Transport Use Case Trials of 5G-HEART Project

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***Abstract*—5G-HEART (5G HEalth AquacultuRe and Transport validation trials) project focuses on realising 5G trials and validating 5G Key Performance Indicators (KPIs) on the vital vertical use-cases of healthcare, transport and aquaculture. In the health area, 5G-HEART validates pillcams for automatic detection in screening of colon cancer and vital-sign patches with advanced geo-localization as well as 5G Augmented/Virtual Reality (AR/VR) paramedic services. In the transport area, 5G-HEART validates autonomous/ assisted/ remote driving and vehicle data services. In the aquaculture area, 5G-HEART validates 5G-based fish farm monitoring systems. Among them, transport sector connected with fifth generation (5G) mobile communications systems will drive transformational changes while bringing social, economic and industrial benefits to the economies that take the lead in its adoption. 5G-enabled industry digitisation for automotive and public transport represents 10% and 8% of the overall $1.3T market in 2026, respectively. In this paper, transport use case trials of 5G-HEART project are introduced.**

***Index Terms*— 5G-HEART, Transport vertical trials, autonomous/ assisted/ remote driving and vehicle data services, etc.**

I. Introduction

THE 5G Communication between vehicles, infrastructure, the cloud and other road users is crucial to increase the safety of future automated vehicles and their full integration in the overall transport system. Cooperation, connectivity, vehicle digitisation and automation are not only complementary technologies; they reinforce each other and will merge completely over time. As it stands, no single technology has emerged as a clear winner for connectivity in the transport sector. 5G brings with it the promise of far more capabilities compared to competing technologies. 5G-HEART as one of 5G PPP Phase 3 projects will deploy innovative digital use cases involving healthcare, transport and aquaculture industry partnerships. 5G-HEART offers the consortium partners, especially the end user partners, a unique opportunity to gain a head start in realising the 5G vision for transport. 5G-HEART utilises an iterative process, which conducts the trials in three phases. The use case scenarios and the related trialling plans are revised during each trialling phase based on the results of the tests, the business analysis performed during the project, the discussions within the consortium and the feedback received from the stakeholders and the owners of the utilised testbeds.

The remaining part of this paper is organized as follows: In Section II, 5G-HEART transport vertical trials are described. Section III contains the conclusion and summary.

II. Transport use cases of 5G-HEART

A. T1S1&T1S2 High bandwidth in-vehicle situational awareness and see-through for platooning

The vehicles in a platoon receive a continuous data stream from the lead vehicle for carrying out the platoon operations. This information allows the time headway between vehicles to become extremely small, even less than a second. The following vehicles in a platoon can drive (more or less) automatically, which may create economic, environmental and safety benefits, increase driving comfort by freeing up drivers to perform other tasks (for passenger cars), and reduce the need for professional drivers (for commercial vehicles).

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 can be achieved by the see-through functionality that characterises the front scene (i.e., as seen by the lead vehicle) 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 manoeuvres of the lead vehicle in response to the driving conditions.

While situational awareness and see-through have been previously applied to warn individual drivers about hazardous driving situations ahead, they have not been considered to support the switch between platooning and individual driving modes. As partial automation levels (e.g., Society of Automotive Engineers (SAE) Level-3 and Level-4) may govern the operation of platoons, the human driver of a platooned vehicle would need to be updated to get ready to take over the control of the vehicle whenever needed. The identified objects ahead and/or real-time video representing the front scene could be used as a visual alert that a given platoon is about to be split for safety and/or efficiency reasons, thus keeping the drivers' anxiety levels low.

This use case scenario is being trialled on the 5GENESIS trial facility located in Surrey, UK. Once the 4G/5G Cellular Vehicle to Everything (C-V2X) support becomes available on the commercial nodes of 5GENESIS, the experimental setup will evolve to a mixed one, where both Software Defined Radios (SDRs) and commercial 4G/5G modems will be used with their performances compared.

B. T1S3: DYNAMIC CHANNEL MANAGEMENT FOR TRAFFIC PROGRESSION

Platoons need a localised, low-latency, high-reliability communication channel to maintain their smooth operation. Due to their mobility, they cannot rely on the traditional broadcasting of messages over one fixed radio channel whose availability may vary from one location to another. Instead, the radio channels used by the Vehicle to Infrastructure (V2I) and Vehicle to Vehicle (V2V) links of the various platoons should be dynamically assigned based on the speed, location and destination of the platoons together with spatial-temporal variability of the various channels.

