PUBLIC-PRIVATE PARTNERSHIP

5G INFRASTRUCTURE PPP

TRIALS & PILOTS

November 2023

5G-PPP.EU

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INTRODUCTION

The 5G Infrastructure Public Private Partnership (PPP) Programme comprises 93 projects organized in three distinctive phases, namely specification, development and experimentation/pilots. Almost all PPP projects have now completed their work, with 8 Phase 3 projects that will be running in 2024. The 93 PPP projects achieved outstanding results and impact, as it has been regularly highlighted in the PPP Programme and the corresponding project websites. The PPP projects have created a plethora of advanced European telecommunication solutions. They also ensured an extremely high momentum and dynamism for the actual trials of these solutions as well as the further development of 5G systems on the road towards 6G networks, including 6G Smart Networks and Services (SNS) Joint Undertaking (JU).

The Phase 2 and Phase 3 projects have validated, trialed, and piloted the 5G technology in many vertical sectors (e.g., Automotive, Industry, Media & Entertainment, Public Safety, Health, Energy, Smart Cities, Transport & Logistics, etc.). The first three "5G Infrastructure PPP – Trials & Pilots brochures" released in September 2019, December 2020 and August 2021 highlighted 30 of the most impactful Phase 2 and Phase 3 Trials & Pilots. These were selected by a panel of experts that assessed their impact and potential. The current brochure n°4 leverages the experience from the previous brochures (including call for inputs and selection by a panel of experts) and brings the attention of readers to 10 additional Phase 2 and Phase 3 Trials & Pilots. These Trials & Pilots have been evaluated and selected, based on several pre-defined criteria (e.g., impact of 5G networks, achieved KPI, Technology and Market Readiness Levels, societal impact, 5G empowerment etc.). The selected Trials & Pilots are listed below according to the 5G Infrastructure PPP Phase / Strategic Objective / Calls timing they belong to and in alphabetical order:

ICT-18-2018, Automotive projects

- **5G-CARMEN:** 5G assisted cooperative and automated manoeuvres in cross border scenarios.
- **5GCroCo:** 5G cross-border service continuity for tele-operated driving.
- **5G-MOBIX:** Spain – Portugal cross border corridor.
- **5G-MOBIX:** Greece – Turkey cross border corridor.

ICT-19-2019, Advanced 5G validation trials across multiple vertical industries

- **5Growth:** Signalling operations for level crossing environments supported by 5G technology.
- **5G HEART:** 5G empowers ambulance services.

ICT-42-2020, 5G Core Technologies innovation

- **FUDGE-5G:** NPN PPDR trials.

ICT-41-2020, 5G innovations for verticals with third party services

- **5G-INDUCE:** Industrial machine control and human interaction services.
- **Smart5Grid:** Remote inspection of automatically delimited working areas at distribution substations.
- **VITAL-5G:** 5G connectivity and data-enabled assisted navigation using IoT sensing and video cameras.

Each of the chosen projects has generated a 2-page flyer outlining the respective Trial & Pilot. These flyers encompass an overview of the Trial & Pilot, its network architecture, deployment aspects, significant outcomes, and the key attributes to 5G technology. They emphasise the benefits and value delivered by 5G networks, which earlier generations cannot offer, illustrating their 5G empowerment.

Clearly, this document demonstrates that the majority of these Trials & Pilots have a significant social impact. They either validate a service that can be monetised or/and introduce a unique disruptive innovation in applications or services.

A bird's eye view of the progress and achievements that the 5G Infrastructure PPP Programme has produced can be directly accessed in the PPP verticals cartography, through specific White Papers and via the multiple webinars organized by the 5G PPP at the programme and projects levels.

Given the vast amount of work being carried out by the portfolio of 5G Infrastructure PPP projects, this Trials & Pilots brochure n°4 is mainly one sample of recent progress. We sincerely hope that you will enjoy reading it as much as we did while putting it together.

Didier Bourse, Carles Antón-Haro, Kostas Trichias, Carole Manero and Miguel Alarcón.

5G ASSISTED COOPERATIVE AND AUTOMATED MANOEUVRES IN CROSS-BORDER SCENARIOS

OVERVIEW

5G-CARMEN is an EC-funded project aimed at demonstrating challenging use-cases for autonomous driving supported by 5G technologies at national cross borders.

Two use-cases have been trialed along the motorway corridor that runs through Italy, Austria and Germany: cooperative and automated lane change manoeuvres and cooperative and automated in-lane manoeuvres. They leverage on 5G connectivity and services running on Mobile Edge Computing (MEC) platforms, as well as PC5 direct communication, to extend the perception of vehicles and support the manoeuvre execution with SAE Level 4 automation (Society of Automotive Engineers defining 6 levels of driving automation from 0 to 5).

The first run of trials was completed between Q2 2021 and Q3 2021 in the cross-border sections of Brenner Pass between Italy and Austria, and in Kufstein between Austria and Germany, with the involvement of different partners operating in the automotive and telecommunication sectors, such as Stellantis and BMW, TIM, Magenta and Deutsche Telekom, Nokia, NEC and Qualcomm, Autostrada del Brennero, and the contribution of research institutes and SMEs (FBK, CNIT, SWARCO, etc..).

5G-CARMEN is one of the three ICT-18-2018 5G PPP corridor projects, with which it collaborated to build a solid base for future activities being carried on in the context of the ICT-53-2020 projects.

ARCHITECTURE

As shown in Figure 1, the pilot is based on vehicles with SAE level 4 autonomous driving capabilities that exchange information through both V2V communication and the 5G network. MEC platforms in the three countries host the services necessary to run the selected use-cases. In order to manage these services and support service continuity when crossing the border an orchestration platform has been developed. The platform works on two layers, locally on each MEC platform, and at a higher level in the cloud. MEC platforms interact with each other and with other services hosted in the cloud, e.g. precise positioning service, Predictive QoS service or the road operators backends.

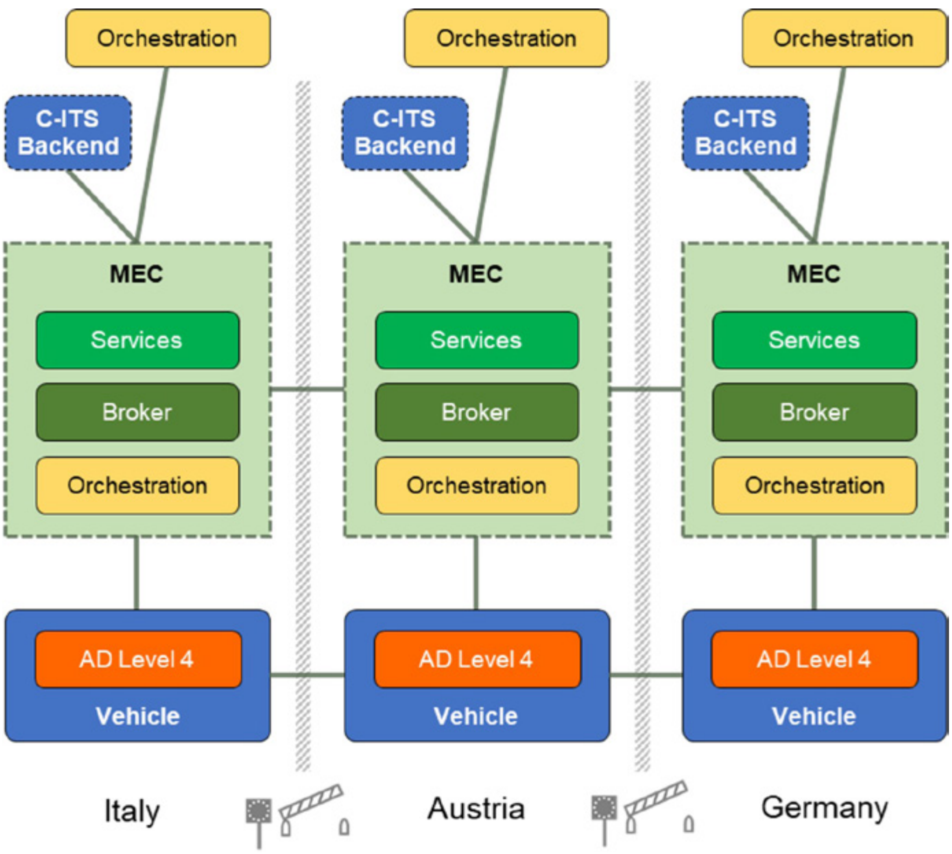

Figure 1: 5G-CARMEN architecture

DEPLOYMENT

5G coverage for the trial was provided in Brennero and Kufstein with commercial networks based on a Non-Stand Alone (NSA) architecture and 5G Spectrum at 3.x GHz. MEC platforms have been deployed in Turin, Vienna and Munich. 5G Networks have been configured with Local Break Out to reduce latency in roaming, and with Fast Network Reselection to reduce the communication gap when crossing the border.

Find more at: https://5gcarmen.eu/wp-content/uploads/2021/10/D3.3-July-2021.pdf

Figure 2: 5G-CARMEN 5G deployments in Brennero and Kufstein

RESULTS

5G showed datarates higher than 300 Mbps in downlink and 60 Mbps in uplink, while RTT latency measurements varied from 20 ms to 60 ms. Field tests showed that fast network reselection minimized session interruption to ~3 sec, and with Local Break Out roaming users latency is comparable to regular users. In tests with 3 BMW vehicles coordinated by the MEC the time to complete the manoeuvre was between 20 s to 150 s. For in lane manoeuvre performed with 2 Stellantis vehicles, trial showed that the number of perceived objects with 5G is doubled. Precise positioning was also validated showing horizontal position error smaller than 20 cm.

Find more at https://5gcarmen.eu/publications/

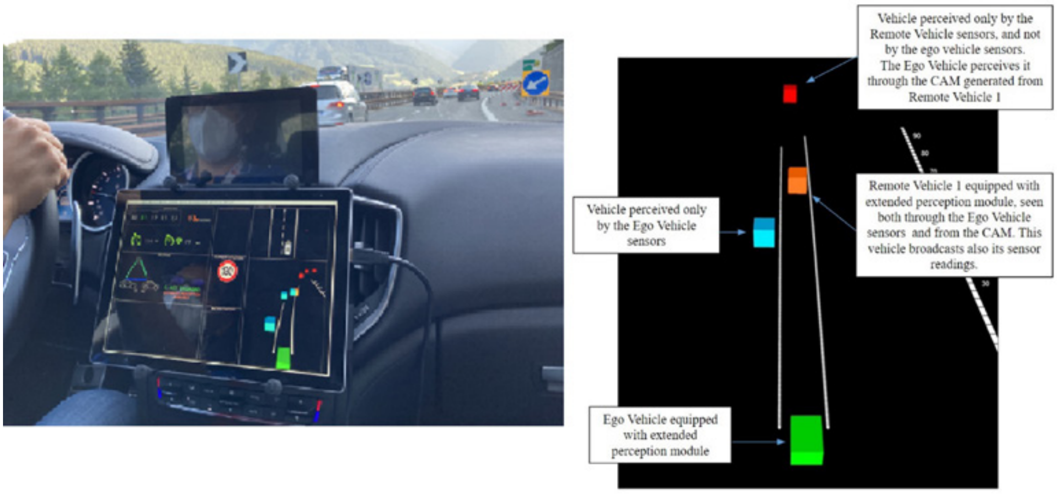

Figure 3: 5G-CARMEN extended perception through 5G network and PC5 direct communication

5G EMPOWERMENT

Cooperative manoeuvring has very demanding requirements for safety reasons. The mobile network must provide Low-Latency, Scalability, Fault Tolerance and Security, which are key pillars of 5G. 5G low latency ensures that time-critical information is transferred well in advance of dangerous situations. In the future, shared data will increase exponentially, as the number of connected vehicles will increase, each vehicle will share more data, and road sensors info could also be transferred. 5G´s increased capacity enables these scenarios. Moreover, 5G supports technologies needed by 5G-CARMEN use-cases such as Precise Positioning, Predictive Quality of Service and Radio Network Information Service (RNIS).

