5G BLUEPRINT

Enabling Functions

5gblueprint.eu

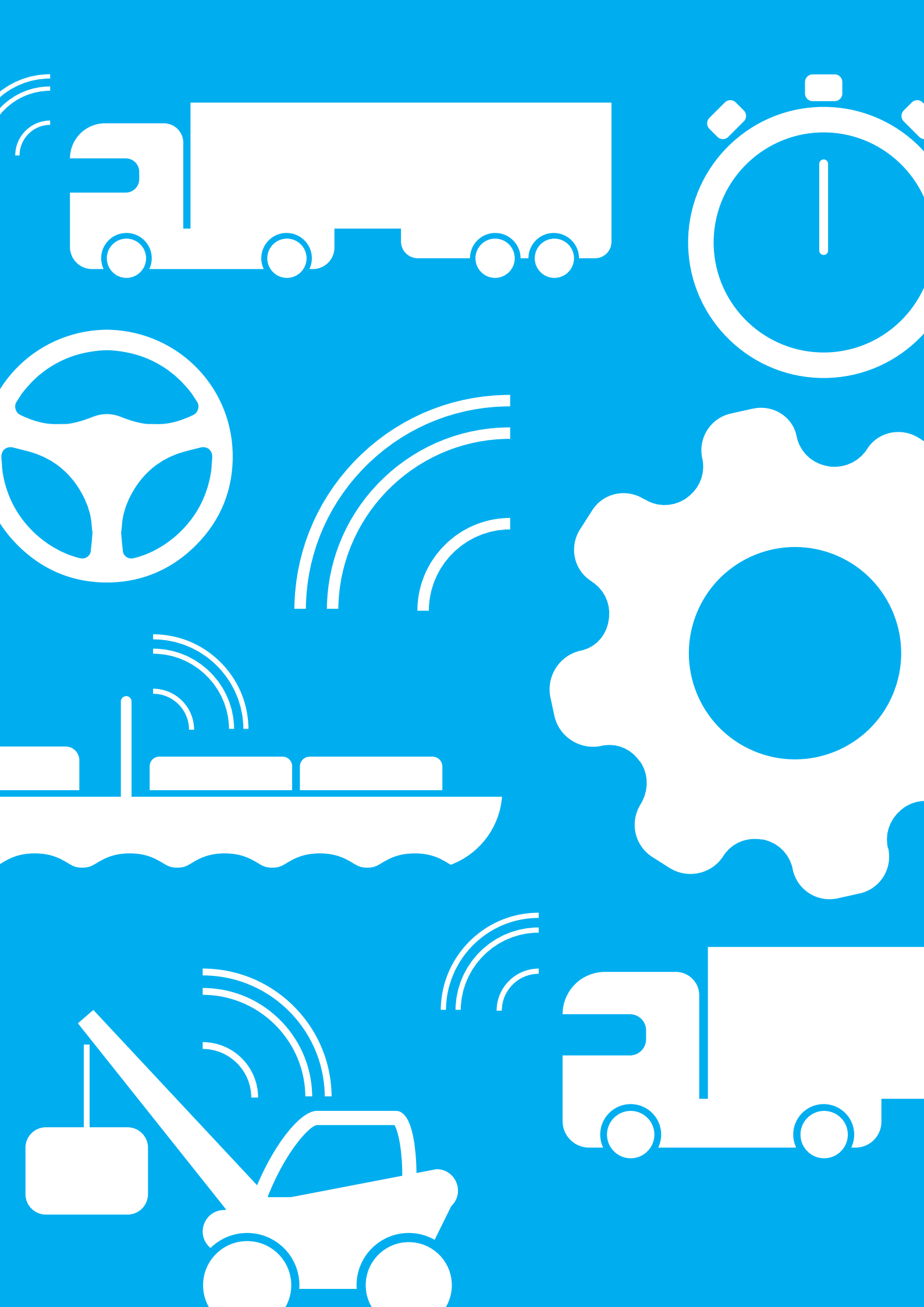


Table of Contents

ENABLING FUNCTIONS

5G-Blueprint designed and implemented the enablers to ensure the safety and efficiency of teleoperated transport.

