5G-HEART Newsletter

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5G HEART
5G Health, Aquaculture and Transport Validation Trials

Project website: https://5gheart.org/

INSIDE THIS ISSUE

In 5G-HEART, the considered transport use cases will be supported by 5G through enhanced wireless connectivity and increased automation.

1. Transport Use Cases

5G is expected to meet the requirements of various advanced use cases of the transport industry through enhanced wireless connectivity and increased automation, which would pave the way to fully connected mobility and autonomous driving.

As such, one of the key verticals to be field trialled in the 5G-HEART project is the transport sector. Specifically, a set of four representative transport use cases have been considered, each of which is further divided into one or more illustrative scenarios:

Use case T1: Platooning	Use case T2: Autonomous/assisted driving	Use case T3: Support for remote driving	Use case T4: Vehicle data services
Vehicles forming a tightly coordinated “train” with reduced inter-vehicle distance, thus increasing road capacity and efficiency.	Semi- or fully-automated driving for safer traveling, collision avoidance, and improved traffic efficiency.	Remote operation of a vehicle by a human operator or cloud-based application.	Interconnecting third-party data sources to connected and automated vehicles via the available 5G infrastructure.
• High bandwidth in-vehicle situational awareness and see-through for platooning. • Dynamic channel management for traffic progression	• Smart junctions and network assisted and cooperative collision avoidance • Quality of service for advanced driving • Human tachograph	• Tele-operated support	• Vehicle prognostics • Over-the-air updates • Smart traffic corridors • Location based advertising • End-to-end slicing • Vehicle sourced HD mapping • Environmental services

2. Situational Awareness and See-through for Platooning

When driving in platoons, the drivers will most likely feel more secure when they can see what is happening ahead of the lead vehicle. This will be trialled in the "*High bandwidth in-vehicle situational awareness and see-through*" scenario, where the front scene (i.e., as seen by the lead vehicle) will be characterized via an augmented reality (AR) video stream communicated to the following vehicles. This could also extend the object/event detection to the trailing vehicles for increased safety (via redundancy) and/or comfort by anticipating maneuvers of the lead vehicle in response to the driving conditions.

This scenario is being trialled by 5G-HEART partners UOS and TUC on the 5GENESIS trial facility located in Surrey, UK as per the high-level architecture described in Figure 1. An incremental methodology has been followed to test each of the required components and functionalities, starting with a baseline 4G setup and moving eventually to a 5G setup. The functionalities offered by this scenario (i.e., situational awareness and see-through) are being developed on top of the basic platooning operation.

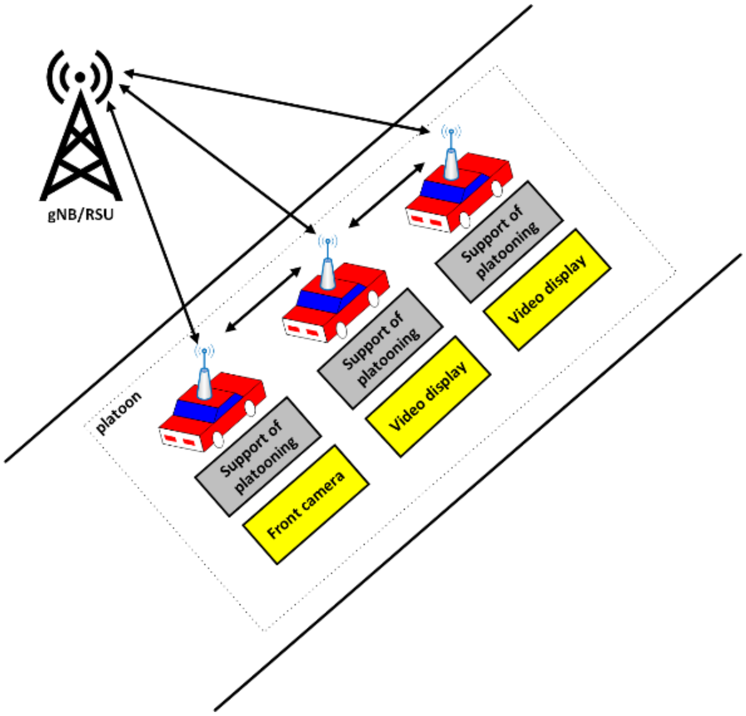


Figure 1. Architecture for *High bandwidth in-vehicle situational awareness and see-through for platooning*.