5gcarmen.eu

5G CROSS-BORDER SERVICE CONTINUITY FOR TELE-OPERATED DRIVING

OVERVIEW

Tele-operated Driving (ToD) technology facilitates the deployment of fully autonomous vehicles. In ToD, a connection is established from a Vehicle Control Center (VCoC) to the vehicle via a 5G mobile network, enabling a human operator to remotely operate the vehicle. Sensor data, primarily video, is transmitted from the vehicle to the VCoC, while control inputs (such as steering wheel and velocity) and guidance commands (like waypoints) are sent in the opposite direction. It is evident that a service like ToD relies on uninterrupted network connectivity. In the 5GCroCo trials conducted between October 2021 and June 2022, the service continuity across-borders was assessed through cross-Mobile Network Operators (MNOs) handovers. In this context, 5GCroCo research, much like other projects within the Horizon 2020 / 5G PPP ICT-18 and ICT-53 initiatives, emphasised enabling seamless service continuity at national borders. The ToD trials were carried out by Bosch, Deutsche Telekom, Ericsson, POST, Orange, Technical University of Munich, Huawei, Volkswagen and other partners.

Figure 1: The exterior (left) and interior (right) of vehicles configured for ToD

ARCHITECTURE

Figure 2 shows the architecture of the 5GCroCo solution for the network deployed in the Luxembourg-Germany border area. In this setup, both the Home and Visited networks are equipped to support cross-MNO handovers. These two networks are interconnected through the S10, S8 and S6a interfaces. These interfaces enable the necessary exchange of information to facilitate the seamless transition of a user between networks in two different countries similar to a typical handover process between two Mobile Management Entities (MMEs) within a single network (e.g., when moving within a single country). An additional component in this architecture is a Quality of Service (QoS) prediction functionality. The feature was developed to provide vehicles with notifications about the expected QoS. The QoS prediction model is trained by using collected data from both communication and application layers.

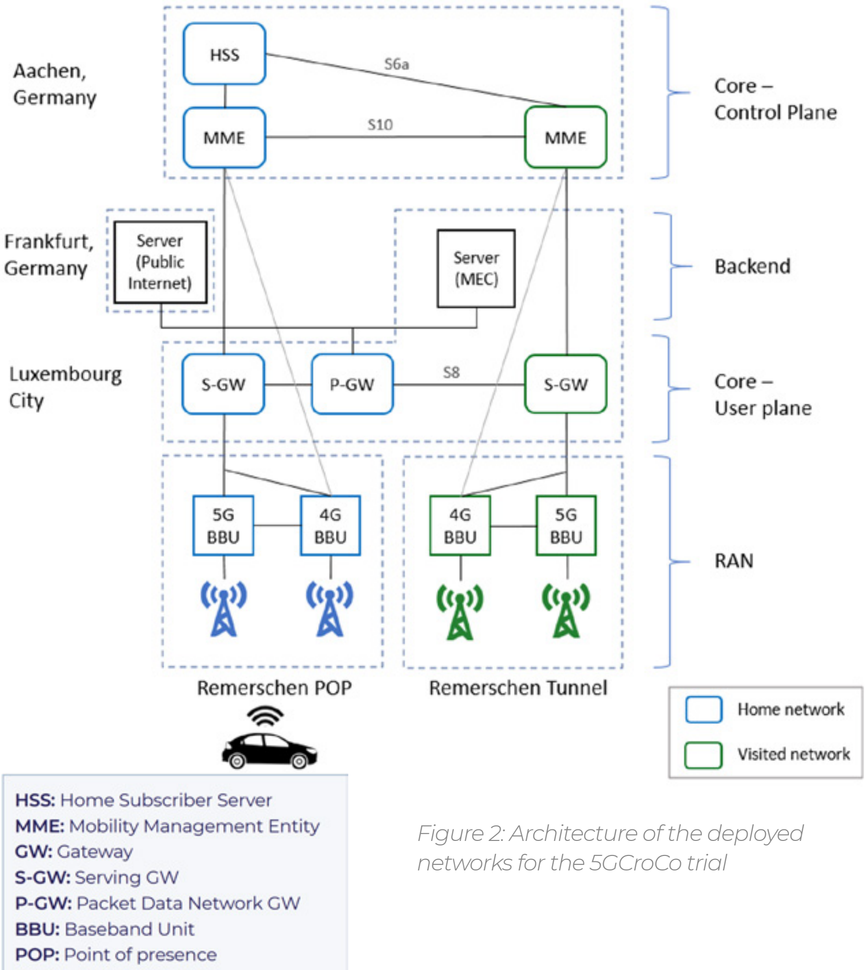

Figure 2: Architecture of the deployed networks for the 5GCroCo trial

Figure 3: VCoC for ToD use-case

DEPLOYMENT

The 5GCroCo ToD trials took place in various areas including fenced and open roads, around the borders between Luxembourg and Germany as well as between France and Germany. The VCoC shown on Figure 3 was located in Schengen. For the Luxembourg-Germany deployment, two Non-Stand Alone (NSA) 5G networks were deployed. The user plane nodes of both network cores were located in Luxembourg City while the control plane nodes were situated in an Ericsson lab in Aachen, Germany. Two bands were used: the 3.7 GHz band was used for 5G coverage with 40 MHz bandwidth in TDD mode. Simultaneously, the 700 MHz band was used for the 4G anchor cells, allocating 10 MHz for both uplink and downlink. A similar set-up was implemented for the France-Germany deployment. For more detailed information on the 5GCroCo deployment, refer to Deliverable D4.1, which is available for download from the 5GCroCo website at https://5gcroco.eu/publications/deliverables.html

RESULTS

The ToD trials involved the measurement of different KPIs. These KPIs can be categorised in two main groups: those associated with the automotive ToD use-case and those related to 5G. In the former group, key KPIs included the service range (measured more than 50 km) and the deviation from the desired path (measured one degree in orientation and up to 2 cm in position), which are crucial for the effectiveness of the ToD case. In the latter group, the focus was on KPIs such as latency (measured below 25 ms), data rate (measured 20 Mbps in the uplink), and reliability (measured above 99 %). In all these cases, the trial results, shown between parentheses in the previous sentence, demonstrated that the 5G network could deliver the required performance levels to meet the demands of the ToD use-case. Furthermore, the cross-border handover time was shown to be almost imperceptible at approximately 100 ms. For more detailed information on the trial results and the specificities of the different user stories within ToD, refer to Deliverable D4.3, which is available for download from the 5GCroCo website at https://5gcroco.eu/publications/deliverables.html.

5G EMPOWERMENT

The ToD use-case strongly benefits from the advantages of the 5G radio network. The low latency, below 25 ms, has proven to be of great importance in delivering visualised information to the human operator in the VCoC as quick as possible. Only if this is ensured, the ToD concept can be used successfully. Additionally, high uplink throughput is essential for ToD to efficiently transmit a substantial volume of sensor data from the vehicle to the VCoC providing the human operator with a comprehensive view of the vehicle's surroundings. The 5G network adeptly handled the 20 Mbps uplink traffic load without any issues. Furthermore, qualitative assessments confirmed that the impact of cross-border handovers on the ToD function is neglectable, and the operation can be maintained while the vehicle is traversing country borders. Moreover, the network's ability to provide accurate QoS predictions played a crucial role. These predictions allowed the ToD service to receive notifications about QoS changes, enabling potential adjustments at the application level.

In summary, 5G has proven its potential to provide significant benefits to the ToD use-case. From the insights gained through the use of 5G, it is concluded that the ToD use-case can be deployed in a much safer and reliable manner, especially in cross-border scenarios, when compared to previous generation of mobile networks.

5gcroco.eu

SPAIN - PORTUGAL CROSS BORDER CORRIDOR

OVERVIEW

The Spain-Portugal (ES-PT) Cross Border Corridor (CBC) is one of the two international corridors of the 5G-MOBIX project. This corridor covers a distance of 250 kilometres between the cities of Vigo and Porto. The ES-PT corridor consortium, composed for 24 partners, covers the entire value chain of 5G technology for CAM, including automotive manufacturers, telecommunications companies, public administrations and research institutions. This corridor has supported the execution of 7 use-cases test. The tests were divided into a first phase at national level, from September 2021 to January 2022, both in Spain and Portugal. and a second phase, focusing on border testing, that was carried out from January 2023 to September 2023. The objective of the tests conducted at ES-PT CBC on 5G-MOBIX has been to show the added value of 5G technology for advanced CAM use-cases, with special focus on the cross-border issues, and to validate the feasibility of the technology to bring automated driving to the next generation of vehicle automation (SAE L4 and above).

Figure 1: ES-PT CBC location and related use-cases and partners

ARCHITECTURE

The ES-PT CBC End-to-End trial architecture is based on the commonly agreed 5G-MOBIX architecture. Two mobile network operators (MNOs), Telefónica and NOS deployed an overlay 5G EPC architecture, NSA (option. 3x) in their Data Centres, located close to their respective border sides, in order to meet the strict requirements imposed by the use-case categories that was demonstrated in this CBC. The Telefónica deployment was shared with the commercial network, while the NOS deployment was a dedicated infrastructure for 5G-MOBIX experimentation. A multi-PLMN solution was used in order to separate commercial traffic from trial traffic. Figure 2 shows an overview of the complementary network architectures of Telefónica and NOS.

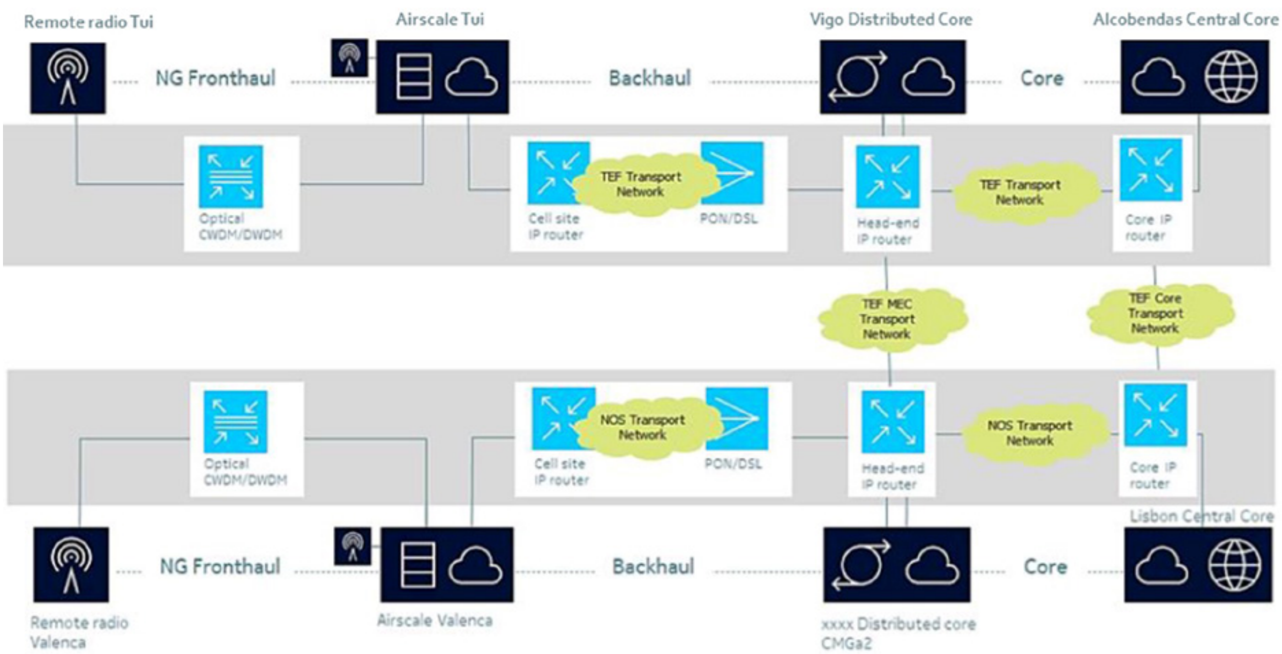

Figure 2: Telefónica & NOS network architecture

DEPLOYMENT

The ES-PT Cross Border Corridor (CBC) stands as one of the two international corridors of the 5G MOBIX project, establishing a connection between the cities of Vigo and Porto. This CBC offers an ideal setting for conducting a diverse array of experiments aimed at demonstrating the benefits of 5G connectivity for user scenarios related to CAM user scenarios.