This use case scenario will be trialled on the 5GENESIS trial facility located in Surrey, UK. Given the limited number of vehicles (i.e., two) available for trials, this scenario is currently being simulated with a high number of platoons to assess the effectiveness of the optimised channel management.

C. T2S1&T2S2: SMART JUNCTIONS AND NETWORK ASSISTED & COOPERATIVE COLLISION AVOIDANCE (COCA); TRIAL TRACK

This use case focuses on providing time critical safety information at intersections as well as improving the overall traffic efficiency amongst corridors. The safety information at the intersection may involve the exchange of precise traffic signal status information, vehicle information (e.g. location, speed and trajectory), as well as location information of Vulnerable Road Users (VRUs).

Next to providing this safety information, these smart junctions could also help in improving the overall traffic flow in various situations e.g., when multiple of these smart junctions are adjacent to each other on the same corridor. That way they would be able to improve the traffic efficiency by creating a green wave or by giving priority to certain types of vehicles. This scenario can be implemented in multiple ways. At the Dutch 5Groningen test facility for example, the earlier mentioned safety information is generally stored in a Local Dynamic Map (LDM) running at the Road Side Unit (RSU). The intersection controller is hosted separately from the RSU and is, amongst others, responsible for controlling the traffic lights at an intersection.

This use case scenario is being trialled on the 5Groningen trial facility located in Groningen, Netherlands.

D. T2S1&T2S2: SMART JUNCTIONS AND NETWORK ASSISTED & COOPERATIVE COLLISION AVOIDANCE (COCA); SIMULATION TRACK

The second scenario –related to the Cooperative Collision Avoidance (CoCA) service– consists in the exchange of Cooperative Occupancy Maps to ensure efficient navigation through different driving situations, such as lane changing, overtaking or entering/exiting highways and intersections. In this context, the CoCA system provides network-assisted safety information to connected and automated vehicles via the available infrastructure to announce a risk of collision and/or the location of other vehicles and vulnerable users on the road (such as pedestrians or cyclists). To do so, the CoCA information is calculated (on-board the vehicle or at the RSU) following an LDM approach [1] to obtain precise digital maps of nearby surroundings (as the approach used in [2]) in order to predict trajectories and the probability of collisions. Then, this information is shared using a specific communication channel such as the 4G Long Term Evolution (LTE)) Vehicle to Everything (V2X) (PC5 mode 4), the cellular LTE or the V2X 5G (side-link or not). In this work, two use cases ((1) all concerned UEs on the road (e.g. vehicles, bus, trucks) are assumed to have an LTE-V2X system embedded and (2) it is assumed that not all the users can support a V2X communication or LDM application such as old vehicles or vulnerable users.) are proposed to evaluate this track through simulations.

This use case scenario is being simulated with a possible subsequent trial on the 5GENESIS trial facility located in Surrey, UK.

E. T2S3: QUALITY OF SERVICE (QOS) FOR ADVANCED DRIVING

This scenario involves the dynamic selection of the appropriate driving mode based on the context at-hand. According to [3], the driving mode is mainly characterised by the Level of Automation (LoA), which reflects the functional aspects of the technology and affects the system performance requirements. While each driving mode has its own merits and advantages, there exist non-trivial traffic scenarios where using an inappropriate driving mode may result in traffic hazards and/or collisions. For instance, automated driving may be allowed only on certain roads (e.g., strategic roads, such as motorways) or prevented on others (e.g., due to adverse weather conditions). As such, the best LoA for a given scenario should be selected based on all the relevant factors (e.g., the operating conditions of the vehicle, design decisions made by manufacturers and regulation in-force).

This use case scenario is being trialled on the 5GENESIS trial facility located in Surrey, UK.

F. T2S4: HUMAN TACHOGRAPH

This scenario focuses on a wearable-based human tachograph service, which provides a 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 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 input information for the fleet management of trucks and busses.

Wearables-based driver condition monitoring can provide useful data also for the active safety systems utilised in cars and other vehicles. In addition, this information would be especially useful for future connected automated vehicles where accident prevention can be aided by sharing information between vehicles and road safety systems, e.g. in the form of anonymized warning messages. When coupled with high-performance connectivity, wearable-based services can furthermore provide driver condition monitoring capabilities to vehicles which do not have an on-board system installed and function as an additional information source for the situational awareness of the network-assisted warning and safety systems.

This use case scenario is being trialled on the 5GTN trial facility located in Oulu, Finland.