To extend the 5GENESIS facility with cellular vehicle-to-everything V2X (C-V2X) support, a set of experimental setups, based on OpenAirInterface (OAI) [1] and software-defined radios (SDRs), have been built. The initial tests have been based on an over-the-air (OTA) video streaming between two static SDRs placed in a controlled environment (i.e., lab). During a transport workshop that will held at the TUC premises, the OAI+SDR setup will be placed inside vehicles, and the see-through functionality will be tested over the vehicle-to-vehicle (V2V) link under different operating conditions (e.g., moving speed, inter-vehicle distance and network load). Once the 4G/5G C-V2X support becomes available on the commercial nodes of the 5GENESIS trial facility, the experimental setup will evolve to a mixed one where both SDRs and commercial 4G/5G modems will be used with their performances compared.

3. Smart Junctions

5G-HEART partners TNO and Dynniq are trialling an ultra-reliable low-latency communication (URLLC) *Smart Junctions* scenario. They are setting up an intersection with a traffic light controller (TLC) and a camera-based object detection system connected to a 5G standalone (SA) deployment to provide time critical safety information at intersections as well as improving the overall traffic efficiency amongst corridors.

As depicted in Figure 2, the infrastructure provides object detections (e.g., vulnerable road users (VRUs)) via ETSI collective perception messages (CPM) towards the vehicles as well as traffic light status information via ETSI MapData Messages (MAP) and signal phase and timing (SPAT) messages. Thanks to this information provided with URLLC, the vehicles can anticipate what is ahead and react in a timely matter.

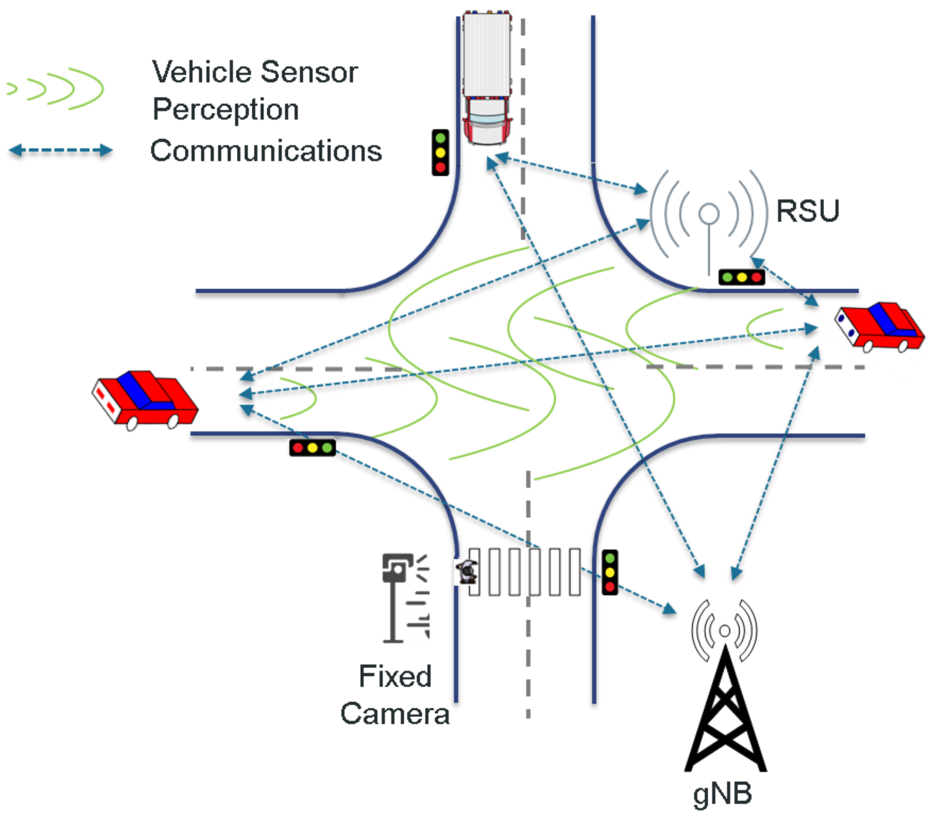


Figure 2. High-level architecture of the *Smart Junctions* use case.