EF1 Enhanced Awareness Dashboard

TELEOPERATION COCKPIT

Dashboard offering real time navigation and routing features, speed advise and instant safety alerts for teleoperators

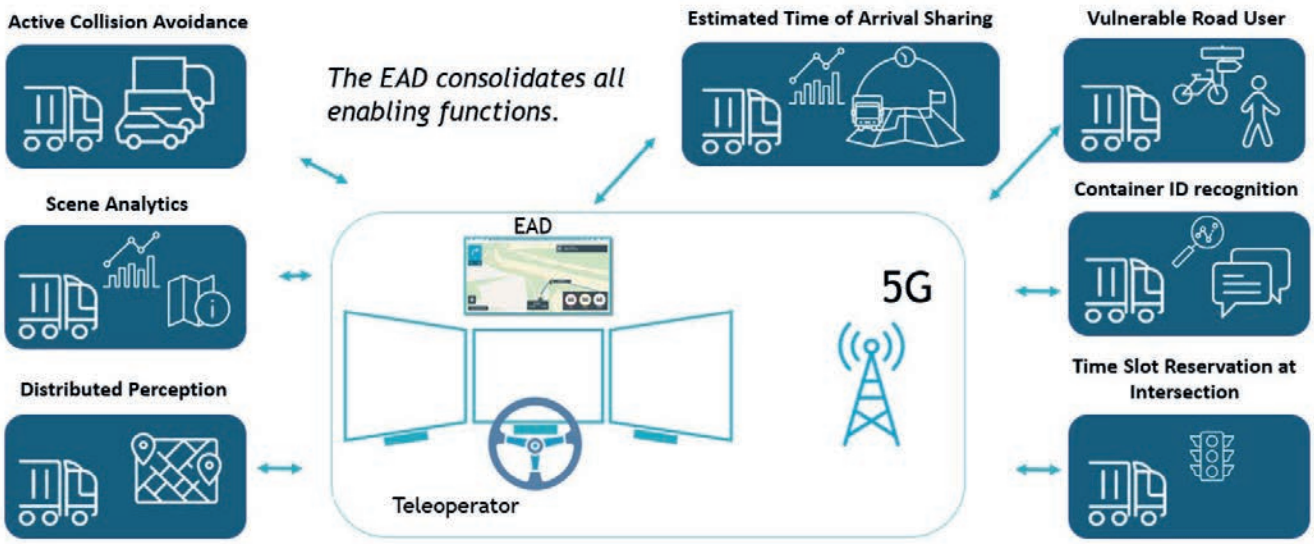
Context

Removing the driver from the vehicle can reduce the teleoperator's situational awareness. Cameras may not provide the same depth and clarity as human vision and can introduce distortion. The aim is to enhance the teleoperator's awareness by providing a dashboard with safety warnings, speed advice and navigation and routing features.

5G-Blueprint partners, led by Be-Mobile, have developed interfaces, APIs, and widgets to integrate Enabling Functions (EFs) into the **Enhanced Awareness Dashboard** (EAD - EF1). This EAD provides a consolidated view of instant safety messages, alongside routing services, including navigation, speed advice, and **Estimated Time of Arrival** (ETA) Sharing (EF7). In this way, the EAD provides the teleoperator with clear and concise information during the journey, enhancing situational awareness on the road and waterway (incl. the shipyard), without overwhelming them with information.

Three innovative back-end modules of Be-Mobile are extended to build 5G Safety Services: Cooperative Intelligent Transport Systems (C-ITS) Geomessaging Platform - enabling connected drivers to receive real-time personalised traffic information based on their geolocation; C-ITS Traffic Light Platform - enabling vehicles and roadside infrastructure, including traffic lights, to communicate with each other over the mobile network; and Route Guidance Platform - identifying the best route taking into account real-time traffic information and road network conditions.

Four safety services are provided to the EAD: (1) **Vulnerable Road User** (VRU) **Interaction** (EF2), which alerts the teleoperator to the predicted paths of pedestrians and cyclists and potential collision locations; (2) **Distributed Perception** (EF4), which provides the teleoperator with an extended range of perception by using sensors from other road users or roadside infrastructure to increase awareness of potential hazards; (3) **Time Slot Reservation at Intersections** (EF3), which allows the teleoperated vehicle to pass safely at traffic lights by providing clearance at specific times; and (4) **Scene Analysis** (EF8), which optimises the logistics of automated guided vehicles, including buffer parking and route terminal optimisation. **Active Collision Avoidance** (EF5), another immediate safety alert, is offered directly to the teleoperator's cockpit. Finally, **Container ID Recognition** (EF6) is a business service offered on the EAD.