G.T3S1: TELE-OPERATED SUPPORT (TESO)

Remote driving is a concept in which a vehicle is controlled remotely by either a human operator or a 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 refined version of the tele-operated support (TeSo) scenario examined specifically in the framework of 5G-HEART, a vehicle is traveling in a public street, bearing high definition (HD) video cameras (front, and potentially right-left side and rear views) and several sensors providing instrumentation data on the driving condition of the vehicle. With the aid of vehicle's instrumentation data and real-time video streaming, a remote human operator can monitor the vehicle and perform manoeuvres if required, i.e., control the direction and speed of the vehicle. In principle, tele-operation may be considered throughout the vehicle journey, or on-demand after the request of the driver for remote assistance. In the considered scenario, tele-operation will take place on-demand.

This section describes the proposed setup and on-going developments in terms of the first trialling phase of this use-case scenario which will be trialled on the 5GENESIS trial facility located in Surrey, UK.

H.T4S1: VEHICLE PROGNOSTICS

An RSU application, having the capability to access the Internet, will enable any passing vehicle to report its current functional state to a local/remote diagnosis service and receive a "Just in time repair notification". A vehicle service application linked to local repair centres needs to obtain and analyse data from the vehicle periodically.

An RSU application can provide this data by collecting in from the passing cars on the road. Based on the analysis outcome, the repair centre will notify the vehicle owner with any identified issues.

This use-case scenario is being trialled on the 5GTN trial facility located in Oulu, Finland.

I. T4S2: OVER-THE-AIR (OTA) UPDATES

Engine Control Unit (ECU) is a generic term for a hardware module with corresponding software in a car that controls some electronic functions within the vehicle system. It controls anything from the steering wheel to the brakes and with automated driving. The ECU is a key part of the vehicle and will possibly need regular software updates.

Over-the-Air (OTA) updates will provide significant cost-savings, as the vehicles will not need to be recalled by a manufacturer or service centre. Note that such an update mechanism requires significant security protection measures.

This use-case scenario is being trialled on the 5GTN trial facility located in Oulu, Finland.

J. T4S3: SMART TRAFFIC CORRIDORS

This use case is motivated by the fact that vehicles can utilize selected routes in order to reduce pollution or congestion, especially for areas that suffer the most. The solution focuses on providing a routing/navigation service, which minimizes the pollution impact for the most Air Quality Management Areas (AQMAs) due to the vehicle's emissions, while simultaneously minimizing the travel time and the respective travel costs for the driver. The scenario looks at how historical and real-time data gathered from air quality sensors and information related to vehicle-emissions can be intelligently utilized and combined to control the routes that a vehicle is recommended or mandated to take in any given journey. This can be achieved through monitoring of emissions and guiding individual, or groups of, vehicles to be routed based on locally implemented emissions corridors. Vehicles such as lorries or older vehicles with high emissions may be guided through a high emissions corridor whilst low emissions or electric vehicles may be given more flexibility on the routes they take to their destination.

This use-case scenario is being trialled on the 5GENESIS trial facility located in Surrey, UK.

K. T4S4: LOCATION BASED ADVERTISING

With vehicle and passenger information readily available, location-based servers can be implemented to stream content (upon request, if required) as well as local advertising or traffic guidance to vehicles and road users. This becomes especially useful in car-sharing models where vehicles are not owned, and the origin and destination of each journey may vary depending on the passengers.

As the adoption of Automated Vehicles (AVs) rises, millions of eyes will be off the road. This creates a world of opportunity where content like games, movies and news will be consumed in vehicles. If music streaming apps were successful at luring millions of radio listeners, self-driving cars and the accompanying new scores of passengers will not just listen to music, but they'll also have the opportunity to binge watch video content, work collaboratively and play video games whilst on route to their destinations.

This use-case scenario is being trialled on the 5GENESIS trial facility located in Surrey, UK.

L. T4S5: END-TO-END (E2E) SLICING

The multiplicity of use case scenarios that may run simultaneously inside the same vehicle calls for a form of customisation to simultaneously support the diverse and often conflicting requirements of each of them. With the recent introduction of softwarisation enablers (e.g., Network Function Virtualisation (NFV) and Software Defined Networking (SDN)) into mobile networks, network slicing has emerged as an efficient tool to create customised logical network instances on the same physical infrastructure. In this respect, different End-to-End (E2E) slices can be used to simultaneously support the various V2X applications running inside the same vehicle. For instance, passengers can watch a HD movie, while a collision awareness application detects a road hazard and triggers an emergency message for the cars behind to slow down or stop to prevent a collision. In such scenarios, a minimum level of isolation is needed to ensure that the operation of one slice does not affect the others e.g., the Quality of Service (QoS) of safety-related V2X applications is not impacted by other applications running on the same network.