This use case scenario is being trialled at the 5GRONINGEN test facility in the Netherlands. Beyond retrieving traffic light status information with ETSI SPAT and ETSI MAP messages, emergency vehicles (e.g., ambulances and fire trucks) will request vehicle priority when approaching an intersection. This disrupts the default operation of dynamically creating green waves for the larger traffic flow. The vehicles will send a signal request message (SRM) to request priority, which will be answered by the roadside unit (RSU) with a signal state message (SSM) after interacting with the TLC. Due to the disruptive nature of such requests, it is very important to restrict access to this priority request service.

4. Human Tachograph

5G-HEART partners VTT and Polar are investigating the possibilities of ubiquitous driver monitoring with wearable sensor devices, 5G communications, and interconnected and cooperative road safety systems under the *Human Tachograph* trial scenario. This scenario focuses on a wearable-based direct measurement/assessment method and technology to assess the physiological status of professional drivers. Wearable sensor devices are typically worn continuously, thus also providing important information from the time spent outside the vehicle. The driver's alertness and fitness-to-drive can be determined from sleep history, recovery status, stress levels and physical activity or lack thereof during the day. In addition, wearable sensors can provide real-time status information about the driver in the car while driving. The combination of historical data and real-time information of the drivers' status could also provide valuable information for the occupational healthcare and fleet management of trucks and buses.

Wearable-based driver condition monitoring can provide useful data for the active safety systems utilised in different kinds of vehicles. However, this information will be especially useful for future connected autonomous vehicles where collision prevention can be aided by sharing information in the form of triggered warning messages between vehicles and road safety systems. If the driver monitoring data, typically restricted to the current state of the driver, is extended to include the potential risk factors identified from the driver's historical data (e.g., sleep deprivation and high stress), more proactive measures can be taken to improve the safety of the driver, passengers and other road users. Wearables, when coupled with high-performance connectivity and service platforms, can furthermore provide driver condition monitoring capabilities to vehicles, which do not have an on-board system installed, or function as part of network-assisted warning and road safety systems.

In the trial scenario, the driver monitoring data collected with wearable sensors are delivered to the application servers residing in the local edge or remote cloud environment through a 5G network as described in Figure 3.

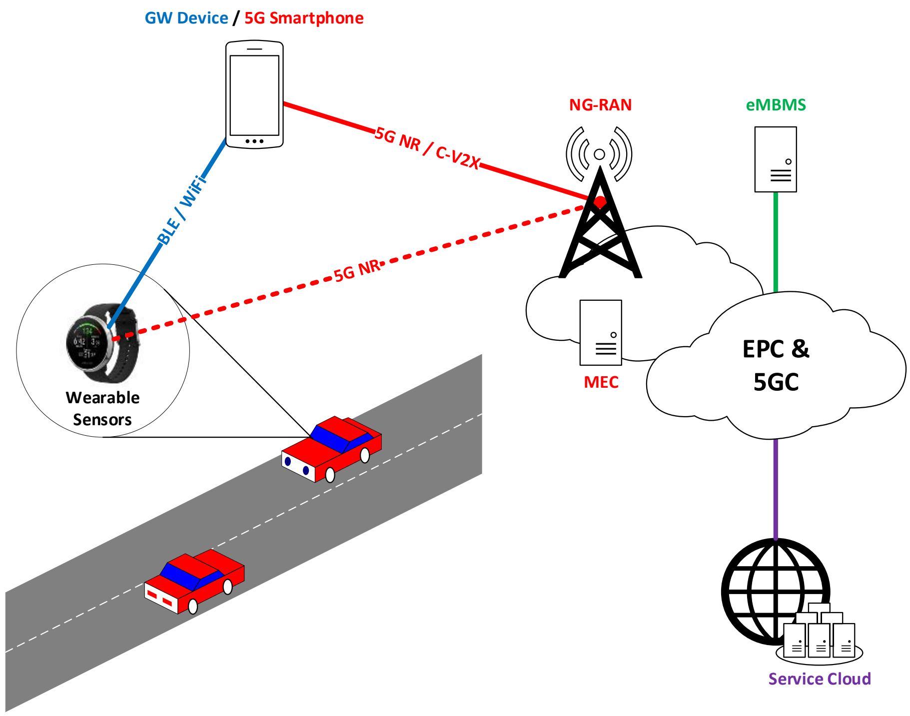


Figure 3. *Human tachograph* architecture.

