policy goals, including strategies in line with the Connecting Europe Facility (CEF) vision and towards implementation of the selected use cases.

III. Discussion

As a result of the 5G Blueprint activities, there will be a clear hands-on understanding of the technical feasibility of an international tele-operated transport solution based on 5G connectivity. Similarly, it will be made clear what the best business model and governance model would be for deploying this concept on a large scale across Europe. Insights that will be broadly disseminated, and hence will reach beyond the borders of the involved project consortium. If this project will be able to make clear that the paradigm of taking the human driver out of the vehicle while not yet replacing it by a machine is feasible from a technical, business and governance perspective, then it will have delivered the blueprint that enables the adoption of an approach towards Connected and Automated Mobility which has an evolutionary instead of a revolutionary nature. The results of this project will hence pave the way for a more realistic and hence feasible transition towards automated mobility, by leveraging on the connected part first, and only in a second phase gradually increasing the automation capabilities of the vehicle itself. This way, benefits of CAM can become a reality in the European Union on a short to medium term, despite the current trend to shift timelines for the market release of L4/L5 autonomous vehicles on public roads more and more into the future.

5G Blueprint will actively liaise with the 5G Infrastructure Public Private Partnership (5GPPP) from the onset of the project. The project stakeholders will assure that the 5G PPP community will be made aware and kept up to date on 5G Blueprints pilot setup and progress, pilot results are presented to the 5G PPP community, and learnings from CAM governance and business models are shared with the 5G PPP community.

Standards are an essential foundation for improving interoperability at a European and worldwide scale. In the design phase compliance with existing standards will be investigated and assured during the integration work, safeguarding maximum interoperability and portability of the implemented solutions. 5G Blueprint will focus on the deployment of 5G CAM solutions and enabling functions. It is expected that this will provide important learnings and elaborations for existing standards, not only from a technical viewpoint, but also in terms of business models and governance. CAM governance and business models will provide insights and recommendations from industry experts on the business and governance aspects of the existing standards. In addition, during the integration, this project will provide technical learnings, elaborations and improvements concerning the existing standards. Active involvement of relevant industry experts in the relevant standardisation bodies, platforms and forums will be organised. A non-exhaustive list of examples is: NEN, NBN, CEN, ISO, ETSI, 5GAA, AECC, TISA, etc.

Remote driving of vehicles provides inherently more road safety. Because tele-operators can work in shifts with predictable working hours, they are less susceptible to driver fatigue. Also, the enabling functions implemented to support tele-operators can also be used to enhance the forward and VRU awareness functions for drivers of non-tele-operated vehicles, thereby contributing to road safety in particular in urban areas. Tele-operators are also safe from road crimes such as robbery and sexual assault, and remotely operated vehicles cannot be hijacked. Therefor tele-operation increases the safety of the driver.

Social inclusion is another important aspect. The regular working hours, option to work part-time and increased safety of teleoperators will make these jobs more alluring to women and can hence contribute to the closing of the gender gap in road as well as inland water transport. As discussed in section 1.3.1, in Europe, only 2% of employed truckers are female. Tele-operation also opens trucking and sailing jobs to people with certain physical disabilities.

IV. Conclusions

5G Blueprint project will result in a clear hands-on understanding of the technical feasibility of an international tele-operated transport solution based on 5G connectivity. Similarly, it will be made clear what the best business model and governance model would be for deploying this concept on a large scale across Europe. If this project will be able to make clear that the paradigm of taking the human driver out of the vehicle while not yet replacing it by a machine is feasible from a technical, business and governance perspective, then it will have delivered the blueprint that enables the adoption of an approach towards Connected and Automated Mobility which has an evolutionary instead of a revolutionary nature. The results of this project will hence pave the way for a more realistic and hence feasible transition towards automated mobility, by leveraging on the connected part first, and only in a second phase gradually increasing the automation capabilities of the vehicle itself. This way, benefits of CAM can become a reality in the European Union on a short to medium term, despite the current trend to shift timelines for the market release of L4/L5 autonomous vehicles on public roads more and more into the future.

V. Acknowledgments

This work was carried out with the support of the 5G-Blueprint project, funded by the European Commission through the Horizon 2020 programme under agreement No. 952189. The views expressed are those of the authors and do not necessarily represent the project. The Commission is not liable for any use that may be made of any of the information contained therein.

References

[1] Sector institute Transport & Logistics. (2019) Ontwikkeling arbeidsmarkt transport & logistiek. [Online]. Available: https://www.stlwerkt.nl/Media/media/Corporate/Over%20ons/Sectormonitor-transport-en-logistiek-2019-Q2.pdf

[2] Logistiek.nl. (2019) Arbeidsmarkt transport en logistiek blijft onverminderd krap. [Online]. Available: https://www.logistiek.nl/carriere-mensen/nieuws/2019/09/arbeidsmarkt-transport-en-logistiek-blijft-onverminderd-krap-101169571

[3] Febetra. (2019) Febetra annual report. [Online]. Available: https://www.demorgen.be/nieuws/negatief-imago-speelt- transportsector-parten bf58bab6/