PUBLIC-PRIVATE PARTNERSHIP

5G INFRASTRUCTURE PPP

TRIALS & PILOTS

August 2021

5G-PPP.EU

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INTRODUCTION

The 5G Infrastructure Public Private Partnership (PPP) Programme comprises several funded projects organised in three distinctive phases, namely specification, development and experimentation/pilots. In the current third phase of the 5G Infrastructure PPP, those projects are achieving further outstanding progress and impact, as it has been regularly highlighted in the PPP Programme website and news (https://5g-ppp.eu/), and the corresponding project websites.

Specifically, since 2015, 92 projects in total have been assigned to work on 5G networks. Out of them, 49 are currently active. Past and present projects have created a plethora of advanced European telecommunication solutions. The third phase of 5G Infrastructure PPP is ensuring 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 to 6G networks. All Phase 2 projects and some of the first Phase 3 projects have now completed their work. The remaining Phase 3 projects, including the new Phase 3 projects which started in September 2020 (12 projects) and January 2021 (18 projects), are now running at full speed.

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 two "5G Infrastructure PPP – Trials & Pilots Brochures" released in September 2019 and December 2020 highlighted 20 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°3 leverages the experience from the previous Brochures (including call for inputs and selection by a panel of experts) and brings to the readers' attention 10 additional Phase 2 and Phase 3 Trials & Pilots that were recently completed. These Trials & Pilots have been evaluated and selected from over 25+ candidates, 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 they belong to and in alphabetical order:

- 5GCity: 5G neutral hosting (ICT-07-2017).
- 5G-EVE: Public safety and environment protection (ICT-17-2018).
- 5G-EVE: Industry 4.0: autonomous vehicles (ICT-17-2018).
- 5G-VINNI: 5G & network slicing for the Norwegian defence (ICT-17-2018).
- 5GENESIS: Mobile video public safety (ICT-17-2018).
- 5GCroCo: 5G cross-border service continuity for CAM (ICT-18-2018).
- 5Growth: E2E transport-aware orchestration (ICT-19-2019).
- 5Growth: Industry 4.0 remote operation of metrology machinery over 5G (ICT-19-2019).
- 5G-SOLUTIONS: Cooperative media production (ICT-19-2019).
- 5G-VICTORI / 5G-EVE: Digital mobility: Public safety, security and infotainment (ICT-19-2019).

Each of the selected projects has produced a two-page flyer including an overview of the corresponding Trial & Pilot, its network architecture, deployment aspects, obtained key results and key features brought by 5G technology, stressing the benefits and value brought by 5G networks that previous generations of mobile networks cannot provide (i.e., their 5G empowerment). Clearly, this document illustrates that most of these Trials & Pilots will have strong social impact or validate a service that will be monetised or bring a unique disruptive innovation application or service.

The broader context and overall panoramic perspective 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 organised 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°3 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, Alexandros Kaloxylos, Miguel Alarcón, Frederic Pujol and Carole Manero.

5G NEUTRAL HOSTING

OVERVIEW

The 5G PPP 5GCity project designed and developed a distributed cloud and radio platform for municipalities and infrastructure owners acting as 5G neutral hosts. The 5GCity platform and service tools allow to orchestrate and deploy services in a completely decentralised 3-tier architecture, where compute, storage and networking are allocated between core and edge segments of the 5G network in the City. The trial was run by Ajuntament de Barcelona, Comune di Lucca and University of Bristol, with support from i2CAT, Nextworks, Accelleran, Cellnex, Virtual Open System, Italtel, Ubiwhere, ADLINK, WindTre.

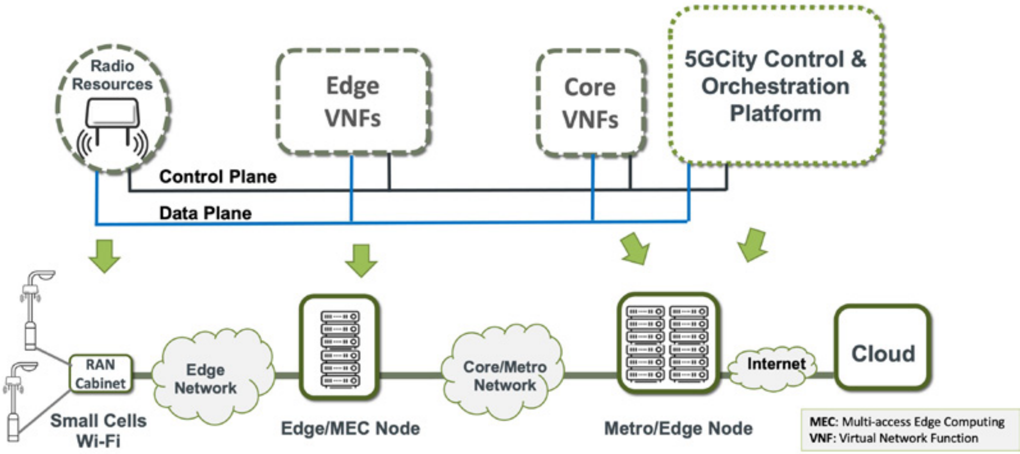


Figure 1: Three-Tier 5GCity architecture

Live trial instantiations and demonstrations were run in three different cities: Barcelona (ES), Bristol (UK) and Lucca (IT), from Q2-2019 until Q2-2020. Trials demonstrated the capacity of a single virtualised and sliceable infrastructure to serve different Mobile Network Operators (MNO) and even vertical operators. In 5GCity, the entity providing and operating the infrastructure is the Neutral Host operator.