The 5G connectivity is provided with a separate 5G gateway (GW) device or, in the future, directly from the wearable sensor device. The collected data is analysed to determine the driver's current status while driving. The real-time data can also be combined with previously collected and analysed historical data in order to enhance the accuracy of the analysis. Based on the analysis results, the application can provide feedback to the driver to maximally maintain his/her fitness-to-drive and recover from the detected stress. In addition, the analysis results can be used to trigger warning messages from the application servers towards road safety systems in order to alert other road users in the area to increased level of risk. The warning messages can be delivered to the other road users either by using unicast transmissions, or in case of larger groups of road users, by using cellular multicast/broadcast transmissions, e.g., in the form of evolved multimedia broadcast multicast service (eMBMS).

One of the main targets for the *Human Tachograph* trials in the 5G-HEART project is to investigate the pros and cons of the different service architecture options especially from the connectivity and communication perspective. For example, when placing the processing related to the real-time sensor data analysis and data fusion with historical data to the 5G GW device, the requirements for the wireless link performance are different than if the processing is done in a 5G network edge or remote cloud environment. The same is true also for the placement of the warning message triggering module. Through practical implementations and field trials, the aim is to find the best compromise between performance and complexity for the service deployment.

5. Support for Remote Driving

Remote driving is a concept in which a vehicle is controlled remotely by either a human operator or cloud computing software. While autonomous driving needs a lot of sensors and sophisticated algorithms like object identification, path planning and vehicle control, remote driving with human operators can be realised using less of them, provided that ambient information is properly transferred and visualised to the remote vehicle operator.

In the framework of 5G-HEART, partners NTUA, UOS and TUC will examine a tele-operated support (TeSo) scenario, considering a vehicle traveling in a public street, bearing HD video cameras (i.e., front, and potentially right-left side and rear views) and several sensors providing instrumentation data on the driving conditions of the vehicle. A remote human operator can monitor the vehicle and perform manoeuvres if required, i.e., control the direction and speed of the vehicle. Tele-operation may be considered throughout the vehicle journey, or on-demand upon the request of the driver for remote assistance. In the considered scenario, it will take place on-demand. All instrumentation data and video streams are communicated to the remote location of the human operator, denoted as the remote operations centre (ROC), which can be either accessed through the core or located at the edge of the network. In the considered scenario, the ROC will be at the edge of the 5G network. The instrumentation data and video feed represent sufficient ambient information that will allow the accurate creation of situation awareness and prompt reaction to emerging hazards (e.g., collision avoidance).

The overall system architecture for the provision of the TeSo service is illustrated in Figure 4. Its main parts are a remote operation-enabled vehicle, the 5G access and core network (CN) infrastructure and the ROC. The access and/or CN infrastructure secures the communication between the vehicle and the remote-control centre and thus, is crucial for the viability of the service. The vehicle is equipped with the appropriate sensors/instruments and actuators to measure and control the vehicle speed, acceleration, steering angle, brake position, as well as cameras to allow video feed. An on-board unit (OBU) that interfaces with the sensors/ instruments and the cameras is responsible to capture such data and enable their usability by other hardware components integrated to the vehicle. One of these components is the so-called ROC gateway (ROC-GW) which is comprised by an Intel next unit of computing (NUC) mini PC and is in charge of the processing and aggregation of data extracted by the OBU and their final transmission over 5G to the ROC. Considering the DL communication scenario, control commands that are transmitted over 5G from the ROC to the vehicle, are received by the ROC-GW and forwarded to the OBU, where their conversion into control commands for the vehicle actuators takes place.

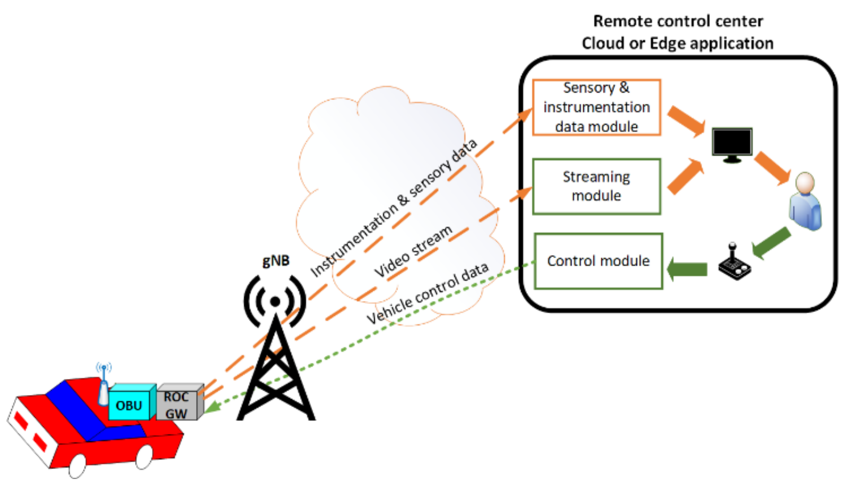


Figure 4. Overall architecture for TeSo.