Along this corridor, two 5G NSA networks was deployed by different partners, with several nodes providing coverage to different areas. Four of these areas were selected for testing the 7 CAM user stories, where different vehicles (autonomous, connected and legacy ones) cooperate with infrastructure taking advantage of 5G capabilities for testing complex manoeuvres and services.

RESULTS

Experiments conducted at ES-PT CBC have confirmed that 5G enables connected and automated mobility with: (1) Low latencies of 18 ms uplink and 9 ms downlink were made possible by edge computing. HR and LBO configurations have demonstrated that the measured E2E latency is suitable for most CAM applications; (2) High performance for HD maps. Users on the ES-PT CBC could achieve an uplink speed of 70 Mbps; (3) Seamless connectivity across borders. Handover times between these networks are remarkably fast, with a delay of only 250 ms, ensuring uninterrupted connectivity for users.

Figure 3: gNB in Spain side. Vehicles used during trials in CBC enviroment. ITS-Center in Manager Center in Porriño.

5G EMPOWERMENT

5G enables the provision of timely, seamless and uninterrupted CAM services in cross-border environments such as the ES-PT corridor and with low latency ensuring fast response times, thus improving safety and efficiency in connected mobility. In addition to latency improvements, 5G technology offers significantly higher data transmission speeds, reaching up to 70 Mbps for high definition (HD) map updates. This high speed facilitates the maintenance of accurate and up-to-date HD maps, which are essential for meeting HD map data requirements. In addition, 5G's ability to provide uninterrupted connectivity when users move from one network to another or from one border to another, with its fast handover of as little as 250 msn, ensures continuous connectivity regardless of user location or network change.

Tests and demonstrations that have been conducted along the Spain-Portugal border have shown the potential and advantages of 5G over previous generations are its lower latency, higher data transmission speeds and better network handover capabilities. Together, these features enable more efficient and reliable connected and automated mobility applications. In addition, the demonstrations made it possible to generate a set of recommendations to establish sustainable business models for the development of 5G corridors in similar environments.

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GR-TR CROSS-BORDER: PLATOONING, TRUCK ROUTING, ASSISTED CROSSING AND SEE-WHAT-I-SEE APP

OVERVIEW

5G Cross-Border Corridor (CBC) has been deployed at the borders between Greece (GR) and Turkey (TR) to conduct real-life trials of cross-border operation of Connected and Autonomous Mobility (CAM) services over 5G. These trials primarily focus on user scenarios related to truck platooning, see-what-i-see application, truck routing and assisted border crossings. These fall into two use-case categories as defined by 3GPP: Extended Sensors and Vehicles Platooning. This CBC covers a service area of 9 km encompassing rigid borders and customs checkpoints. The trials were initiated in 2019 and completed in 2022. Their objective was to assess the 5G technology and deployment options commercially available. A particular focus was placed on evaluating the impact on service continuity and the latency experienced when transitioning from one operator to another while executing the GR-TR user scenarios.

Figure 1: The final demo at GR-TR cross-border corridor

ARCHITECTURE

The end-to-end trial architecture of the GR-TR CBC is aligned with the widely accepted 5G-MOBIX architecture. 5G connectivity within the CBC is delivered by Cosmote on the Greek side and Turkcell on the Turkish side. This is achieved using 5G Non-Stand Alone (NSA) overlay networks, built on 3GPP Release15 Radio and Core equipment provided by Ericsson. The trial cells operate within the 3.5 GHz band, while Active Antenna Systems (AAS) are installed on both sides, using New Radio carrier with a bandwidth 100MHz. To ensure minimal to zero interference between two adjacent networks, regardless of Time Division Duplex (TDD) pattern used, a guard band of 50 MHz selected for the deployment. Furthermore, 3GPP-defined interfaces have been established to facilitate roaming and Inter-PLMN handover between the two networks, as illustrated in Figure 2.

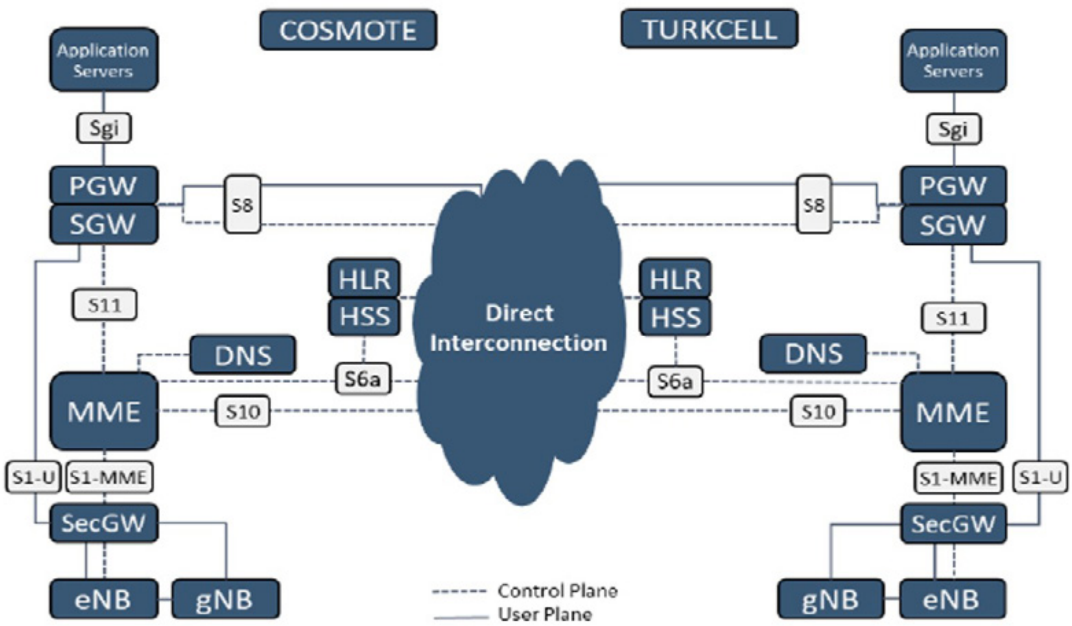


Figure 2: Network architecture at GR-TR cross-border corridor

Figure 3: GR-TR cross-border deployment layout

The GR-TR Cross-Border Corridor is one of the two international corridors, a key transportation point between Europe and Asia, connecting neighboring towns in Greece and Turkey, namely Kipoi (GR) and Ipsala (TR) as illustrated in Figure 3. This corridor holds great importance for international trade. Consequently, it offers an ideal environment for conducting various experiments aimed at showcasing the benefits of 5G technology and connectivity in scenarios involving CAM) users.

The trials confirmed that 5G empowers connected and automated mobility, yielding the following achievements despite the challenges of cross-border environment: (1) Network reliability of 5G connections between On-Board Units and Cloud is 100%; (2) Seamless inter-Public Land Mobile Network (PLMN) handovers are feasible even across country borders with handover interruption times of less than 200 ms, no impact on CAM services; (3) In terms of service continuity, the project demonstrated how combination of Local Breakout Routed Roaming and Edge Computing render latencies in the visited network identical to those in home network; (4) Round trip times averaged less than 100 ms for all routes, including hard border; (5) To ensure seamless video streaming in “See-What-I-See”, E2E latency between User Equipment on the trucks was 70 ms. Comprehensive information regarding above outcomes and Key Performance Indicators of this pilot is available in the publicly available reports .

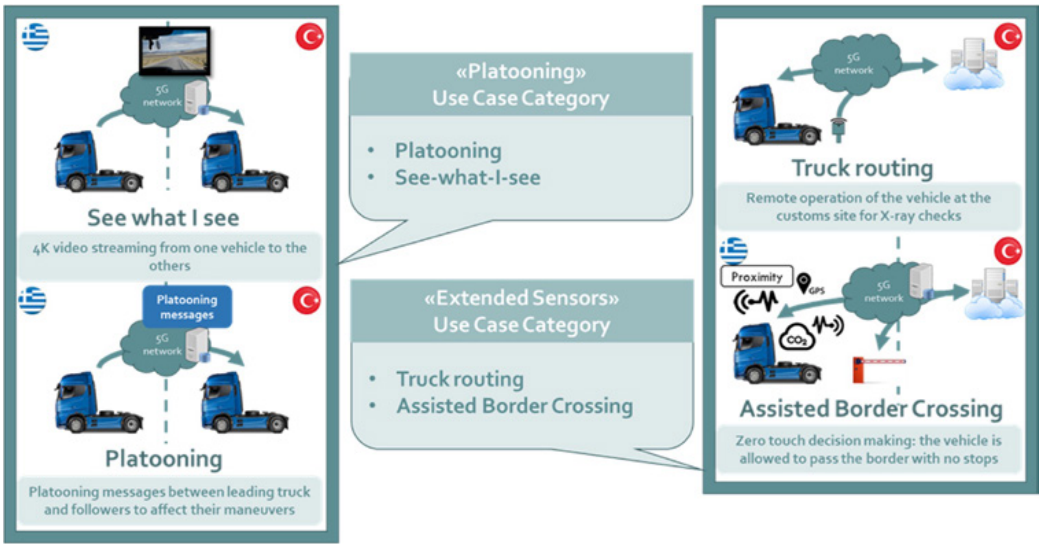


Figure 4: GR-TR cross-border use-cases

5G EMPOWERMENT

5G technology’s ultra-low latency, high data throughput, reliability, edge computing capabilities, V2X communication, enhanced sensor fusion, and remote management make it the ideal platform for advancing Connected and Autonomous Mobility (CAM). These features empower autonomous vehicles to operate safely and efficiently in complex environments, ultimately accelerating the development of CAM technologies. 5G’s ability to deliver seamless CAM services in cross-border corridors between Greece and Turkey is pivotal for advancing autonomous vehicle technology. 5G stands out providing ultra-low latency, e.g. below 20 ms, as well as service continuity with handover interruption times below 200 ms during cross-border. These capabilities ensure very quick responses, significantly enhancing safety and efficiency in connected transportation, a level of quality of service 3G/4G cannot deliver.

5g-mobix.com

SIGNALLING OPERATIONS FOR LEVEL CROSSING ENVIRONMENTS SUPPORTED BY 5G TECHNOLOGY

5GROWTH

OVERVIEW

In the Transportation vertical pilot, Efacec Engenharia e Sistemas, S.A, Altice Labs and IT Aveiro leveraged the 5Growth platform in conjunction with the ICT-17 5G-VINNI infrastructure on signaling operations for Level Crossing environments, addressing critical (Use-case 1) and non-critical communications (Use-case 2), validating 5G usefulness. The two use-cases were deployed at the University Campus and in the Aveiro harbour.