ARCHITECTURE

Figure 2 depicts a case where three active slices provide connectivity to users on street.

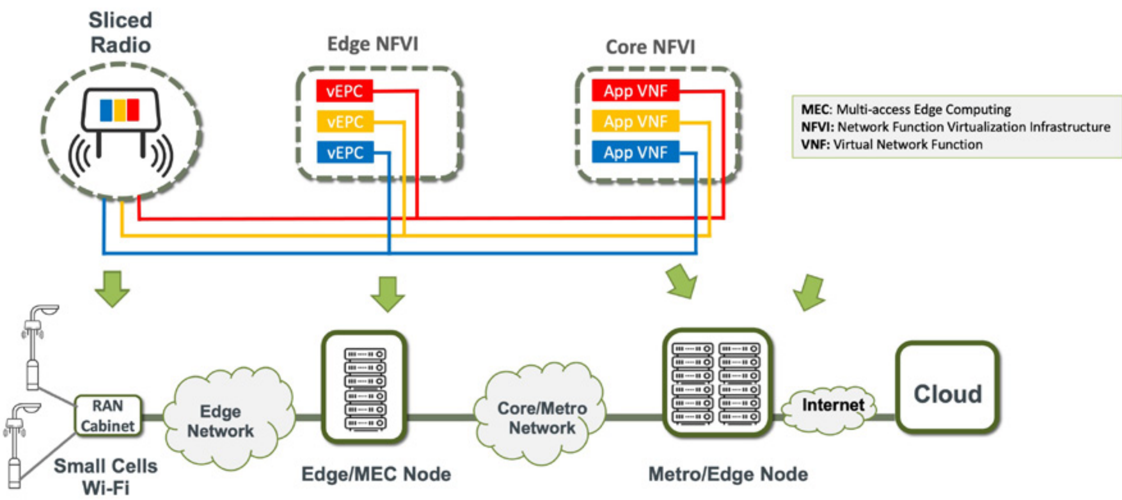


Figure 2: 5G Neutral Hosting over the 5GCity infrastructure

Each slice is composed of the physical Radio Access Network (RAN) access over a dedicated Public Land Mobile Network Identifier (PLMN-ID), and the necessary network connectivity to the compute infrastructure, where a virtual Evolved Packed Core (vEPC) is deployed for each slice. Slices are isolated and User Equipment (UE) can only attach to the slices for which the users have been registered in the vEPC. In 5GCity, Accelleran Small Cells installed on lampposts were used as Radio Units, various vEPC were deployed (Attocore, NextEPC or Open5GS), and application VNFs derived from different media and smart city use-cases tested. More details are available in the 5GCity Architecture and Business Model: https://kutt.it/KBGV99

DEPLOYMENT

The 5GCity deployment is based on the creation and activation of several network slices over a shared infrastructure. Each slice was composed of a compute chunk, network chunk and mobile radio chunks. The network slices deployed through 5GCity Software Defined Network (SDN) and Network Function Virtualization (NFV) orchestration systems emulate different Mobile Network Operators (MNO) acting as virtual network operators on top of the 5G Neutral Host.

Specific details of the deployments in the three cities are provided in the following links:

- Pilot Infrastructure in Barcelona (ES): https://youtu.be/XSYzm-vrUtc
- Pilot Infrastructure in Lucca (IT): https://youtu.be/H3H7qeHZSTQ
- Pilot Infrastructure in Bristol (UK): https://youtu.be/OkTvZzHEXNI

RESULTS

The trials carried out in the three cities were all successful and 5 key performance indicators (KPI) are indicated in the table below:

KPI	Target Value	Obtained Value		
		Barcelona	Bristol	Lucca
Multi -tenancy	≥ 3 slices	3 slices	3 slices	3 slices
User Experienced Data Rate	30 Mbps cumulative across slices	44.7 Mbps	45.5 Mbps	44.7 Mbps
Data Plane Delay	<=15 ms	11.3 ms	11.5 ms	8 ms (edge), 10 ms (core)
Isolation guarantees	Ensured	Ensured	Ensured	Ensured
Slice Deployment Time	<= 30 s	21.35 s	26.53 s	36.72 s**

**due to temporary reduction of the resources assigned to the 5GCity Platform components in terms of vRAM and vCPU

A full description of the 5GCity Neutral Hosting demo with reference to measured KPIs is available at https://youtu.be/vDiysgZfU0o.

5G EMPOWERMENT

The type of research carried out within the 5GCity project has developed great potential to impact over different stakeholders within the whole 5G value chain.

Municipalities are the privileged entities to act as future 5G neutral hosts because they own and manage the best urban spaces where 5G Small Cells can be deployed. Telcos and service providers can have the possibility to more easily provision services in the cities, by utilizing dense Small Cell deployments, and thus avoiding deep infrastructure transformations and the associated costs before being ready to enter the market in the cities. Vertical industries also are impacted by the 5GCity Neutral Host: they can simply lease – on demand – their private network and the resources needed for their business application from the Neutral Host, hence concentrating in their core application offering. SMEs working for both Telcos and Verticals can have more opportunities to join the value-chain, as the neutral host platform opens a number of opportunities for offering custom solutions and various support services (from service design to operations).