On the other side of the network, a human operator handles the remote control of the vehicle, empowered by the visualization of the transmitted data and a set of functionalities provided by the deployed software application. In particular, the remote-control application consists of several sub-components, namely the sensory & instrumentation data, streaming and control modules. Each of these three sub-components interfaces with an appropriate indicator/controller. The first two interface with a visualization indicator enabling the human operator to monitor the driving conditions and state of the vehicle, while the control module interfaces with an input device (e.g., keyboard and joystick) to allow the issuing of commands to the vehicle.

All these components have been developed and are currently being integrated into the architecture. A screenshot of the ROC graphical user interface (GUI) application with sample output can be seen in Figure 5. A map depicting the vehicle trace (i.e., received global positioning system (GPS) coordinates), is located in the upper right corner. Telemetry information (e.g., steering wheel angle, throttle and brake percentage) and the vehicle state (e.g., velocity) are presented in the left upper corner. The window's central components display the four video streams from the vehicle-mounted cameras (from left to right and top-down: back, left, front, and right cameras). Finally, the control-related components are located at the bottom row of the window. To the right, two bars visualize the percentage of throttle and brake given as input by the user. To the left, the selected radio button declares the used angle increment, while the steering wheel angle that will be sent to the vehicle is (re)calculated after every user input and displayed in degrees. The user inputs can be alternatively provided from the keyboard via the respective arrow keys. The steering wheel angle and throttle/brake percentage correspond to the input provided by user and serve as a way of setting the desired value, whereas the telemetry information displayed at the upper left corner describes the current state of the vehicle that was lastly reported by the on-board sensors and instruments.

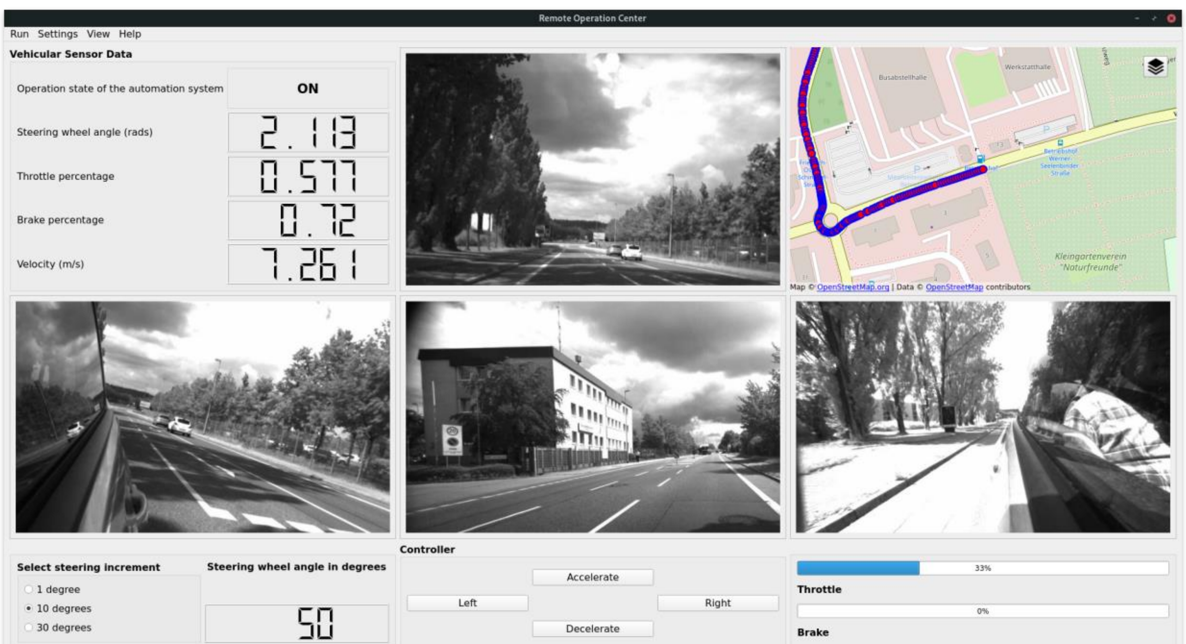


Figure 5. ROC GUI Application.