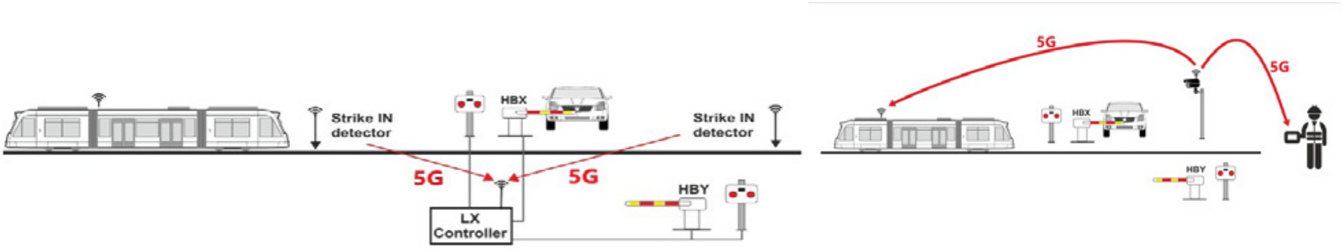


Figure 1: Transportation pilot use-cases: critical communications (left) and non-critical communications (right)

ARCHITECTURE

The Transportation Pilot involved a 5G SA network providing communications between the train detecting sensors, the Level Crossing controller, the train drivers and maintenance teams. This network comprised a 5G Core based on Fraunhofer Fokus Open5GCore Release 5 and a 5G O-RAN provided by ASOCS, which included the CU, DU (both at IT Aveiro) and RU(implemented on the top of a water tower at Aveiro harbour, 7 km away from IT building). Additionally, a carrier-grade 5G SA network at IT Aveiro premises was also used.

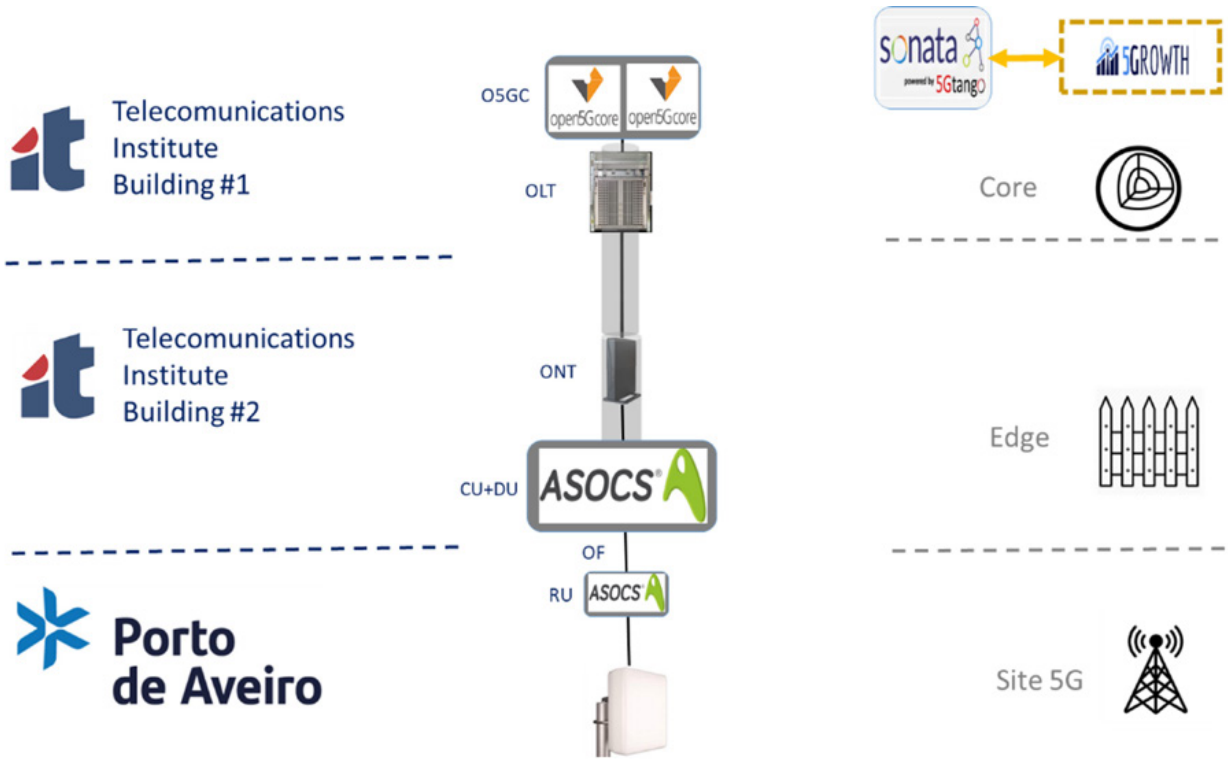


Figure 2: Transportation pilot - 5G infrastructure

The first trial consisted of the level crossing controller managing safety traffic operations with information from sensors and two signalling cabinets deployed along the track, detecting train presence and safely transmitting track information to the controller. The second use-case used GPS location and 5G, enhancing safety conditions at the level crossing. Sensors detect the train at a configurable distance. Video images are captured in real-time and transmitted via 5G to the train driver's console.

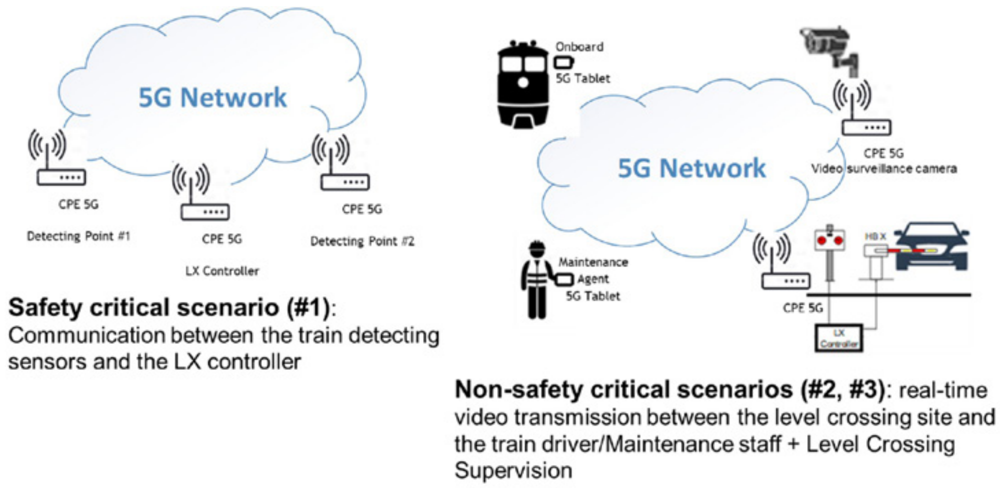
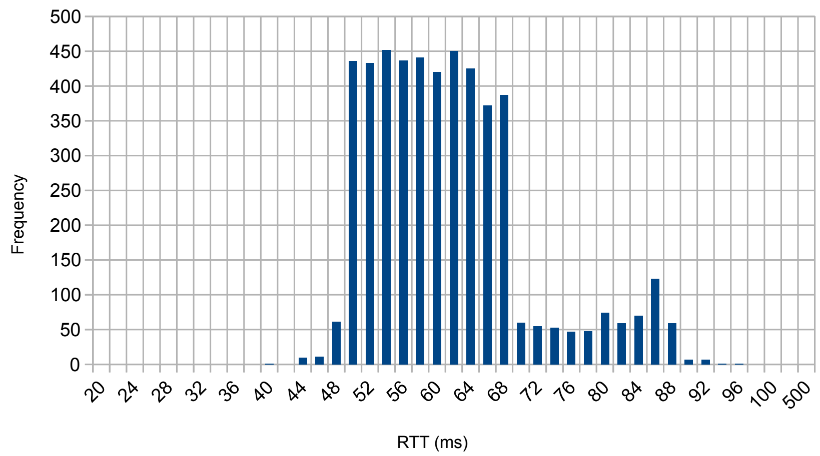


Figure 3: Transportation pilot use-cases

Results collected at Aveiro harbour via a secure VPN encrypted tunnel provided significant results (average end-to-end latency: 30 ms, min: 19 ms; max: 47.6 ms), jitter of 4.703 ms, no packet loss at 64Mbps while moving). For more detailed information, including in-depth technical details, specific findings, and comprehensive results, please refer to the official project documentation: https://5growth.eu/wp-content/uploads/2019/06/D4.4-Final_validation_and_verification_report.pdf



Time (ms)	Min	Avg	Max	Jitter
RTT	39.843	60.585	95.237	9.406
Latency	19.922	30.293	47.619	4.703

Figure 4: Use-case validation on end-to-end latency and RTT

5G EMPOWERMENT

5Growth successfully validated 5G URLLC and eMBB capabilities for transport critical and non-critical communications. Validation at vertical premises demonstrated good performance values for various KPIs including latency, packet loss, bandwidth and availability. Additionally, the project validated 5G innovations for interdomain/inter-operator service deployment and advanced secure communication mechanisms (Moving Target Defense, Cyber Mimic Defense), leading to significant capex and opex reductions, lower installation or maintenance times and improved safety, compared to cabled communications.

5growth.eu

5G EMPOWERS AMBULANCE SERVICES

5G HEART

OVERVIEW

This 5G Stand-Alone (5G SA) trial validated how 5G enhances ambulance services from both medical and transport perspectives. Ambulance services seek healthcare solutions with higher quality and improved cost-effectiveness. Many are interested in enhancing pre-hospital triage and efficiency, requiring accurate and timely decisions during emergencies for swift patient transportation.

The objectives of this trial included: (1) Application-level testing and verifying the usability of remote video (and potentially ultrasound) services by ambulance professionals; (2) Application-level testing and verifying how "Intersection Safety Information Provisioning" can improve road safety and efficiency when vehicles, including ambulances, pass through intersections; (3) Evaluating the capability of 5G to support both applications in the context of ambulance services, even with the presence of other data traffic; (4) Assessing the effectiveness of 5G network slicing in ensuring radio network resources for the delivery of prioritised vertical traffic.

This trial took place in both indoor and outdoor settings in September 2021 and June 2022 respectively. The trial received contributions from 5G-HEART partners including TNO, RedZinc, Dynniq and support from Ambulancezorg Groningen and 5Groningen.

ARCHITECTURE

The network architecture overview is shown in Figure 1. The platform is organised in two pairs of edge and core locations:

- An indoor 5G SA network , with a gNodeB (gNB) and an edge server in Hoogezand, Netherlands and a 5G core network in Groningen, Netherlands.
- An outdoor 5G SA network , with another gNB and another edge server in Helmond and another 5G core network in Den Haag, Netherlands.

These two pairs share a common database (not shown in the figure), which is accessible to network functions responsible for subscriber authentication and authorization.

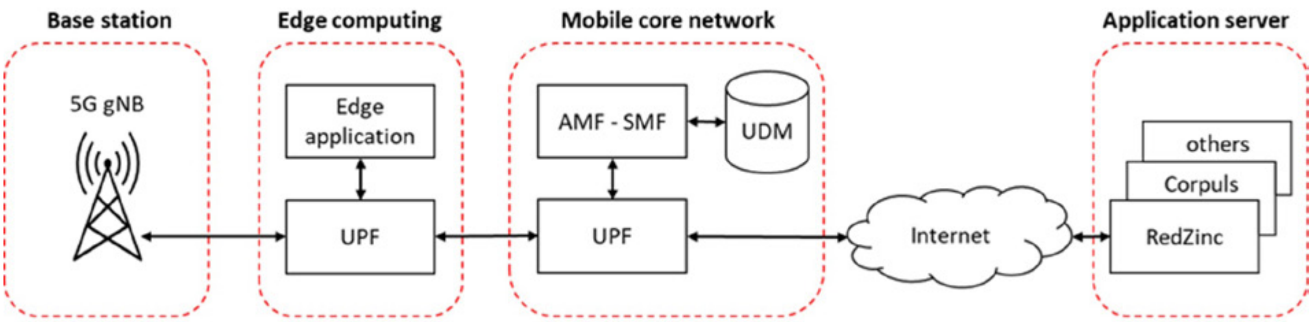


Figure 1: Logical structure of the 5G network used for the trials

Application servers may also be located remotely and accessed via Internet. For the trials, both the RedZinc server (used for the delivery of video-audio feed from a camera headset of the paramedic) and the Corpuls® server (used for the delivery of vital patient data from the electrocardiogram device) are located in Frankfurt, Germany.