Integration of all Enabling Functions into the Enhanced Awareness Dashboard

Results

The Key Performance Indicator (KPI) measurements for the EAD were collected during both laboratory and field testing, as well as through surveys. These metrics encompass factors such as the instant availability of route information, safety and support functions (e.g., real-time display of VRU information, including predicted paths and potential collision risks, feedback on priority requests, object detection, container identification, and scene details). The EAD met its target by achieving a 100% display efficiency. The KPI measurements related to speed advice and warning integration also successfully met the specified display latency target of less than 1 second. These measurements were derived from a comprehensive analysis of metrics and tracing data on the road. In addition, the integrated yard map view and information related to path, estimated time of arrival, and tracking error information were successfully tested to support automated docking.

In terms of communication technology, it can be concluded that both 5G NSA and SA outperformed 4G, ensuring highly accurate and timely information, while 4G was sufficient but at lower performance. Consequently, 5G received higher ratings for the impact and usefulness of the Enabling Functions compared to 4G, suggesting a more positive user experience and a better perception of the technology's value. Accuracy was also rated higher for 5G technology, particularly for 5G SA, indicating better reliability and precision compared to 4G.

Partners involved

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EF2 Vulnerable Road User (VRU) Interaction

Collision warning for teleoperators and vulnerable road users

Context

To safely teleoperate vehicles on public roads and yards the teleoperator should be made aware of potential traffic conflicts with other road users. In particular, the interaction with Vulnerable Road Users (VRUs) such as pedestrians and cyclists in urban and industrial areas requires extra attention, as VRUs may be obscured by buildings, stationary vehicles, etc.

If road users could predict the path they are about to follow and share this information digitally with other road users in their vicinity continuously, imminent collision risks could be identified and warned. This requires mobile networks that enable large numbers of small data packets to exchange in real time and remain reliable.

Through network slicing, 5G will make this possible. As part of the 5G-Blueprint project, Locatienet trialled a service that demonstrates how 5G can be used to warn VRUs of approaching TOVs and to warn teleoperators of VRU crossing the path of their teleoperated vehicle.

Results

VectorDrive solution:

- Lightning-fast smartphone app, every second:
  - Prediction of possible paths using local map topology in the handset
  - Selection of most likely path
  - Publication on the exchange service
  - Collection of nearby paths and detection of path conflicts
- Warns VRU through haptic, audio and visual cues
- Message exchange compliant with EU standards for connected traffic
- Runs on any Android 5G handset
- Exchange service can be deployed in the network Edge

Trials showed:

- URLLC slice suitable for safety critical services
- Service is safe to operate in industrial areas and urban areas with good 5G cell coverage
  - Service continuity 99.9%
  - Message throughput: 97% (city) to 99.0% (port area)
  - Round-trip latency: 242ms (city) to 167 ms (port area)

Partners involved

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locatienet

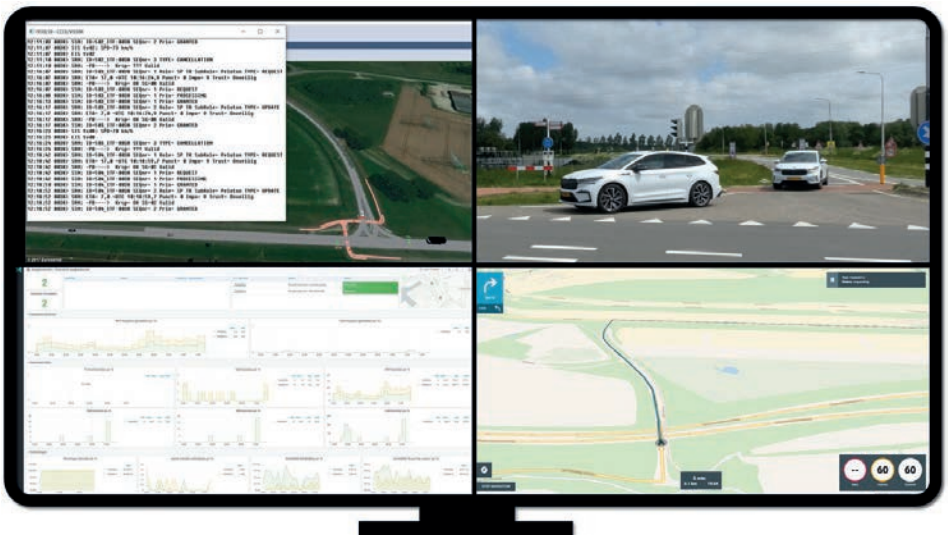
EF3 Time Slot Reservation at Intersections