The project published all its orchestration software as Open Source to increase impact and uptake. More details are available on the 5GCity Software Organization on GitHub: https://github.com/5GCity

PUBLIC SAFETY AND ENVIRONMENT PROTECTION

5G EVE

OVERVIEW

This trial leveraged 5G to realize an advanced air quality monitoring service for smart cities. The motivation and importance of this use-case was evident as air pollution poses a major threat to health and climate (according to the World Health Organisation). Therefore, the objective of this trial was to take advantage of 5G and more specifically, of the 5G EVE developed infrastructure in order to demonstrate the accurate identification of polluted atmosphere and the immediate notification of the interested parties. To this end, as depicted in Figure 1, the trial included (i) air quality monitoring sensors, (ii) a 5G gateway that reads measurements from the sensors and transmits them to the 5G RAN, (iii) 5G NSA network (Radio and Core), and (iv) a cloud platform (WINGS ICT Solutions STARLIT platform). The 5G network and gateways were controlled/managed through the 5G EVE framework (portal and inter-working layer). The trial took place on July 2020 for the first time and was repeated during the first quarter of 2021. The 5G-EVE involved partners are: WINGS ICT Solutions, Ericsson Hellas and Hellenic Telecommunications Organization.

A video of the demonstration is available at: https://www.5g-eve.eu/videos

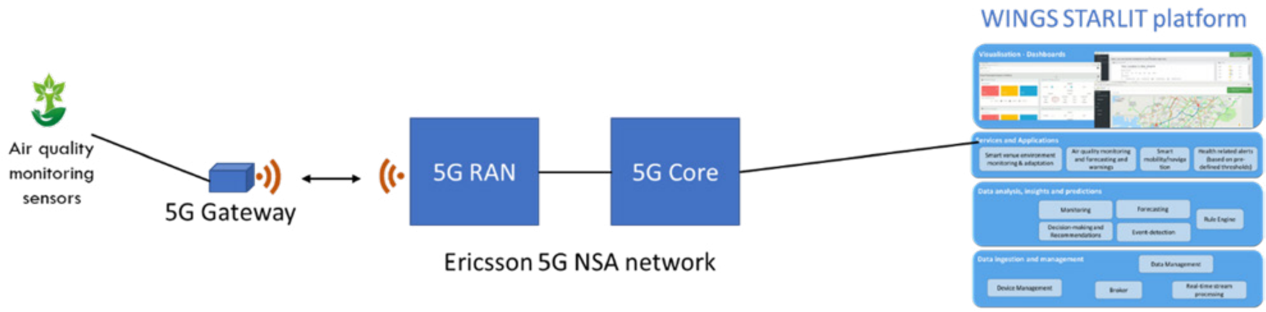


Figure 1: Trial overview

ARCHITECTURE

Figure 2 presents in more detail the trial architecture. As depicted the trial was totally controlled through the 5G EVE's framework and more specifically, through the modules/mechanisms that are deployed in the three layers (portal, interworking layer, Greek site). The first layer aimed at defining/executing the experiments in a user-friendly way and for this purpose, an intent-based tool had been developed. This layer focused on the translation of the requests into specific requirements, which were being forwarded through the interworking layer towards the sites. At the Greek site, apart from the use-case main elements (sensors, gateways, analytics platforms), OSM was deployed for covering the orchestration needs and a Kafka broker was deployed for collecting measurements and KPIs.