Indoors, a gNB was installed with six directional antennas mounted on a warehouse wall at a height of 8 m, along with an additional six omni-directional antennas fixed to the ceiling. The configuration is illustrated in Figure 2, where the "Office" was used to emulate the place of a remote doctor, and the "Warehouse" as the site of emergency. Outdoors, another gNB was deployed near a highway intersection, featuring two directional antennas to optimize network coverage for the highway. Figure 3 shows the outdoor route and antennas for this setup. Both gNBs operated on the 3.5 GHz band with a bandwidth of 100 MHz and a sub-carrier spacing of 30 kHz.

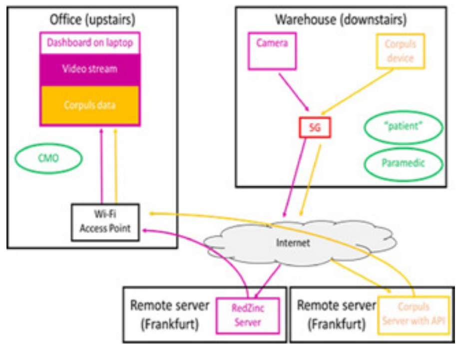


Figure 2: Trial setup indoor scenario (Hoogezand, NL)

Figure 3: Trial setup outdoor scenario (Helmond, NL)

The verification process confirmed critical outcomes: (1) Improved decision-making, enabled by real-time video and vital patient data sent from the paramedic to a remote specialist; (2) Intersection priority: by requesting and receiving a "green light priority", an ambulance can swiftly navigate intersections, expediting the patient's journey to the hospital; (3) 5G's role in real-time and reliable communication: with a measured round-trip time down to 7 ms and over 70 Mbps UL throughput; (4) Network Slicing for mission-critical services, ensuring sufficient radio resources for delivering such services, even in the presence of background traffic (see Figure 4).

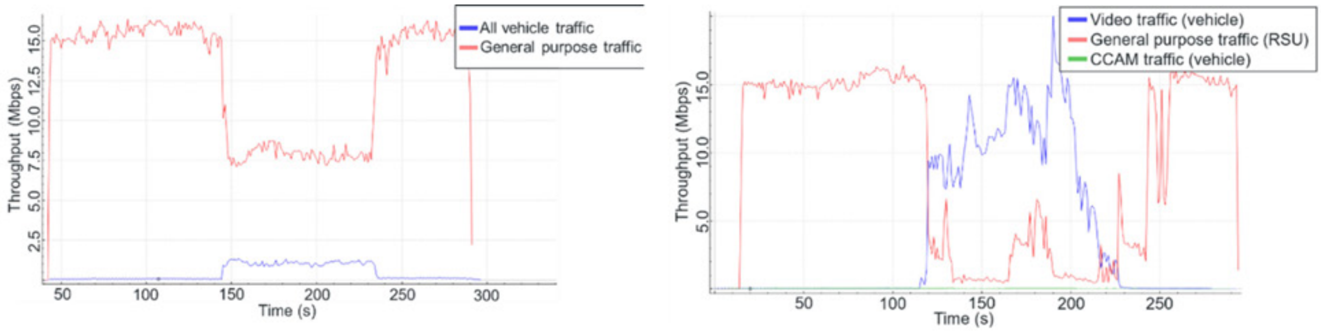


Figure 4: Performance of video services without (left) and with (right) network slicing in the presence of background ("general purpose") traffic, along the route of Figure 3

Please refer to the video links below for more information of the results: https://www.youtube.com/watch?v=f5fxYYQEIl8&t=6s and https://www.youtube.com/watch?v=U0oICsJnaaQ

5G EMPOWERMENT

The essential features showcased in this trial encompass: (1) eMBB for video streaming even with multiple video streams: average UE uplink throughput up to 79 Mbps has been measured during the trials; (2) URLLC for reliable and real-time green traffic light requests and responses: round-trip time down to 7 ms has been measured with a local edge server; (3) End-to-end network slicing with QoS differentiation which ensures sufficient radio resources for delivering mission-critical services, even in the presence of background traffic; (4) Edge computing enabling low-latency communication: local servers have been used in the trials to host 5G User Plane Function (UPF), with the rest of the 5G core network located in a remote office building. With 5G-enabled remote video streaming and "green light priority", ambulance services can enhance pre-hospital triage and efficiency, resulting in better patient treatments and higher cost effectiveness.

5gheart.org

RAPID DEPLOYMENT OF BROADBAND COMMUNICATIONS FOR PPDR VIA PORTABLE 5G PRIVATE NETWORKS

FUDGE-5G

OVERVIEW

The primary trial objective was to showcase the capacities of a Stand-Alone (SA) private 5G network in providing broadband services to first responders and special forces. The trial focused on validating the integration of 5G SA components and deploying Public Protection and Disaster Relief (PPDR) specific applications in a mobile vehicle created by Telenor and named Network-on-Wheels (NoW). This all-in-one solution hosting radio, core and other applications, proved its transportability during events with the Norwegian broadcaster NRK and during the NATO response 2022 in Norway, confirming its readiness level (TRL of 9). An upgraded version is currently in use for the SNS Stream D project, Imagine-B5G.

In September 2022, the trial simulated a rescue mission where the NoW's 5G network kept emergency personnel connected and involved ICT-42 FUDGE-5G partners such as Telenor, Athonet an HPE acquisition, OneSource, Thales and Huawei. The Norwegian Defense, Nemergent, Goodmill Systems and Triangula were part of the advisory board and provided additional equipment for the NoW.

ARCHITECTURE

The NoW served as a 5G SA solution, providing on demand coverage with guaranteed Quality of Service (QoS), computing at the edge, fully autonomy, the ability to connect partners' edges, security and ruggedness, and quick deployment with straightforward operation. The 5G Core (5GC) is provided by Athonet, integrated in ruggedized servers for mission-critical usage, and especially adapted to on-demand Stand-Alone private network deployments in PPDR scenarios. It also features the capability of self-healing and resiliency. The 5GC is connected over an exposed N5 interface to a Mission Critical Application (MCX), featuring instant messaging, man-down alerts, group chat, voice and video calls; and image sharing. The radio is provided by Huawei, a BBU DSB 4900 and an AAU5636 3400 MHz. Other relevant PPDR applications are on-boarded.

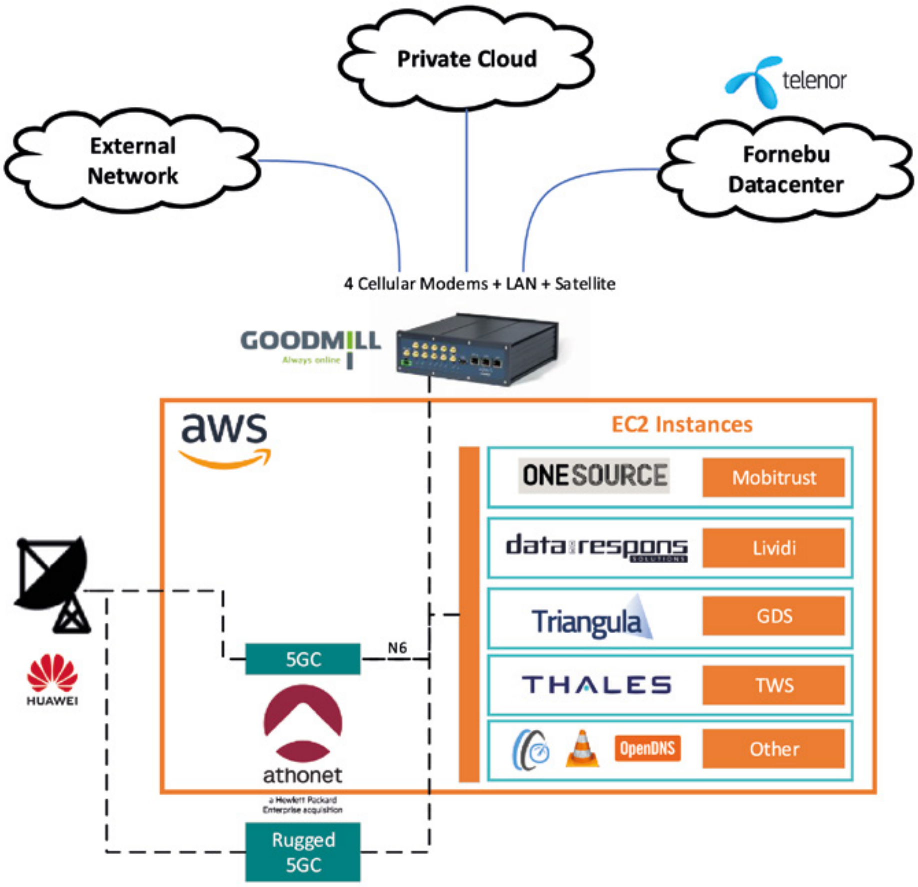


Figure 1: Diagram block highlighting the equipment and applications on-boarded in the NoW

DEPLOYMENT

On September 8, 2022, the ULENDT conference was held in Lom, Norway; featuring a simulated search and rescue trial. To address the challenge, the FUDGE-5G NoW was deployed in the emergency area to provide connectivity and enable communication between the first responder teams. In the rescue trial, the Athonet 5G core and other PPDR relevant applications were deployed on an AWS Snowcone edge server in the NoW. A multichannel router solution from Goodmill Systems was integrated, capable of aggregating multiple links. Additionally, the trial incorporated Mobitrust situational awareness, Triangula gunshot detection and Push to talk from Nemergent. Norwegian Defense, Norwegian Air Ambulance and Red Cross acted as stakeholders for this trial.

More info at https://www.telenor.com/stories/advance/new-mobile-5g-solution-could-be-a-game-changer-in-emergency-operations .

Figure 2: Execution of the trial and rescue demo using the FUDGE-5G NoW

RESULTS

The trial successfully confirmed the integration of 5G SA components along with the use of PPDR specific vertical applications within the NoW platform. The stakeholder, Norwegian Defense, prioritized the actual technology implementation and execution, focusing primarily on DL and UL throughput values. Instead, more effort was put on the validation of some of the functional requirements, such as deployment speed or backhaul integration. It demonstrated the ability to rapidly establish a secure, autonomous 5G network with essential services. Additionally, the trial recorded downlink and uplink throughputs of 433 Mbps and 130 Mbps respectively for the 40 MHz bandwidth. while supporting six live HD feeds at various locations. The solution has received industry recognition, winning the "Best use of advanced technology" award at the International Critical Communications Awards 2022. More info can be found in FUDGE-5G D4.3 Deliverable.

5G EMPOWERMENT

Softwarization of 5G facilitated the integration of the 5G core and various cloud-based vertical applications into a rugged, all-in one solution on an AWS Snowball Edge server, creating portable 5G nodes.

Use of secure, portable 5G bubble networks for the rapid deployment of a communication networking response to natural disasters or emergency situations like landslides, earthquakes and floods, when the terrestrial network is damaged or unusable, was validated.

Enhanced throughput achieved through Multiuser MIMO and increased bandwidth in 5G Bands, enabling live broadcasting of multiple video streams to different emergency service centres and personnel (433 Mbps DL, 133 Mbps UL)

fudge-5g.eu/en

INDUSTRIAL MACHINE CONTROL AND HUMAN INTERACTION SERVICES

5G INDUCE

OVERVIEW

This pilot aimed at validating automated and human-aided control solutions for industrial machinery. It included three use-cases: automated AGV (Automated Guided Vehicle) management, gesture-based operation and Augmented Reality (AR)-aided remote control. ABB Robotics' industrial AGVs, equipped with YBVR's cameras and Fivecomm's 5G Stand-Alone (SA) modems, stream raw video through a fully-fledged 5G SA network provided by Ericsson to specialized applications. These applications recognize gestures from the video feed and transmit the necessary commands over 5G back to the AGV to make it stop or change its direction, or they add an overlay of real-time information about the AGVs operation that can be visualized on AR goggles.

Final pilot validation tests were conducted at Ford premises between February and May 2023. The pilot was developed and tested within the framework of ICT-41 5G-INDUCE project at 5TONIC Lab in Madrid and Ford Motors factory in Valencia. The pilot demonstrates the strong replicability and potential for exploitation of the solutions.