Conflict-less and safe crossing of intersections for truck platoons without stopping

Context

EF3 Time Slot Reservation ensures conflict-free crossing of intersections equipped with intelligent traffic lights for TeleOperated Vehicles (TOV) by reserving a time slot for a "green-lighted" passage. This reduces the likelihood of collisions at intersections and ensures smooth navigation through the intersection. This is particularly important for truck platoons, as the guarantee of passing through an intersection without stopping not only reduces time, but also fuel consumption, while increasing the likelihood of the platoon remaining intact. It also makes intersections more predictable and manageable for the teleoperator, who knows in advance that the TOV will have a green light to pass.

TOVs can request and reserve a time slot using C-ITS messages. During the reserved time slot, a platoon of TOVs is guaranteed a green light. The teleoperator can monitor the status of the request through the Enhanced Awareness Dashboard (EF1) and receive speed advice (EF7) as the TOV approaches the intersection.



Two platooning vehicles seamlessly crossing an intersection in Vlissingen (RT) using EAD (RB), monitoring logging of the traffic light (LT) and C-ITS connection point (UDAP) (LB)

Results

The Time Slot Reservation function has been successfully demonstrated on multiple runs of vehicles passing through traffic lights. These lights were equipped with the adapted C-ITS use case for intersection priority requests using the Signal Request Message (SREM) and the Signal Status Message (SSEM). Finally, the performance of 4G versus 5G communications was monitored.

5G is between 10% and 25% faster than 4G, with slightly less variation in the clock deviation caused by clock synchronisation over the wireless link.

Partners involved

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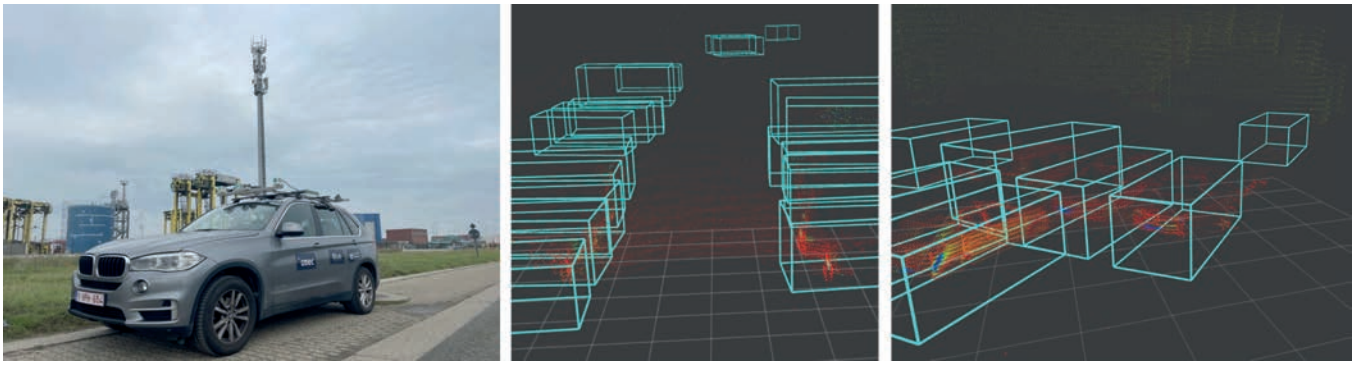
EF4 Distributed Perception

Shared situational awareness providing real-time object detection based on perception data fusion captured from different viewpoints