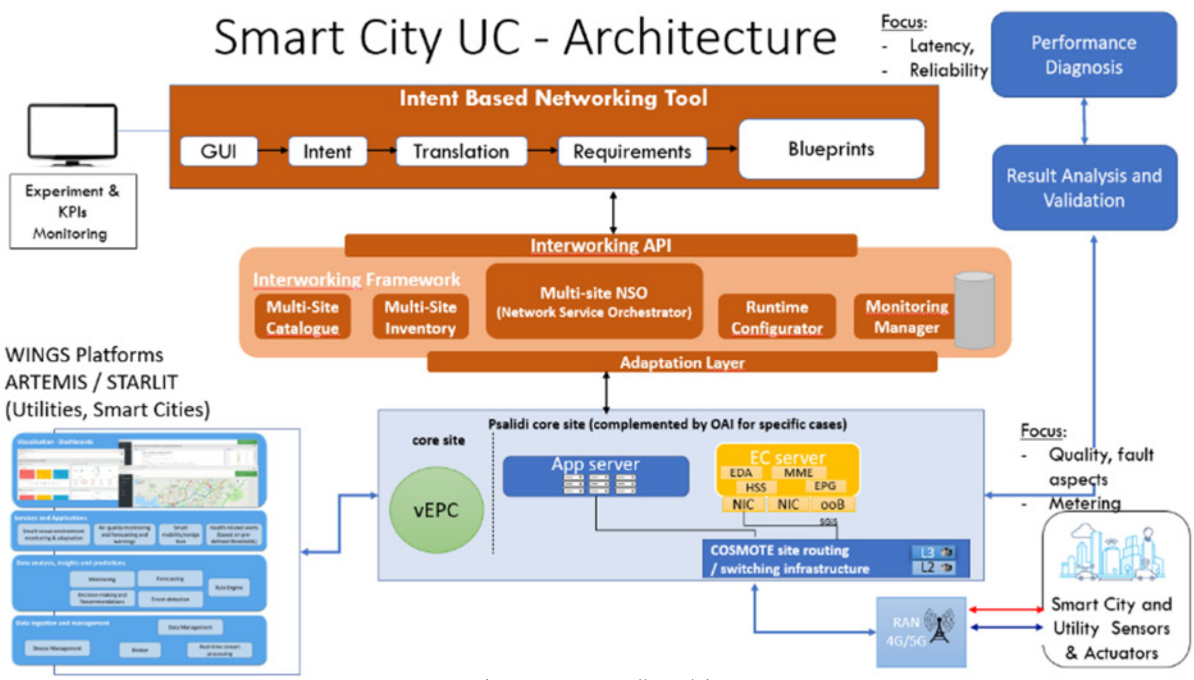


Figure 2: Overall architecture

DEPLOYMENT

The trial took place at OTE Academy premises in Athens (Figure 3). The air quality station was installed there as part of the Smart City infrastructure. A 5G Gateway was also deployed close to the sensors and was responsible for collecting data from them and for communicating with the 5G RAN acting as a 5G terminal. The purpose of the 5G Gateway was to provide the required connectivity between sensors and the rest of the infrastructure. The WINGS cloud platform was also available on site and hosted by a cloud server. A video of the trial ("5G EVE Greek site Webinar") is available at: https://www.5g-eve.eu/videos/

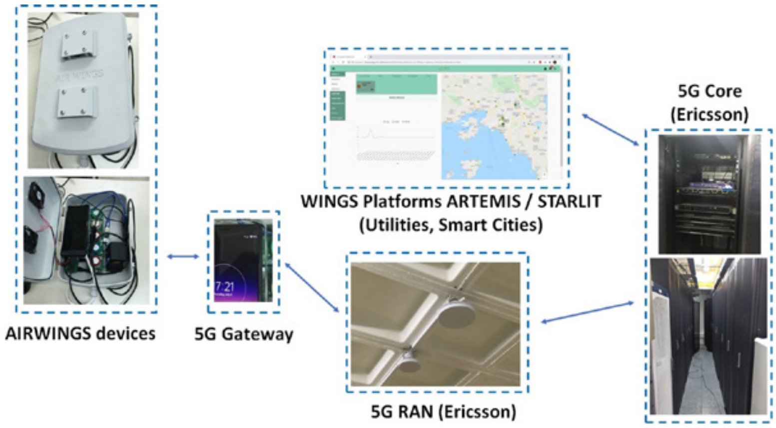


Figure 3: Trial deployment @ OTE Academy premises (Athens)

RESULTS

The trial was supported by the visualization dashboards that were included in the WINGS STARLIT platform (Figure 4). A few selected KPIs were closely monitored during the trial. In particular, there were vertical KPIs of interest such as the "Request response time" and the "Number of sensors supported", as well as network KPIs of interest such as the "RTT latency" and the "Bandwidth (UE side / Server side)". As depicted in Figure 5 (through the 5G EVE's KPI validation tool), latencies in the area of less than 10ms were actually achieved.

Figure 4: Air quality monitoring/analysis/validation/feedback to dashboard

5G EMPOWERMENT

In this trial, measurements from the air quality monitoring station were sent to the WINGS STARLIT platform over an mMTC slice. The platform processed these measurements, generated forecasts about the status of various environmental parameters and triggered actions related to air quality monitoring and health recommendations. The key point for the success of the trial was the accurate, reliable and extremely fast transmission of the data through the 5G network in both directions. This capability enabled immediate reactions in cases of air quality degradation. Finally, it is worth mentioning that 5G will also further fuel IoT applications, through the mMTC services and the ability to interwork with URLLC and, where relevant, with eMBB. This will bring further applications that will change the way we work and live.

INDUSTRY 4.0: AUTONOMOUS VEHICLES

5G EVE

OVERVIEW

The objective of this pilot is to assess the viability of operating in factories 5G connected Autonomous Guided Vehicles (AGVs), with the control of the vehicle virtualised at the edge of the network i.e., moving the control of the vehicle out of the physical unit and implementing it in a computing node that meets the latency requirements for the AGV operation. The AGV collects the information from its sensors and sends it to the virtual controller through a wireless connection, initially 4G and then 5G NSA. This information from the sensors is processed in the virtual controller, identified as virtual PLC (Programmable Logic Controller), which generates the orders to be executed by the AGV actuators. These orders are sent again through the wireless connection to the AGV, where they lead the actions of the different actuators in the next action period. 5G-EVE partners are: ASTI Mobile Robotics, Ericsson, University Carlos III Madrid, Telefónica I+D, IMDEA Networks. Use-case developed in the context of the 5G EVE project. It has also been used for the Boost4.0 project (https://boost40.eu/).

ARCHITECTURE

The trial architecture is depicted in the following figure:

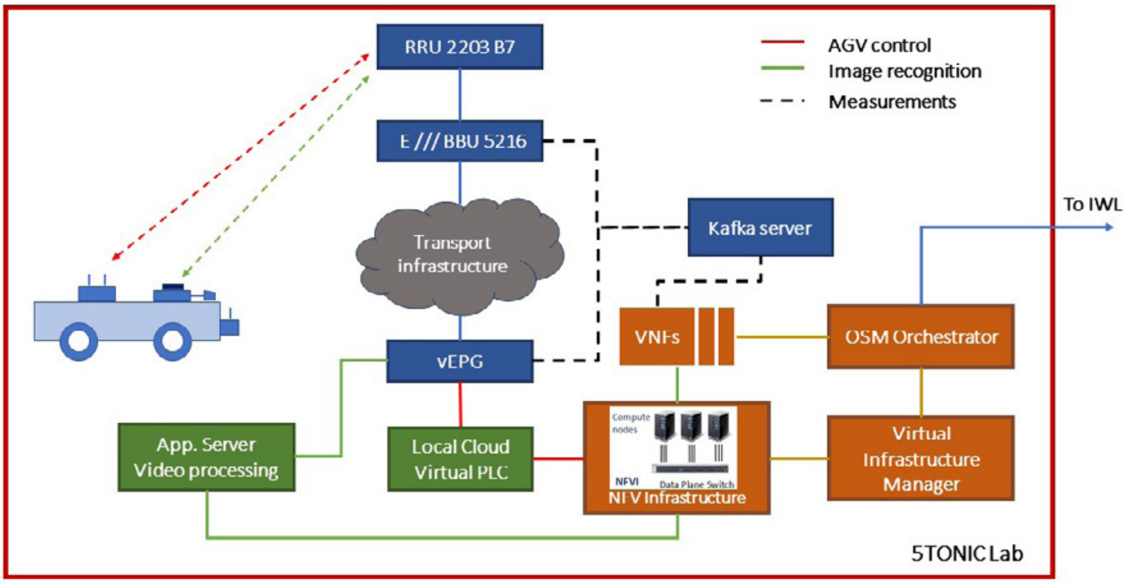


Figure 1: Testbed area between Politecnico di Torino and Porta Susa train station.

The system encompasses:

- Radio Access network supporting high performance 5G NSA access.
- Virtual EPC supporting NSA access.
- Virtualised processing platforms, implementing the functionalities required to support the trial, virtual PLC and real time video image recognition.
- Orchestration platform, in charge of instantiating the processing functions, as well as configuring the VNFs.
- Measurement infrastructure based on Kafka bus, which collects measurements from network and processing functions to derive network and service KPIs.

The system is connected to the Interworking Layer (IWL) in Turin to allow the launch of tests from the 5G EVE portal. It is also connected to the Kafka-based measurement platform, where the relevant KPIs are collected.

DEPLOYMENT

The trial has been implemented at the 5TONIC lab, where a circuit for two AGVs has been deployed. 5G NSA coverage is provided at the lab, operating in bands 7 and n78. The AGVs incorporate two wireless routers that support two connections linked to: (i) Implementation of the virtual PLC controlling the AGV, in charge of different procedures (Tracking the marked route, Collision avoidance of obstacles in the AGV route, Actions associated with tracking marks deployed in the route). (ii) Real-time image processing, mainly to identify what obstacle (person, object, etc.) has activated the collision avoidance mechanism. It is supported by a camera deployed in the AGV.

The controlled AGV is an Easybot model, designed and manufactured by ASTI and used in real factories worldwide.

RESULTS

The trial demonstrated that it can be feasible to support an operating model based on the use of virtual PLCs with 5G to control a fleet of AGVs operating in a factory. Measured latency was 10 ms, which is in the lower bound of ASTI's proposed requirements, and reliability exceeded 99,9999%. Supporting this operational model has several potential advantages for current and future use of AGVs in factories: (i) Potential coordination among AGVs, optimization of routes and rerouting in case of failure, are all facilitated by implementing a centralised control of the factory's AGVs, (ii) Lower cost of the AGV, as it has not to incorporate the processing capabilities (which would be critical for the future, as otherwise AGVs would be required to generate maps from LIDAR (Light Detection and Ranging) measurements, (iii) Easier maintenance of the equipment, e.g., software upgrades have not to be carried out for each AGV, (iv) Higher reliability through the virtualization of the centralised processing.

The trial has been showcasted in EuCNC 2019 as a stand-alone system and in EuCNC 2021 integrated in the 5G EVE platform. It has also been presented to companies such us PSA, Volkswagen, Innovalia or Gestamp Group.

Figure 2 shows the results of the battery consumption of the AGV in two different configurations: one, shown in blue, using 4G and another one, in orange, using a 5G configuration. Those results illustrate the benefit of using 5G, mainly due to the low end-to-end delay between the AGV and the remote controller, which permits the AGV to stir over the path smoothly.

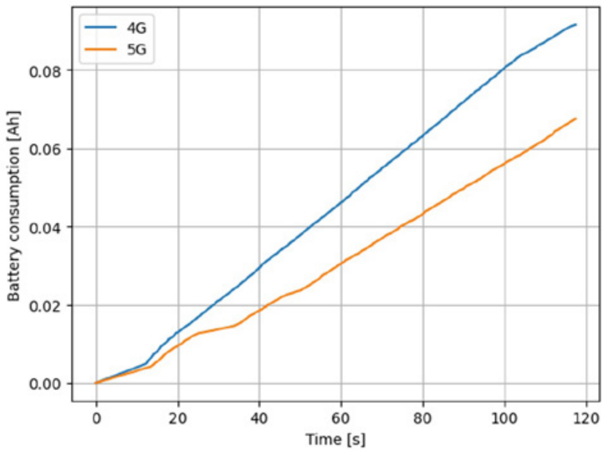


Figure 2: Battery consumption using 4G and 5G.

5G EMPOWERMENT

The operational model, to ensure feasibility, requires that the performance of the AGVs operation remains the same as if the classical, on-board control would be maintained. ASTI estimates that the following network related KPIs should be achieved: (i) Latency: to ensure that the AGV works correctly in all operating conditions, the maximum delay (between the generation of the measurements by the sensors till the associated orders are received at the AGV) should not be greater than 10-15 ms, (ii) Reliability: 99.999% probability of correct reception of packets in both directions of the link.