The experience of partners involved in 5G-enabled I4.0 pilots in 5G PPP projects such as ICT-17 5G EVE and ICT-19 5Growth was leveraged, and learnings from this pilot have been made available to other ICT-41 projects.

ARCHITECTURE

The 5G-INDUCE Spanish experimentation facility provides the capability of deploying and test multiple configurations and distributions of the components within the overall solution. Figure 1 illustrates the logical architecture of the pilot as well as one of the specific distribution scenarios considered in the project. The 5G Radio Access Network (RAN) SA coverage and the User Plane function (UPF) are provided at Ford factory, where the user devices are placed, supported by the 5G Core SA Control Plane functionalities at 5TONIC (350 Km away), and by a near-edge computing facility at Universidad Politecnica de Valencia (25 Km away). Find more detail in section 3 of 5G-Induce D5.2: https://private.5g-induce.eu/Documents/PublicDownload/278

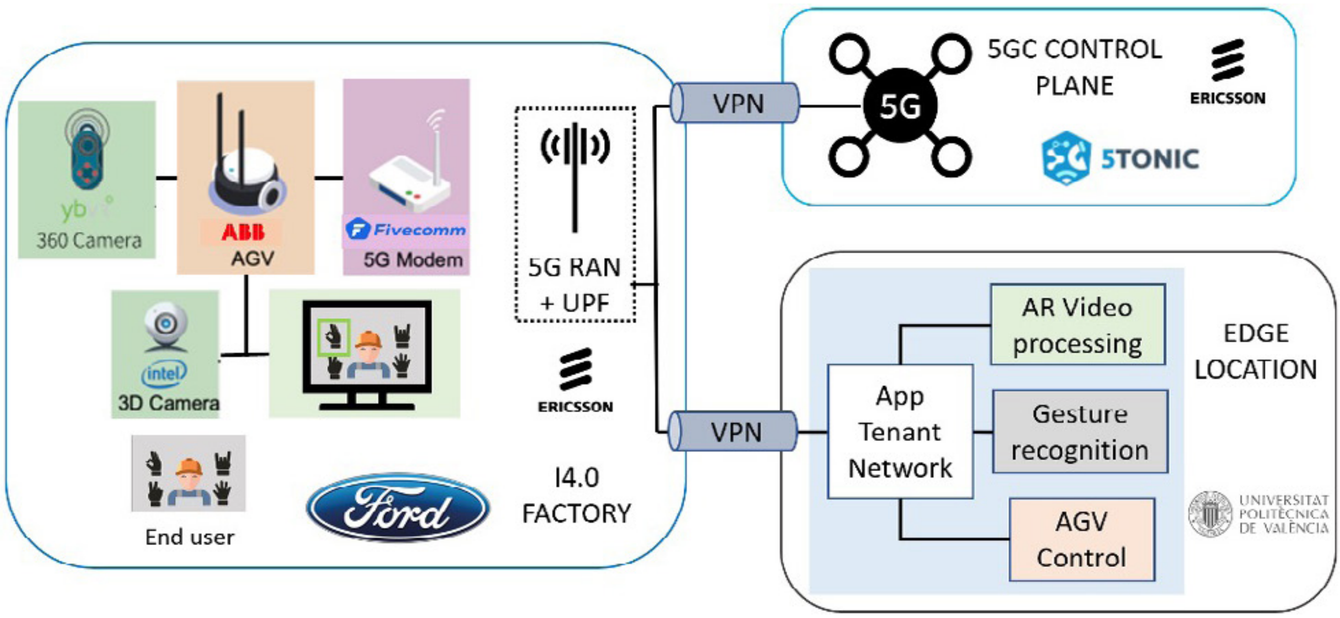


Figure 1: Logical and distributed architecture of the pilot

DEPLOYMENT

At Ford factory, both indoor and outdoor coverage at 3.5 GHz band is deployed to support the AGV operations. This deployment includes the use of five radio DOTs (indoor antennas) connected via ethernet plus the Radio 4408+Antenna 6524 (outdoor) connected by optical fiber to cover the AGV itineraries, and a rack equipped with 5G RAN+UPF which had been previously validated at 5TONIC. The pilot applications are deployed and tested in different Edge computing scenarios at 5TONIC lab, UPV premises and Ford factory premises.

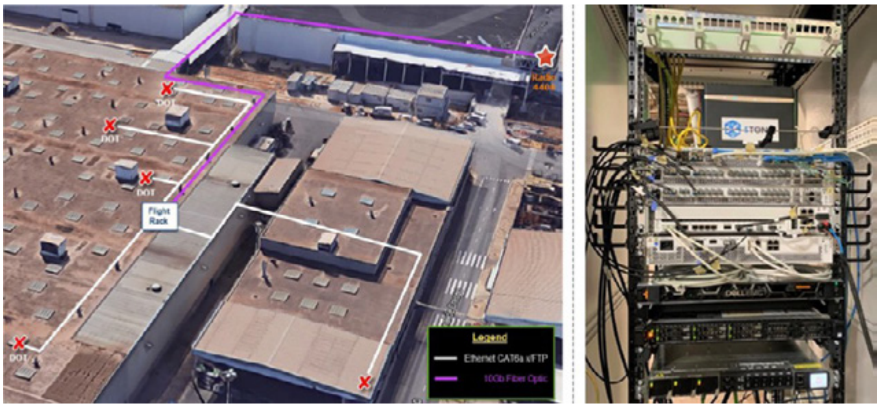


Figure 2: 5G RAN and UPF deployment at Ford factory

RESULTS

During previous testing at 5TONIC in June 2022, the validation of End-to-End (E2E) network slicing was a significant achievement (press release): using Radio Resource Partitioning, resources were granted for the use-cases traffic, ensuring they were not impacted by other concurrent traffic flows. During final testing at Ford factory, the deployed 5G SA Rel16 network met well the capacity demands of all use-cases running together. A Round Trip Time (RTT) of 40 ms was measured adding the travel from the application to the UE, the processing in the UE and the travel back.

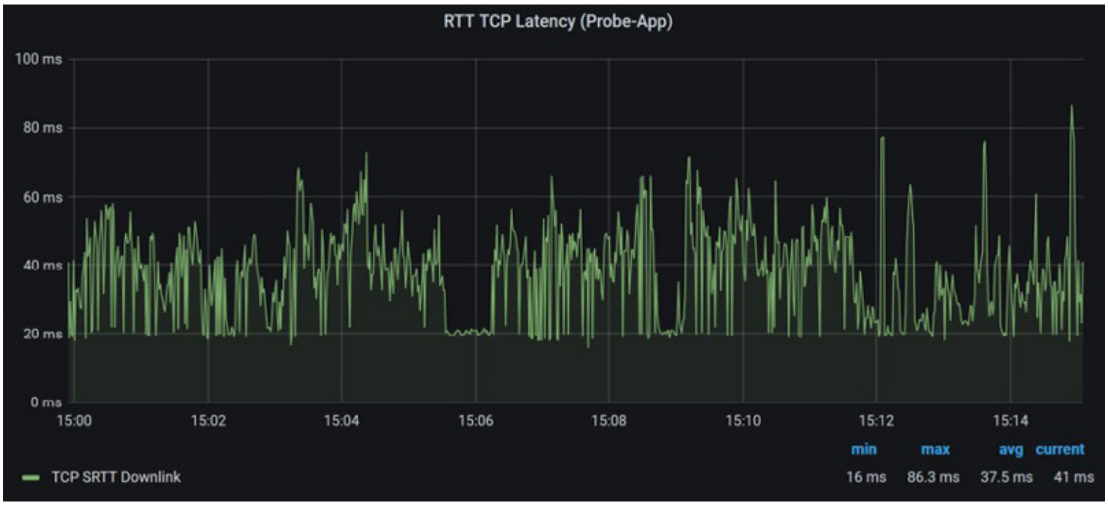


Figure 3: RTT latency of user plane traffic in Downlink

For more information about the results of the trial, please visit: https://www.5g-induce.eu/index.php/outcomes/

5G EMPOWERMENT

5G eliminates the need for wired connections which can be inflexible and expensive, and often unavailable at certain locations. Additionally, 5G technology is harnessed for three KPIs: very low latency, crucial for minimising the RTT of the E2E traffic, particularly when complex time-costly image processing is involved (expected 12 ms of one way delay average in the radio interface), high-reliability, which ensures the smooth synchronization of control processes within their set time-outs (expected 99% of packets under 15 ms of latency), and guaranteed UL data rates, enabler for concurrent streaming of independent videos (expected 20 Mbps for each connected AGV). Finally, flexible distribution of Cloud Network Functions (CNFs) and applications, either central, on near Edge or on far Edge, allows to achieve optimal performance at controlled costs.

5g-induce.eu

REMOTE INSPECTION OF AUTOMATICALLY DELIMITED WORKING AREAS AT DISTRIBUTION SUBSTATIONS

Smart5Grid

OVERVIEW

This pilot was one of the four energy vertical pilots of the Smart5Grid project, funded under Phase III of the 5G PPP Programme. Its goal was to develop an automated process for monitoring workers and their tools as they access primary power substations, enhancing existing safety measures. A private 5G network with edge computing capabilities was deployed and tested from February to September 2023. The precise positioning is achieved through: (1) Portable bracelets worn by workers, equipped with Ultra-WideBand (UWB) tags; (2) 3D cameras placed within the working area to detect the presence of workers. Both systems transmit the collected data over the 5G network to a specific Network Application (App) running on the edge. This Network App processes the data, creates a virtual 3D security zone and triggers audio-visual and physical warnings when required. The alarm is activated: (1) when workers or their tools cross from the safety zone into the danger zone; (2) when workers manually press an SOS button on their bracelets; or (3) in the event that the bracelet detects a sudden fall of a worker. Partners working in the pilot were e-distribución, i2CAT, Sidroco, Nosia, Atos, Engineering and Enel.

ARCHITECTURE

The pilot architecture shown in the picture involves user equipment like cameras transmitting information over 5G New Radio (NR). The radio unit is connected to a vRAN server linked to core and app server where a kubernetes cluster managed by Neutroon (AWS – Amazon Web Services) hosts the Network App. Before the deployment process, the Network App is verified and validated outside the substation by the Smart5Grid Platform, ensuring functionality in the production environment. This testing process is managed by the Network App Controller (NAC): Once the Network App is uploaded in the Open Service Repository (OSR), the Network App is forwarded to the Validation and Verification (V&V) framework, to make sure it is working properly before moving to the production environment..