Context

This Enabling Function aims to improve the teleoperator's dynamic situational awareness. Using the sensors of other road users or roadside infrastructure, the teleoperator's field of view is extended, giving the teleoperator a detailed, dynamic view of the traffic ahead. The result is an enhanced map of objects around the moving truck, which is constantly updated. Achieving such a real-time shared world view involves three challenges: how to efficiently transmit this information (e.g. objects vs. pixel data), who needs what information (i.e. relevance), and most importantly, how to communicate this information in real-time. The use of 5G can provide an answer to these questions. The capabilities of 5G to support this technology will be explored, paving the way for the next generation of enhanced collaborative perception services. Distributed perception is the ability of a perception system to collect real-time data from different sensors and sources placed on different vehicles within the convoy. The primary objective of distributed perception is to provide a comprehensive and up-to-date understanding of the convoy's surroundings, including road conditions, traffic and obstacles.

The key components of the distributed perception developed include: V2X Communication, data Fusion, object detection.



Test setup (left) and object detection results (right)

Results

- In terms of the EF4 KPI object detection results, the proposed fusion method was able to achieve an excellent result in terms of the best compromise between object detection accuracy and bandwidth requirements.
- In terms of communication technologies, both 4G and 5G technologies were demonstrated. 5G achieved excellent performance in terms of service continuity assurance, perception message sharing and latency compared to 4G.
- In terms of perception message sharing, both 5G NSA and SA technologies exceeded the target, ensuring highly up-to-date information, while 4G achieved efficient but lower performance in this aspect.

Partners involved

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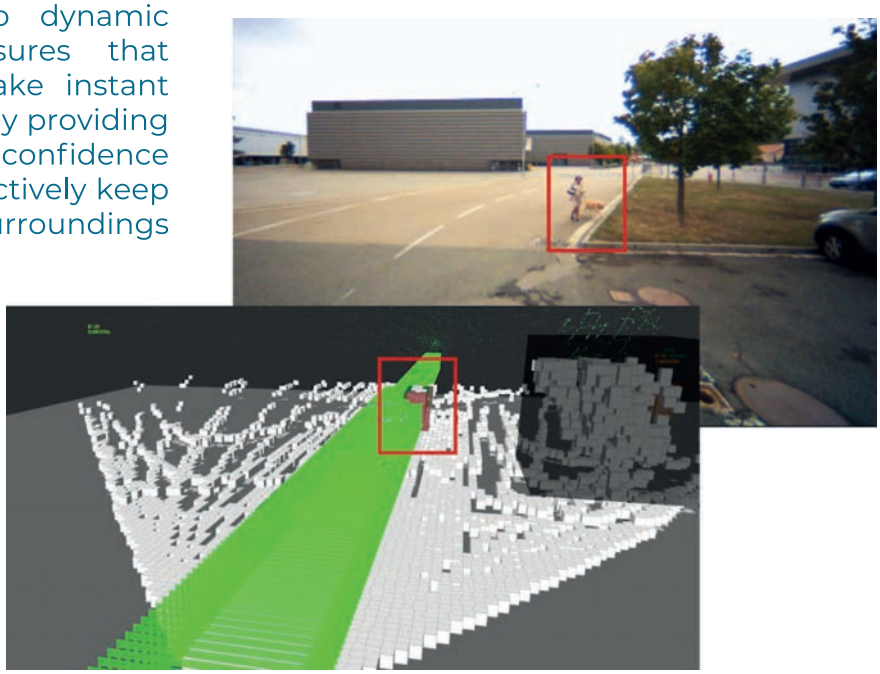
EF5 Active Collision Avoidance

A self-contained safety system integrated into the tele-operation to enhance the safety awareness of driverless vehicles in emergency situations

Context

The EF5 Active Collision Avoidance system for tele-operation is designed to provide an extra layer of safety, acting as a vital safety net for remote operators.

Whether it's navigating challenging terrain, dealing with unexpected obstacles or reacting automatically to dynamic situations, this system ensures that teleoperated vehicles can make instant decisions that put safety first. By providing real-time feedback, it gives the confidence that remote operators can effectively keep both the vehicles and their surroundings safe.



Results

Ensuring safety in emergency situations: The system should be particularly effective in emergency situations, such as sudden obstacles or unpredictable actions by other road users. It should provide fast and appropriate responses to ensure the safety of the vehicle and its surroundings.