This use-case scenario is being trialled on the 5GENESIS trial facility located in Surrey, UK.

M. T4S6: VEHICLE SOURCED HIGH-DEFINITION (HD) MAPPING

Several mapping and self-driving companies have already started to produce and consume HD maps. However, it is still early days in terms of how these maps are being built, the richness of information they contain, and how accurate they are. Companies are iterating quickly on making these HD maps better and as such there is little standardisation between various providers and consumers, but this is being investigated, e.g., in the UK by British Standards Institution (BSI) with Ordnance Survey. Therefore, the creation and management of HD maps forms a specialised function in the autonomy stack of AVs.

This use-case scenario is being trialled on the 5GENESIS trial facility located in Surrey, UK.

N. T4S7: ENVIRONMENTAL SERVICES

Vast amounts of environmental sensors exist both on board vehicles as well as in roadside infrastructure, but currently that data is not consolidated, integrated and used outside very specific and isolated applications for which each sensor is deployed. With the availability of 5G capabilities and infrastructure the opportunity for massive transfer and consolidation of on-board and roadside environmental sensor data and the utilisation of that data in different scenarios and applications becomes possible.

Key for the implementation for this use case would be a centralised hub or exchange that would consolidate, process, translate and make available the collected data and information. Some distributed processing and consolidation might be desirable for some applications, e.g. either at the vehicle On-Board Unit (OBU) or RSU.

In vehicles, a wealth of environmental data can be accessed and collected using an OBU integrated or connected to the vehicle systems, including light sensors, wiper data and suspension sensors. Roadside infrastructure will include air quality sensors, non-ionizing radiation sensors, acoustic noise sensors which could be integrated into the same system for data collection and integration.

Weather and environmental sensor data can be used to create hyper local weather maps aiding drivers and AVs is day-to-day driving. Driver warnings and advisory speed limits would be an example of applications of such data from a vehicle point of view. External transportation systems would also use such data for proactive traffic management in real time.

This use-case scenario is being trialled on the 5GENESIS trial facility located in Surrey, UK.

III. CONCLUSION AND SUMMARY

In this paper, 5G-HEART transport use case scenarios have been introduced. The table 1 summarized the trial scenario and planned trial facility, location and partners.

Table 1: Planned trial locations and involved partners of the transport use case scenarios

Use case scenario	Planned trial facility	Planned trial location	Scenario **owner** and partners
T1S1&T1S2: High bandwidth in-vehicle situational awareness and see-through for platooning	5GENESIS	Surrey, UK	EPI, TUC, **UOS**
T1S3: Dynamic channel management for traffic progression	5GENESIS	Surrey, UK	EPI, TUC[1], **UOS**
T2S1&T2S2: Smart junctions and network assisted & cooperative collision avoidance (CoCa)	5Groningen	Groningen, Netherlands	CEA, DYNNIQ, EPI, **TNO**, TUC, UOS
	5GENESIS (possibly)	Surrey, UK (possibly)	
T2S3: Quality of service (QoS) for advanced driving	5GENESIS	Surrey, UK	EPI, NTUA, TUC[1], **UOS**
T2S4: Human tachograph	5GTN	Oulu, Finland	POLAR, **VTT**
T3S1: Tele-operated support (TeSo)	5GENESIS	Surrey, UK	EPI, **NTUA**, TUC, UOS
T4S1: Vehicle prognostics	5GTN	Oulu, Finland	EPI, UOS, **VTT**
T4S2: Over-the-air (OTA) updates	5GTN	Oulu, Finland	EPI, UOS, **VTT**
T4S3: Smart traffic corridors	5GENESIS	Surrey, UK	EPI, OCC, TUC, UOS, **WINGS**
T4S4: Location based advertising	5GENESIS	Surrey, UK	**EPI**, TUC[1], UOS
T4S5: End-to-end (E2E) slicing	5GENESIS	Surrey, UK	EPI, NTUA, TUC[1], **UOS**, VTT
T4S6: Vehicle sourced high-definition (HD) mapping	5GENESIS	Surrey, UK	**EPI**, TUC, UOS
T4S7: Environmental services	5GENESIS	Surrey, UK	**EPI**, TUC[1], UOS

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