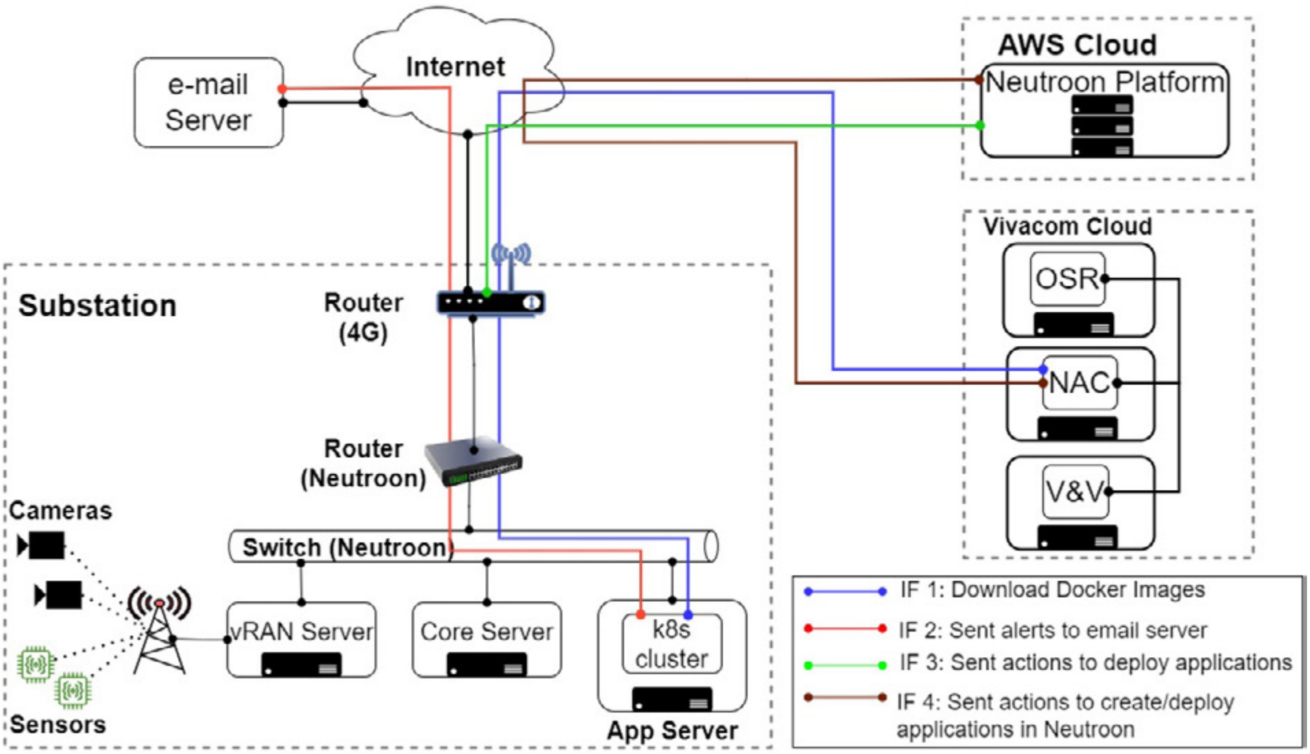


Figure 1: Use-case architecture

The 5G Stand-Alone (SA) network implemented in the substation includes a base station, vRAN servers, app servers, and the 5G core. A dedicated network slice has been created specifically for the pilot, featuring isolated computing resources, a Public Land Mobile Network Identity (PLMNID) for 5G NR, and a local 5G Core. To achieve precise positioning of workers and tools, UWB anchors have been strategically placed at the site. These anchors transmit data via a 5G Customer Premises Equipment (CPE) to the edge application. Additionally, cameras installed in the infrastructure are connected to another 5G CPE within the same dedicated slice, providing real-time worker position information to the monitoring application. More information can be found: https://smart5grid.eu/use-cases/use-case-2/

Figure 2: Left: monitoring field devices. Centre: physically delimited area. Right: outside view Ecogarraf substation

Performance tests were performed to assess the capacities of the 5G network. These tests involved transmitting both UDP and TCP based traffic, as both are used by the Network App that assures the safety of workers:

KPI	Required	Measured
UDP Uplink/Downlink (Mbps)	>=10	66.1 / 95.6
TCP Uplink/Downlink (Mbps)	>=10	66 / 58.3
End-to-end Delay (ms)	< 100	13.8 (UE<-> 5G core)
Availability / Reliability (%)	99.99%	100%
Isolation	Yes	Yes

Table 1: Expected KPIs and results

The necessary performance was achieved across all KPIs: over 60 Mbps available for uploading data from the sensors and cameras. Additionally, a small latency of 13.8 ms and 100% reliability and availability were measured during three weeks of runtime. Isolation was assured, as user equipment can only access services from their own slice. In summary, the requirements for the remote inspection service were met.

5G EMPOWERMENT

The use of a 5G SA setup and the deployment of a private 5G network in this trial enable full control over the 5G network resources, allowing precise allocation to the deployed services. This offers significant advantages on crucial KPIs such as end-to-end delay below 20 ms, over 60 Mbps UL data throughput, 100% availability and reliability, when compared to alternatives like Wi-Fi. The use of dedicated network resources makes it possible to implement a real-time service for monitoring the safety of workers, ensuring that the service is secure and isolated from other potential services, thanks to the use of a dedicated slice. Additionally, the Network App and the Smart5Grid platform facilitate an easy deployment, orchestration, and management of the services.

smart5grid.eu

5G CONNECTIVITY AND DATA-ENABLED ASSISTED NAVIGATION USING IOT SENSING AND VIDEO CAMERAS

OVERVIEW

The VITAL-5G Romanian trial dealt with implementing a data-enabled assisted navigation application using IoT sensing system and video cameras installed in Galati port and on ships and barges (cargos). The Galati port is the largest on the Danube River and the second-largest in Romania. It is an entry point for large shipping traffic from the Black Sea towards continental Europe and was part of the Rhine-Danube Trans-European Transport Network Corridor. The trial is performed on a series of ships belonging to CNFR NAVROM, a Romanian river transport company, carrying millions of tons of various goods through both internal and external routes. Several Network Applications are evaluated during the trial as depicted in Figure 1.

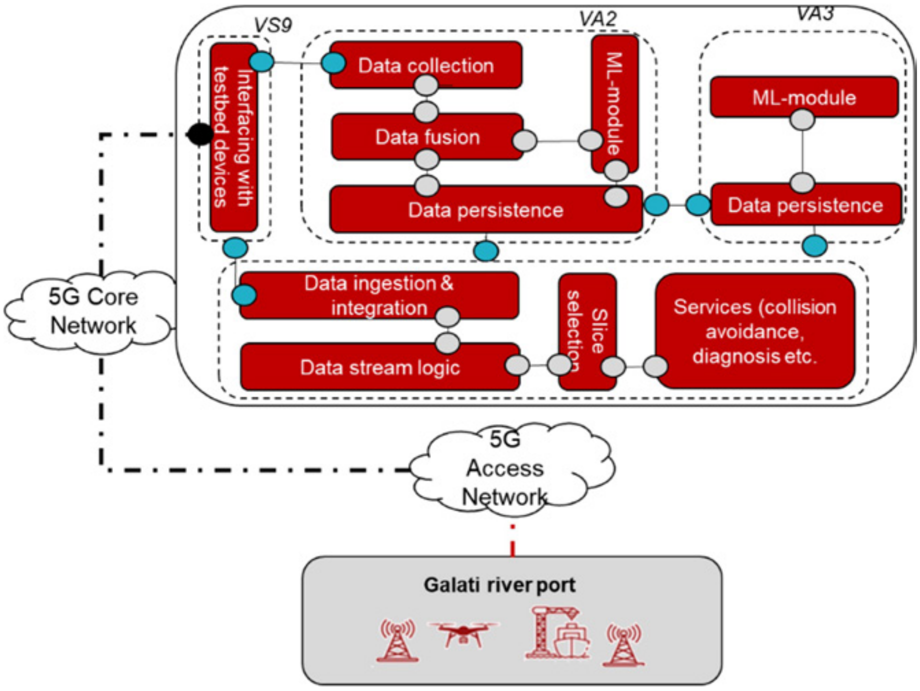


Figure 1: VITAL-5G Romanian trial site overview

ARCHITECTURE

The testbed architecture is based on 3GPP Rel. 16 with 5G SA and provides automatically deployment of end-to-end slicing like eMBB and URLLC based on network programmability implemented. There are deployed two gNBs (N78 radio band), one in Bucharest in the 5G Lab (https://5glab.orange.ro/en) and one in the Port of Galati with the 5G Core located in Bucharest. The 5G SA Core is connected with the EDGE computing infrastructure where the Network Applications are automatically deployed and are running. The VITAL-5G centralized platform provides unified interfaces to the users for onboarding and experiments activities, services monitoring and also is connected to the 5G testbed for network (RAN, Core) for services and slice orchestration.

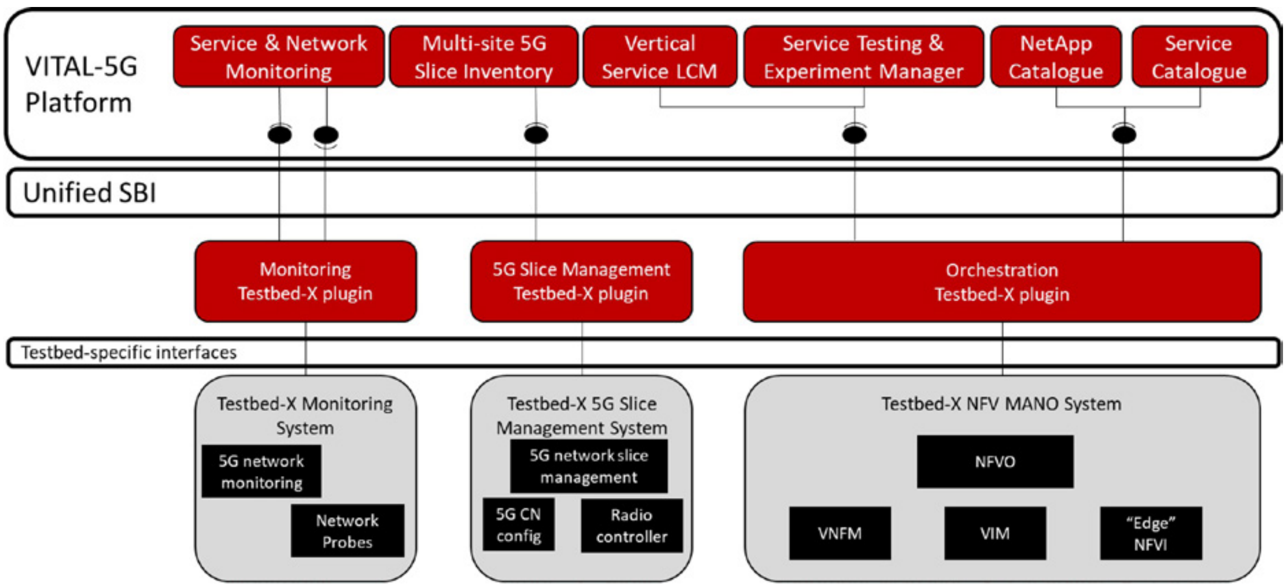


Figure 2: VITAL-5G trial architecture

DEPLOYMENT

The trial took place in the port of Galati on a NAVROM ship, where the necessary hardware and software (racks, cables, cameras, sensors etc.) was installed. A dedicated CAN-BUS interface for data collection from NAVROM ship's engines was developed. Depth sensors (+DST2), AIS data interfaces and DVR of cameras were ready for data transmission to a PLC. Weather and air quality stations were also installed in Galati port. A 5G multi-slice outdoor router was installed on the ship and was used for collecting the data and transmitting them to the 5G network through dedicated network slices, based on the Network Application services requirements (mobile broadband or low-latency), as for the trial the end-to-end 5G network slices were available.