Throughput and capacity are not critical parameters for this UC, although they may become in its evolution. Also, a zero-latency handover, as enabled by Release 16 Conditional Handover or Dual Active Protocol Stack (DAPS), would be quite beneficial, as factories are likely to be covered by more than one cell. All these KPIs cannot be achieved using 4G technology (although suboptimal operation or operating in conditions that do not require the KPIs indicated above is feasible with 4G and even Wi-Fi), so 5G becomes an enabler for the support of control of AGV fleets with virtual PLCs.

5g-eve.eu / 5tonic.eu

5G & NETWORK SLICING FOR THE NORWEGIAN DEFENCE

OVERVIEW

A trial was conducted with the Norwegian Defense in the 5G-VINNI Norway facility site in May 2020. A dedicated and fully isolated Network Slice was implemented for the Norwegian Defense using NSA 5G and DECOR. It was successfully demonstrated how a user in the Military could obtain different quality of service when connected to the Military Network Slice and the Commercial Network Slice. Advanced functionality was implemented in the slice such as Autonomous Edge Cloud, Security-as-a-Service and onboarding of third party applications such as voice, push-to-talk and other own-developed Military services. The demonstration in May 2020 focused on the slicing capability, QoS assignment, Security-as-a-Service and how services are auto-provisioned from an end-to-end orchestrator and how orchestration can be done across central and edge cloud.

A RAN site is deployed in the Military camp. This is a 3-sector site with gNBs in the 3.6GHz and 26GHz bands and eNB in 2.1GHz band. A satellite for redundant backhaul is also installed there.

A customer application called Hermod provided by the Norwegian Defence onboared into the slice was successfully tested. The Hermod application is used by military-grade devices connected to the 5G slice to auto-discover each other and then establish direct communication between the devices.

ARCHITECTURE

The following network elements were used in the trial with the Norwegian Defence: (i) NSA 5G Core by Ericsson, (ii) gNBs and eNBs by Ericsson and Huawei, (iii) Generic VNF Manager (G-VNFM) by Ericsson, (iv) NFV Infrastructure (NFVI) by Nokia - OpenStack and KVM, Nuage SDN, servers, switches, storage, (v) NFV Orchestrator (NFVO) by Nokia, (vi) E2E Orchestrator by Nokia, (vii) IMS by Metaswitch, (viii) Firewall and Security-as-a-Service by PaloAlto, (ix) Transport network by Telenor.

Three NSA slices and two Stand Alone (SA) slices are implemented in 5G-VINNI Norway facility site.: (i) NSA Defence Slice for URLLC, in this case dedicated for the Norwegian Defence. (ii) NSA Slice#1 is for eMBB and used by different customers. (iii) NSA Slice#2 is for mIOT and used by different customers. (iv) SA Slice#1 and #2 will be used by different customers.

The demonstration illustrated how the defence user connect to NSA Defence slice and to NSA Slice#1 for eMBB.

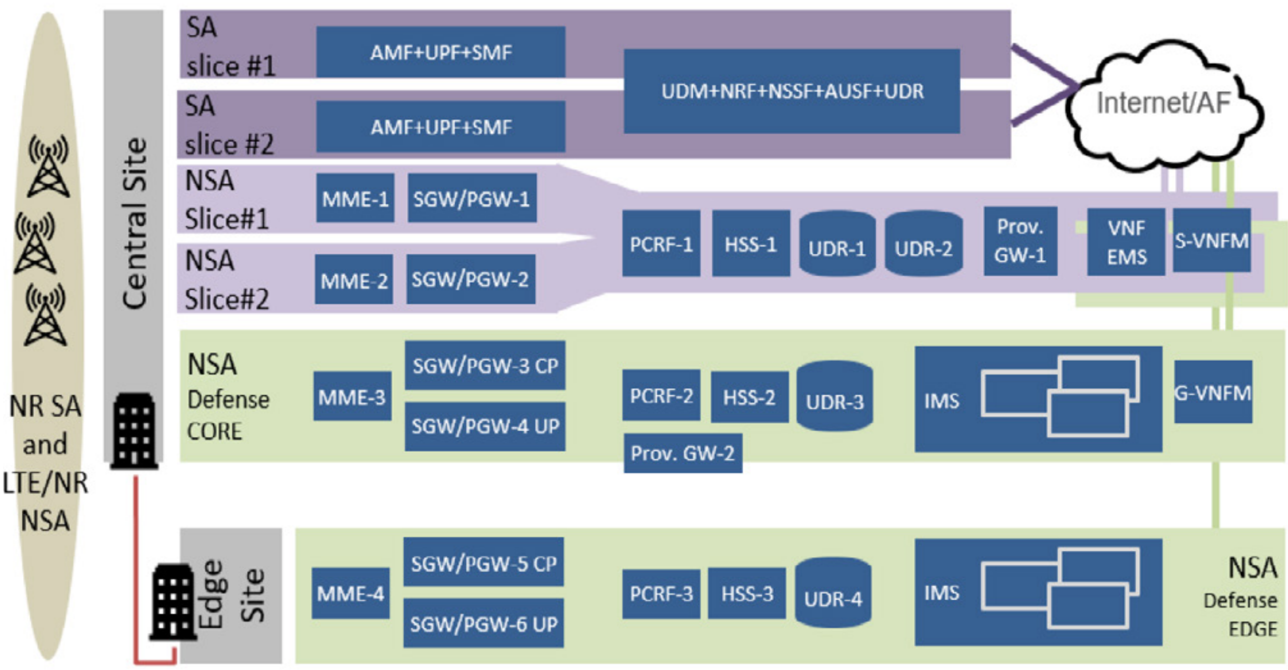


Figure 1: Network Slices implemented. In the May 2020 demo the NSA Defence slice (URLLC) and the NSA Slice 1 (eMBB) were used.