In the context of the 5G-HEART project, the evaluation of the 5G network connectivity, according to the derived network key performance indicators (KPIs), will be performed considering a single-vehicle trial under strictly defined environmental and driving conditions so as to ensure the driver's safety. The integration tests are currently performed remotely, and progressively, the complete control loop of the scenario will be available for preliminary testing of the basic identified KPIs. The next step will include the first field trials on actual roads.

6. Smart Traffic Corridors

The motivation for the *Smart Traffic Corridors* use case scenario is driven by the environmental policies aiming at minimizing the pollution impact of transportation, which is of growing importance. This scenario focuses on providing a navigation service, which would capture such policies and restrictions by providing routing options in accordance to the emission profile of vehicles. For instance, high-emission vehicles (e.g., lorries) may be guided through a high-emission corridor, whilst low-emission (e.g., electric) vehicles may be given more flexibility on the routes they may take to their destinations. Based on the policy rigor, end-user needs (e.g., time constraint) and other relevant factors (e.g., road closures), the system focuses on providing the optimal route suggestion.

5G-HEART partners WINGS and UOS are trialling this use case scenario according to the high-level architecture depicted in Figure 6. The key components involve air-quality sensors to identify the most environmentally degraded areas, an end-user mobile application responsible for tracking the vehicle-user profile with the respective restrictions and the service cloud which mainly comprises of a database and central decision-making entity.