Versatile integration: EF5 is a standalone system that can be seamlessly integrated into any type of teleoperated or autonomous vehicle.

Reduced human error: For teleoperated or autonomous vehicles, these systems aim to significantly reduce the impact of human error, which remains a significant factor in road accidents.

Improved information sharing: Sharing critical real-time data, primarily about obstacles and the environment, with other systems in the project.

Partners involved

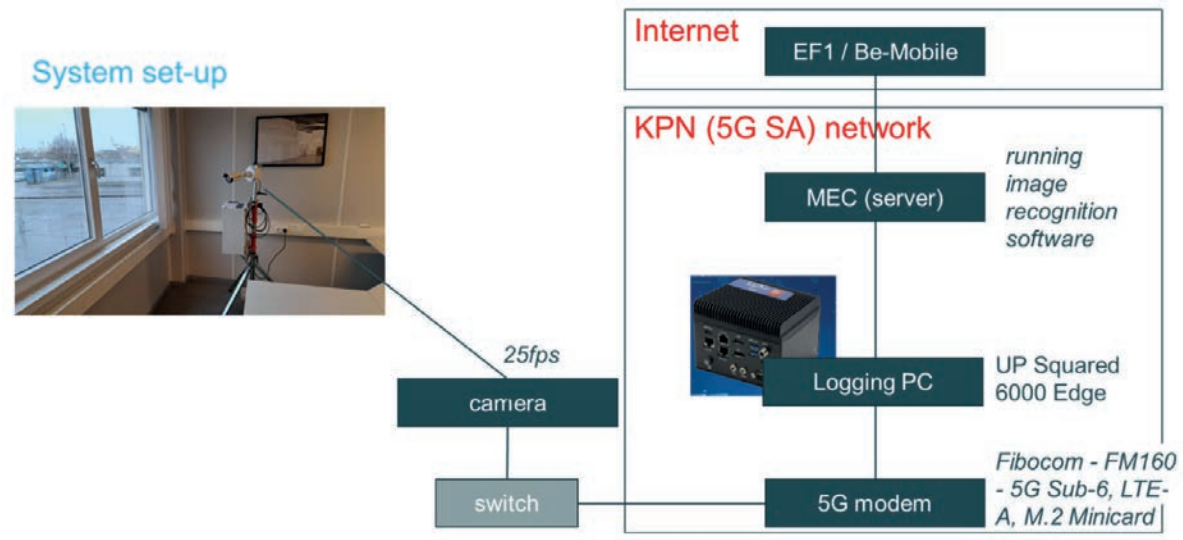
roboauto

EF6 Container ID Recognition

Camera-based container/railwagon recognition using MEC (Mobile Edge Computing) on 5G SA network

Context

The test focuses on determining whether the 5G SA network is suitable for Mobile Edge Computing (MEC) in a real-life situation. A camera and a 5G modem will be placed locally on the Verbrugge Scaldia premises in Vlissingen. The video feed is streamed 24/7 to software running on an edge node in KPN's network, rather than physically next to the camera. At the edge, Sentors' software analyses the incoming feed and scans for container and railwagon codes.



Results

- Successful MEC implementation, where containers and railwagons can be scanned using only a camera and a 5G modem.
- Statistical relevant tests: extensive logging in the period of April – October 2023, 24/7 at 25 frames-per-second.
- Measuring radio performance (SINR, RSRP, RSRQ) and end-to-end performance (bitrate, corrupted frames). Results have been submitted in a paper.
- The “as is” results thus far would be good enough for commercial usage.

Partners involved [sentors] kpn VERBRUGGE INTERNATIONAL B.V.