DEPLOYMENT

The Ericsson gNB and eNB used in the trial are shown in Figure 2. The Nokia NFVI, the E2E Orchestration system (FlowOne) and the NFV Management and Orchestration (MANO) used in the trial are deployed in a central cloud location (Figure 2). The Edge Cloud includes servers and switches from Nokia, a firewall from PaloAlto, a cell site router from Huawei and a baseband unit from Huawei (Figure 3). The commercial transport network by Telenor was used to connect a Provider Edge router towards the transport network.

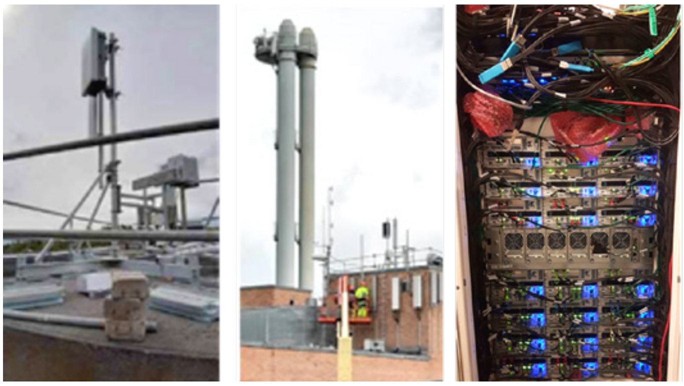


Figure 2: Picture of the Ericsson gNB used in the demo in May 2020. The central NFVI to (right)

Figure 3: Picture of the Huawei gNB (3.6GHz and 26GHz and eNBs (2.1 GHz) in the military location. Extended mast installed by 5G-VINNI. Edge Cloud (right)

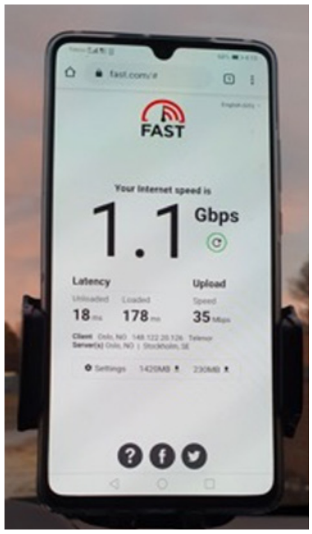
RESULTS

The demo showed how a Military user can connect to both the Military slice and the Commercial slice and how different QoS profiles can be assigned to each slice. About 500Mbps downlink and 70 Mbps uplink was achieved when connecting to the Military Network Slice and about 50Mbps downlink and 30 Mbps uplink when connecting to the Commercial slice.

The highest throughput achieved at this site with 5G using 80 MHz channel in the 3.6GHz band and 4G using 10 MHz channel in 2.1 GHz is shown in the figure on the right.

The demo illustrates how a vertical customer such as the Norwegian Defence can use Security-as-a-Service to configure their own security policies and use other security functions for their Network Slice.

The demo showed how an end-to-end orchestrator can automate distribution of 5G network functions across the Central and Edge Cloud sites.



5G EMPOWERMENT

The key features brought by this 5G trial are:

- Dedicated network slice with full isolation for the Defence
- Differentiated QoS for different Slices
- Orchestration of services across a distributed Cloud involving Edge and Central sites
- Security-as-a-Service for the vertical customer, the Norwegian Defence in this case
- End-to-end orchestration
- On boarding of customer applications into the slice

5g-vinni.eu

MOBILE VIDEO FOR PUBLIC SAFETY

OVERVIEW

The trials were executed during July 2020 in the area of Ada Byron Building at University of Málaga (UMA) campus and during July 2021 in the Málaga city center using the 5G deployment of 5GENESIS. The objective was to evaluate the use of mobile video for Police operations in order to enhance public security. The Málaga Police Department participated as final user equipped with commercial mobile phones to receive and transmit live video around the coverage area of the deployed 5G network.

This trial is part of the PPDR (Public Protection and Disaster Relief) use-case developed in several projects, including the 5G PPP projects 5GEPICENTRE and AFFORDABLE5G, where the 5GENESIS Málaga platform is also used.

The involved partners are Municipality of Málaga, Telefónica, University of Málaga.

ARCHITECTURE

The first trial was executed in the University of Málaga (UMA) campus area and the second one was done in the Malaga city centre, the final application area of the use-case. The figure below provides a high-level view of the architecture. The 5G radio deployment available at the city centre is operated by Telefonica and connected via fibre connection to the core network and the 5G radio network available also at the Ada Byron building and operated by the UMA. The video solution, including the server and the application installed at the mobile devices, was provided by the company IDIS. Commercial 5G mobile devices were used by the policemen to transmit in real time the video to the tactical command center. Once there, the video is relayed to other police officers on demand. The policemen can also receive the video recorded by the fixed cameras or by the other agents. The motorcycles from the police and the mobile tactical command center were also equipped with 5G devices to provide them with 5G data connectivity.