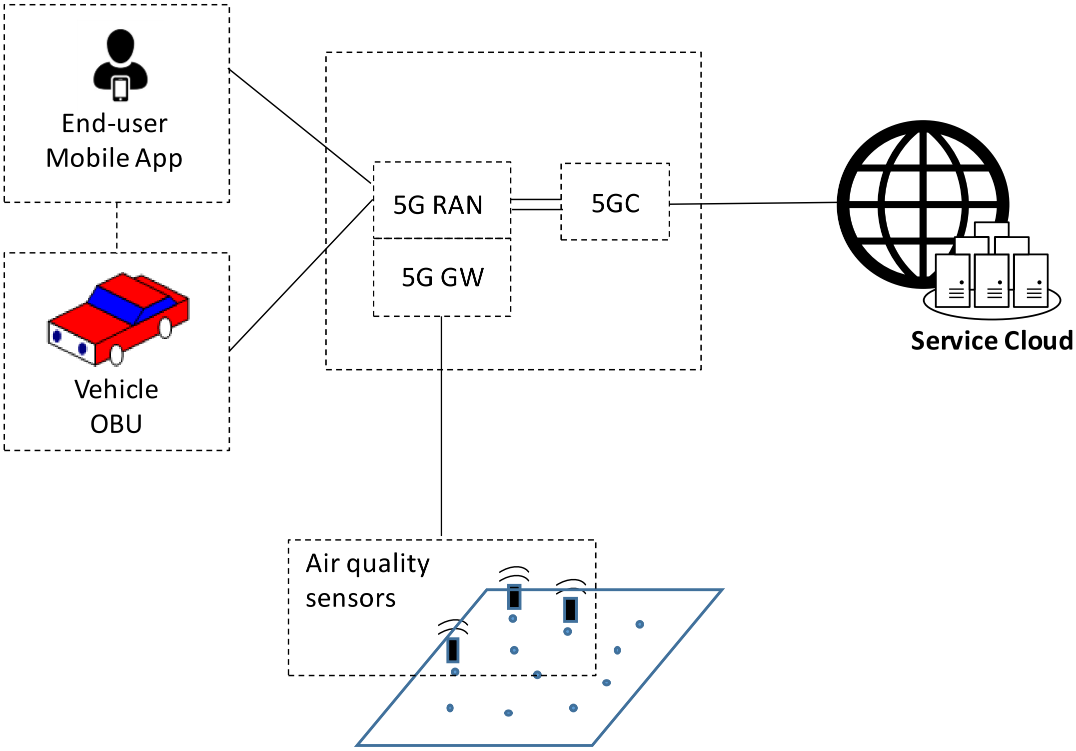
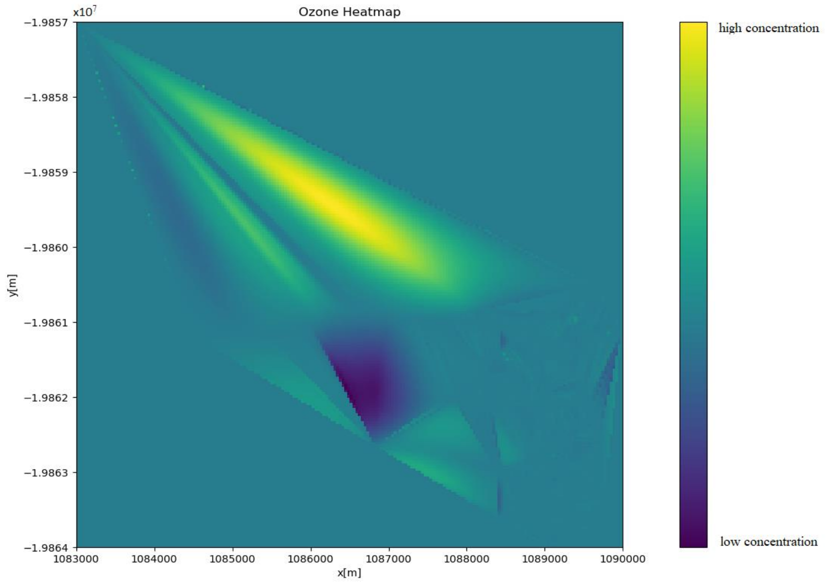
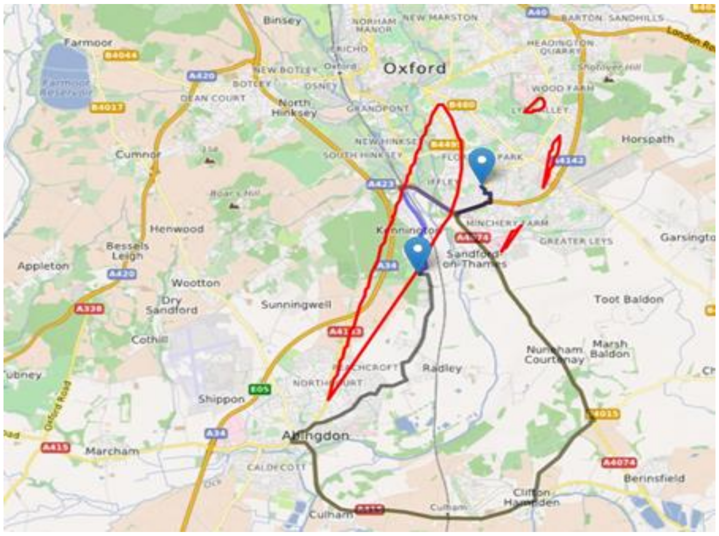


Figure 6. *Smart Traffic Corridors* architecture.

During the initial tests, air-quality sensor data, covering the Oxfordshire region in England in 2018, were used. The concentration of ozone (O3) was used as an indicator of the air quality during the preliminary analysis. A screenshot from the resulting qualitative 'ozone - heatmap', using cubic interpolation on the scattered data, can be seen in Figure 7(a). The associated regular and configured routes can be seen in Figure 7(b). The used coordinates are based on Universal Traverse Mercator (UTM) Zone 30, while the Open Route Service was used for the routing requests. It can be observed that the configured route avoids the zone with high ozone concentration as indicated by the heatmap enclosed by the red line. It is worth pointing out that this initial demonstration assumes that the indicated zone should be strictly avoided even if the alternative route is much longer. Such assumption will be relaxed in the future through a proper weighting of all relevant factors.



(a)



(b)

Figure 7. (a) The 'ozone – heatmap' and (b) The regular (purple) and configured (green) routes.

7. Vehicle Sourced HD Mapping

Autonomous Vehicles (AVs) not only require on-board sensors to perceive the world around them, but also maps to aid their decision-making process. Maps of roads and infrastructure will take years to capture and consolidate. Furthermore, there is the added issue of managing changes to these maps over time.