Figure 3: 5G SA deployment and experimentation in Galati

RESULTS

The pilot has achieved the key objectives of the Network Applications business functionality over the 5G network, the trial's applications being successfully automatically deployed in the testbed with proper service characteristics. The measured KPIs, as network deployment and instantiation, multi-slices creation and end-user's application's association to the service's slice, end-to-end services and slice performance assurance (low-latency delay < 5 ms) concludes the achievements for an advanced 5G open experimentation testbed. The pilot provides enhanced capabilities in terms of automatic services deployment, traffic prioritization, monitoring and dynamic slice control, providing new business approach and opportunities for the 5G verticals

5G EMPOWERMENT

The pilot results confirmed the 5G enhanced capabilities compared to previous generations, in terms of network performance. Notably, it showed improvements in network performance such as the throughput (1Gbps) or reduced delay for critical services (5ms one-way end-to-end delay). The trial demonstrated a novel approach to implementing services through the VITAL-5G centralized orchestration platform which manages the service life-cycle-management within the proper network slice. The trial also highlighted the end-to-end network and service monitoring with KPIs displayed on dashboards for Network Applications experimenters. The implemented network multi-slice with dynamic service profile control provides the ability to efficiently allocate network resources to services communication requests.

vital5g.eu

HIGHLIGHTS ON THE VERTICAL SECTORS

5G EMPOWERMENT AND COLLABORATIONS

Although the 5G Infrastructure PPP programme is slowly ending, many projects have still been active in 2023, working on core technology innovations, smart connectivity beyond 5G and service provision to vertical sectors. Significant efforts have indeed been allocated to develop innovative solutions for multiple vertical industries. Many PPP publications on 5G and verticals including among others (1) the 5G Infrastructure PPP White Paper "Empowering Vertical Industries through 5G Networks – Current Status and Future Trends"[1] ; (2) the 5G Infrastructure PPP key achievements version 3.0[2], 3.1[3] and 3.2[4]; (3) the 5G Infrastructure PPP White Paper "Service Performance measurement methods over 5G experimental networks"[5]; (4) the PPP Vertical Cartography webpages[6]; and (5) the recent 6G-IA webinar "A 6G Vision: 3GPP Release 19 & Vertical Industries Requirements"[7] emphasize the demonstrated effectiveness of the 5G Infrastructure PPP prototypes, trials and pilots in showcasing the tangible empowerment that 5G networks provide to vertical sectors. The publications explain how vertical services KPIs can be mapped into network KPIs and how enhanced technological KPIs such as throughput, delay reliability, along with inherent network flexibility and rapid service deployment have established an optimal environment for service developers. This setting enables the design and delivery of services and applications that will significantly impact the European economy and the daily life of citizens. In the context of the 5G Infrastructure PPP, tangible results from the experimentation platforms have been systematically collected from multiple projects and analysed to demonstrate the clear benefits of 5G networks, and to indicate what also remains open for further research activities towards 6G networks. The key 5G features regularly highlighted in the PPP publications include Network Slicing, Mobile Edge Computing, Functional Split in RAN, Advanced Security, Smart Network Management, Location Services & Context Awareness, 5G NR Capabilities, Softwarization, Service Chaining, Traffic Steering, Spectrum and Coverage, Guaranteed QoS...

The Trials & Pilots included in this Brochure n°4 address the following verticals: Industry 4.0, Connected Mobility, Health, Transportation and Logistics, Public Safety and Energy. Some of the key 5G enabling features demonstrated in the Brochure n°4 Trials & Pilots include:

- Automatic management and novel approach of E2E improved services, allowing dynamic adaptations.
- Support of advanced critical services providing new business approaches and opportunities.
- Successful delivery of diverse highly demanding applications with dedicated isolated slices.
- Validating very high capabilities of 5G including high reliability, high data throughputs for uplink and downlink communications including video.
- Dedicated slice for isolated computing resources allowing precise positioning of workers and tools, monitoring the safety of workers. Significant advantages on crucial KPIs such as end-to-end delay below 20 ms, over 60 Mbps UL data throughput, 100% availability and reliability, when compared to alternatives like Wi-Fi.
- Enhanced security and safety thanks to very high data throughputs and high reliability enabling multiple videos streams.
- Ability to manage a high number of connected objects safely.
- Integration of automated-aided control solutions in a flexible distribution of network cloud functions.

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[1] *https://5g-ppp.eu/wp-content/uploads/2020/09/5GPPP-VerticalsWhitePaper-2020-Final.pdf*

[2] *https://5g-ppp.eu/key-achievements-v3*

[3] *https://5g-ppp.eu/key-achievements-v3-1/*

[4] *https://5g-ppp.eu/phase-3-key-achievements-3-2/*

[5] *https://5g-ppp.eu/wp-content/uploads/2021/06/Service-performance-measurement-methods-over-5G-experimental-networks_08052021-Final.pdf*

[6] *https://verticals-cartography.5g-ppp.eu/?_ga=2.92090451.833367660.1698140288-240316981.1688368566*

[7] *https://5g-ppp.eu/event/a-6g-vision-3gpp-release-19-vertical-industries-requirements-webinar/*

- Integration of 5G Core with diverse cloud-based vertical applications, culminating in the emergence of an all-in-one solution.
- Effective deployment and use of secure and portable "bubble" networks in swiftly establishing crucial responses.
- Validating continuous optimisation of networks and computing resources.
- Efficient support of cross-borders CAM scenarios with DL Data Rates up to 300 Mbps, UL Data Rates up to 60 Mbps, RTT latency between 20 ms and 60 ms and session interruption during network reselection close to 3 seconds. Roaming users latency comparable to home users when Local Break-out used. Precise positioning achieved with horizontal position error smaller than 20 cm.
- Seamless CAM connectivity across borders with handover times as low as 250 ms between two neighbouring networks. Low latencies for cooperative message exchange, with DL latency of 9 ms and UL latency of 18 ms achieved with the use of edge computing. Uplink Data rates of up to 70 Mbps ensuring fast and efficient HD maps updates.
- Meeting demands of Teleoperating (ToD) driving use with Latency <25 ms, UL Data Rate ≥ 20 Mbps and Reliability > 99% and qualitative assessments of neglectable impact of cross-border handovers on ToD, operation being maintained while the vehicle is traversing country borders.
- Increased service continuity across countries with a combination of Local Breakout Routed Roaming and Edge Computing, which render latencies in the visited network identical to those in home network. Handover interruption times of less than 200 ms with no impact on CAM services.
- Enhanced safety and efficiency in truck platooning, routing and see-what-I-see applications enabled by ultra-low latency services and demonstrated in cross-border corridors.
- Successful validation of signalling operations at level crossings aimed to detect train proximity and, as a consequence, trigger safety mechanisms in the crossing (barriers, bells, etc.) and live streaming of video to the train driver console. High reliability (negligible packet loss at 64 Mbps) and low latency (30 ms average with 4.7 ms jitter).
- Enhanced healthcare services in ambulances via (i) improved decision-making, enabled by real-time video (round-trip time down to 7 ms over 70 Mbps) and sending vital patient data from the paramedic to a remote specialist; and (ii) efficient management of intersection priority at traffic lights expediting the patient journey. Network Slicing guaranteed sufficient radio resources for delivering such services, even with background traffic.
- Rapid deployment secure, portable 5G bubble networks for the provision of broadband communication services for first responder teams and special forces, this including six live HD feeds at various locations.
- Efficient service life-cycle-management, end-to-end network and service monitoring and resource allocation with network slices.
- 5G high-reliability and high-throughput performance for uplink communications allowing reliable transmission of the vast amount of 4K video, removing the painful dependency of this type of remote live production video solutions with wired infrastructure.

This latest and last 5G Infrastructure PPP Brochure n°4 illustrates again how strong Europe is on vertical trials. It clearly demonstrates the impacting and successful implementation of the PPP Programme and projects, showing the tight interconnections and synergies between the various projects. The PPP heritage brochure and figure released[8] in October 2023 summarize the direct projects follow-ups, the interconnections and components (re-)use between the 93 PPP projects and the utilization of (ICT-17) Platforms projects by the (ICT-19) Verticals Pilots projects. The outcome of these trials and pilots is already forming the needed technological bridge to connect the 5G to the 6G era.

[8] *https://5g-ppp.eu/5g-ppp-heritage-2023/*

CONCLUSION AND NEXT STEPS

From the evaluation of the 5G Infrastructure PPP project outcomes, it becomes apparent that the flexibility and modularity of 5G networking solutions are the pillars for the creation and support of a 5G ecosystem. Also, the latest 5G Infrastructure PPP White Papers illustrate why 5G networks are needed for the efficient support of the vertical industries and what are the key benefits they bring on the table, compared to previous generations of cellular networks. Certainly, the work for the further evolution of telecommunication networks is far from being completed. Tighter links and a better understanding between the verticals and the telecommunications solution providers are needed. Moreover, the vast amount of expected new services will seriously challenge 5G networks in terms of complexity and performance. The 5G Infrastructure PPP clearly provide a solid basis towards 6G networks and the Smart Networks and Services (SNS) era.

This brochure n°4 has provided an overview of 10 outstanding Trials & Pilots, with Phase 3 projects further addressing key vertical industries. The Trials & Pilots aimed to measure the potential impact of 5G in the daily operation of vertical industries in the path to full digitization.

We sincerely hope this brochure n°4 will encourage readers to look for more information and details, visit the PPP and projects websites, watch the Trials & Pilots videos, read the related documents, and interact with PPP participants in meetings, workshops, and conferences.

This PPP T&Ps brochure n°4 is the final one in the PPP T&Ps brochure series. Currently, many other interesting and promising T&Ps are now starting to be developed in the context of the 6G / Smart Networks and Services (SNS) Joint Undertaking (JU), also leveraging the PPP experience, Platforms and T&Ps.

EDITORS & CHAMPIONS

The editors of this PPP Trials & Pilots brochure n°4 are Didier Bourse (Nokia), Carles Anton (CTTC), Kostas Trichias (6G-IA), Carole Manero (IDATE) and Miguel Alarcón (Martel).

The following Table summarizes the key PPP champions involved in the 10 Trials & Pilots highlighted in this brochure n°4.

TRIALS & PILOTS	TRIALS & PILOTS CHAMPIONS
5G-CARMEN: 5G assisted cooperative and automated manoeuvres in cross-border scenarios	Matteo Gerosa (FBK), Edwin Fischer (DTAG), Victor Garrido (BMW), Filippo Visintainer (CRF), Roberto Fantini (TIM), Marco Liebsch (NEC) and George Avdikos (8BELLS)
5GCroCo: 5G cross-border service continuity for tele-operated driving	Andreas Schimpe (TUM), Apostolos Kousaridas (Huawei), Tobias Müller (Bosch), Israel González Vázquez (Volkswagen), Selva Vía and Miquel Payaró (CTTC)
5G-MOBIX: Spain-Portugal cross-border corridor	Notwithstanding the effort by the entire ES-PT team, the champions are Irene Saco Lopez and Marta Miranda Dopico (CTAG)
5G-MOBIX: GR-TR cross-border: platooning, truck routing, assisted crossing and see-what-i-see app	Gökhan Kalem, Afrim Berisa and Ersan Algül (Turkcell), Fofy Setaki (COSMOTE), Arda Taha Candan (TUBITAK BILGEM), Tahir Sari (Ford Otosan), Serhat Köl (Ericsson TR), Ioannis Masmanidis (Ericsson GR), Andreas Georgakopoulos and Konstantinos Trichias (WINGS), Sotiris Messinis and Konstantinos Katsaros (ICCS), Vasilis Maglogiannis and Dries Naudts (imec) and Olga Segou (Netcompany)
5Growth: Signalling operations for level crossing environments supported by 5G technology	Daniel Corujo (Instituto de Telecomunicações), Álvaro Gomes (Altice Labs), Paulo Paixão (EFACEC), Hugo Martins (EFACEC)
5G-HEART: 5G empowers ambulance services	Haibin Zhang, Bastiaan Wissingh, Daan Ravesteijn, Ramon S. Schwartz, Adrian Pais, Matthijs Vonder, Yohan Toh, Iñaki Martin Soroa and Toon Albers (TNO), Donal Morris (RedZinc), Marie-Pauline Roukens (Ambulancezorg Groningen), Xiaoyun Zhang (Dynniq)
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5G-INDUCE: Industrial machine control and human interaction services	Diego San Cristobal and Suraj Rajan Sirwani (Ericsson), Alberto Sánchez (Ford), Manuel Fuentes and Pablo Trelis (Fivecomm), Miguel Angel Martinez (YBVR), Laura Gonzalez (ABB)
Smart5Grid: Remote inspection of automatically delimited working areas at distribution substations	Inmaculada Prieto Borrero and Ana Romero Garcia (Edistribución), August Betzler and Andrés Cárdenas Córdova (I2Cat), Theocharis Saoulidis (Sidroco), Sergi Cadenas (NOSIA), Sonia Castro and Guillermo Gómez (Atos), Antonello Corsi (ENG), Daniele Porcu (Enel)
VITAL-5G: 5G Connectivity and data-enabled assisted navigation using IoT sensing and video cameras	Marius Iordacheand Cristian Patachia (Orange RO) and George Suciu (BEIA)

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