EF7 Estimated Time of Arrival Sharing

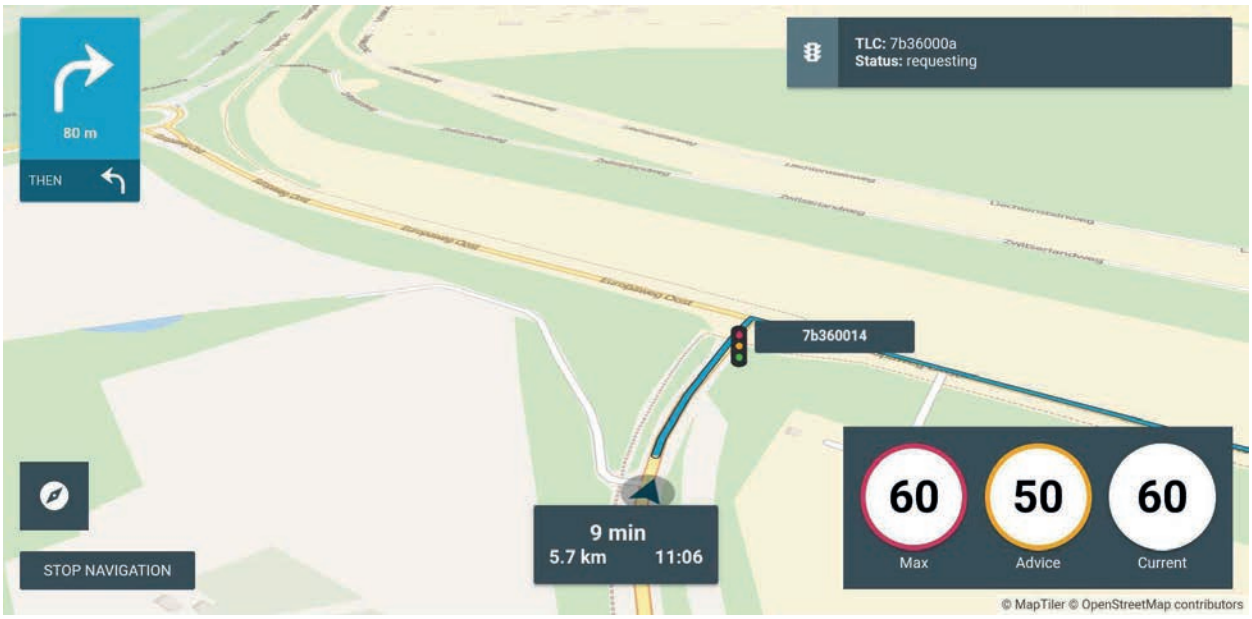
The Estimated Time of Arrival delivers real-time ETA and routing data to the teleoperator and partners

Context

The continuously displayed Estimated Time of Arrival (ETA - EF7) is fundamental to the 5G Blueprint project's Enhanced Awareness Dashboard (EAD - EF1) and serves as the foundation for critical functionality. Be-Mobile has developed an ETA API for versatile functionality. The ETA plays a key role in VRU safety alerts (EF2), calculating waypoints for VRUs and teleoperator vehicles, quickly identifying potential collisions and issuing alerts. It also determines junction priority (EF3) and communicates with the Intelligent Traffic Light Controller (iTLC). In addition, the ETA supports the Teleoperator Vehicle docking process.

Results

Be-Mobile's C-ITS geomessaging and C-ITS traffic light platform serve as the foundation for both the ETA API offering and the traffic light priority service within the 5G-Blueprint project.



The ETA module delivered exceptional performance with 100% uptime, efficient throughput (60 ETA calculations per minute), positive user acceptance, a fast median processing time of 6 milliseconds for ETA requests, and low latency for real-time warnings, ensuring up-to-date information.

In terms of the EF7 KPI results for communication technologies, both 4G and 5G technologies demonstrated excellent performance in terms of ensuring service continuity, ETA throughput, and processing times. For the ETA calculations, both 5G NSA and SA technology exceeded the target, ensuring highly accurate and up-to-date information, whereas 4G achieved efficient but lower performance in this aspect.

Partners involved

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EF8 Scene Analytics

Anomaly detection in video streams

Context

This enabling function focuses on real-time processing of video streams from cameras surrounding the teleoperation area.

It uses self-learning algorithms to generate trends of pedestrian or motorised traffic within a given area. The trends are then used to generate safe and unsafe areas, which in turn are used to send safety alerts to operators, particularly via the EAD (EF1).

The self-learning nature of this EF allows it to be easily deployed in different environments. It can also be used in environments where cabling is difficult or impossible, as well as in temporary installations thanks to the benefits of 5G connectivity.

Results/selling points

- Compatibility with various tech stacks by needing only a video stream: standard Real Time Streaming Protocol (RSTP).
- Versatility as it can be integrated into existing setups and self-learning capabilities reduce configuration time.

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