Further, AVs require a new class of maps. Current maps and mass market location-based tracking using global navigation satellite system (GNSS) technology provide accuracy within a range of meters. HD maps for AVs need to represent the world at a centimetre level resolution, which is orders of magnitude greater than the resolution that map services offer today. AVs demand such a high resolution because they need to routinely execute complex manoeuvres such as nudging into a bike lane to take a turn and safely passing cyclists. For example, marked bike lanes in Europe are typically 1.2 – 1.5 m wide at a minimum, but are recommended to be between 1.5-2.5 m in width. Other factors such as the type of road or junction, distance from the kerb, road signage as well as other considerations impact the design of these lanes. Centimetre-level accurate maps are a must for an AV to be able to confidently reason about its position within a lane, assess distance from vehicles, cyclists, road infrastructure and potentially unique road features (e.g., potholes or other road conditions) to confidently take action. As such, an innovative means to collect and maintain up-to-date data would be to source this information through on-board sensors which would stream back to a regional or central service, firstly to establish baseline maps and subsequently to manage change detection.

5G-HEART partners EPI and UOS are trialling this use case scenario according to the high-level architecture described in Figure 8. Data from the various sensors in the vehicle (e.g., light detection and ranging (LiDAR), camera and GPS) are uploaded to the backend server over 5G communication links. The higher bandwidth provided by 5G is used so that high volume of real time data can be uploaded, even in conditions of high vehicle density, as in urban scenarios.

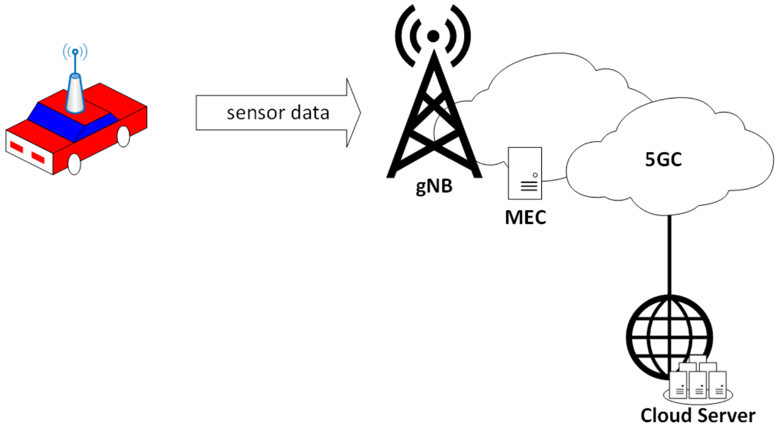


Figure 8. Overall architecture for *Vehicle Sourced HD Mapping*.

To trial the scenario, a low-cost autonomous rover is used as a mobile research platform which can be configured with different sensors. An OBU, realized using standard Intel industrial computer, gathers and uploads the data generated by the various sensors (e.g., LiDAR, GPS and camera) to the backend. The OBU runs robot operating system (ROS), which is widely used in the industry for robots and AVs. This is essentially a software environment that runs on top of Linux distributions (e.g., Ubuntu). For the initial tests, a SLAMTEC RPLIDAR A3 LIDAR [2] was used, which would later be upgraded to much higher resolution devices (e.g., the ones offered by Velodyne) with the possibility of fusion of other sensors (e.g., cameras).

For 5G connectivity, a 5G consumer premises equipment (CPE), namely Huawei LF 7880 CPE [3], is used to connect to the 5GENESIS trial facility maintained by UOS in the Guildford campus. At the server side, rackmount systems in the University data centre are used to run virtual machine images of Ubuntu Linux. Applications at the server aid in the upload and translation of sensor data to map images, while the creation of maps is done offline due to the incurred computational overhead. The autonomous rover and CPE used for the trials are shown in Figure 9.

Figure 9. Rover and CPE used for Vehicle Sourced HD Mapping.

The testing involves measuring the relevant KPIs (e.g., upload throughput and device density) using both 4G and 5G accesses, thereby demonstrating the advantages of 5G for such high bandwidth use cases. The impact of mobility under various speeds will be tested further, in the later phases of the project.

8. Summary

This newsletter presents a sub-set of the use cases of the transport vertical considered by the project 5G-HEART. A set of extensive field trials are being conducted to evaluate the extent to which 5G can meet the requirements of each of these through enhanced wireless connectivity and increased automation.

For more in-depth understanding of the current status of these trials, please read our latest deliverable (i.e., *"D4.2: Initial Solution and Verification of Transport Use Case Trials")* available at the project website [4].

References

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