Figure 1: Pilots architecture

DEPLOYMENT

The deployment used at both sites is based on 5GNR (5G New Radio) Non-Standalone (NSA) Option 3x. The most relevant options in the 5G configuration applied during the trials, where all traffic was transmitted through the 5GNR nodes, were the following:

Duplex mode: TDD	DL MIMO Mode: 2x2 Closed Loop SM
Band: n78	Modulation: 256QAM
Channel Bandwidth: 40 MHz	Uplink Proactive scheduling.
Cell Power: 40 dBm	UL and DL data only NR.

The whole trial was monitored to measure video-related KPIs and potential network issues. The video quality was good enough to support standard Police practice.

Pictures illustrate the paired gNodeB (5G) and eNodeB (4G) deployed at the Ada Byron Building for 5GNR NSA (right) and the paired nodes deployed at the city centre (left).

Figure 2: 5G deployment at Ada Byron building

Figure 3: 5G deployment at Malaga city centre

RESULTS

Live video quality for security in mobility conditions could be affected by packet losses, jitter and throughput. The 5G throughput and some features like Proactive Scheduling, which reduce time to load first media frame, guarantees better resolution and latency than 4G systems, as shown in Figure 4 and Figure 5.

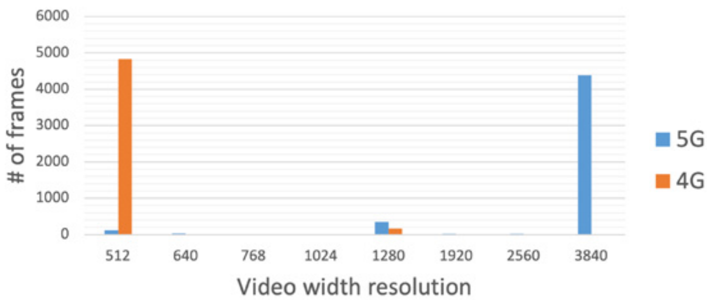


Figure 4: Video resolution in 4G vs 5G

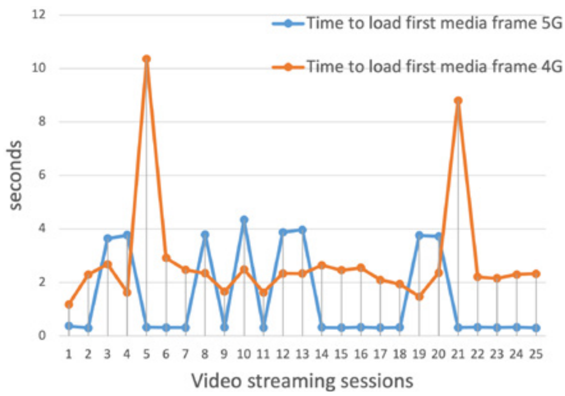


Figure 5: Time to load first media frame 4G vs 5G

5G EMPOWERMENT

The main outcomes of the trial were: (i) The identification of the coverage area for good quality for a moving vehicle, (ii) the assessment of the whole architecture of the 5G private network for experimentation, (iii) the identification of scheduler configurations for reducing latency, (iv) the confirmation of the suitability of this video transmitted at urban speed for Police operations.

The full videos of the trials are available at https://www.youtube.com/watch?v=9H6OkjX74iw and https://www.youtube.com/watch?v=cY4sq4KGCvY&t=33s

5genesis.eu

5G CROSS-BORDER SERVICE CONTINUITY FOR CAM

5GCroCo

OVERVIEW

Services such as High-Definition (HD) Mapping and Anticipated Cooperative Collision Avoidance (ACCA) for Connected and Automated Mobility (CAM) applications demand uninterrupted network connectivity. In Europe, where Mobile Network Operators (MNOs) typically serve only a single country, this is especially challenging when driving through national borders. Currently, vehicles search and register with an MNO in the country they enter only after the MNO connection in the country of origin is lost, which can interrupt the service for several minutes. Clearly, this situation is not acceptable for CAM services where service continuity is key, e.g., for safety reasons. In this context, 5GCroCo, in line with other Horizon2020/5G PPP ICT-18 and ICT-53 projects, investigates cross-border/-MNO handover, which enables seamless service continuity at country borders.

As part of the project activities, 5GCroCo deployed a large-scale test and trial network in the border between Germany and Luxembourg. Between October 2020 and March 2021, trials were conducted by Ericsson, Orange, HTW, and Volvo (among others) to evaluate the HD Mapping and ACCA use-cases.

Figure 1: Remerschen POP 5G cell site. Display of the HD Mapping client system while conducting the Trial and detail of the used equipment

ARCHITECTURE

Figure 2 shows the architecture of the 5GCroCo solution, where the Home and Visited networks support cross-MNO handover. The two networks are connected through the S10, S8 and S6a interfaces. The necessary exchange of information is carried out through these interfaces so that a user can be handed over between the networks in two different countries (as would happen in a border crossing), in the very same fashion as in a regular handover between two MMEs in the same network (e.g., when traveling within a single country).

HSS: Home Subscriber Server
MME: Mobility Management Entity
GW: Gateway
S-GW: Serving GW
P-GW: Packet Data Network GW
BBU: Baseband Unit
POP: Point of presence

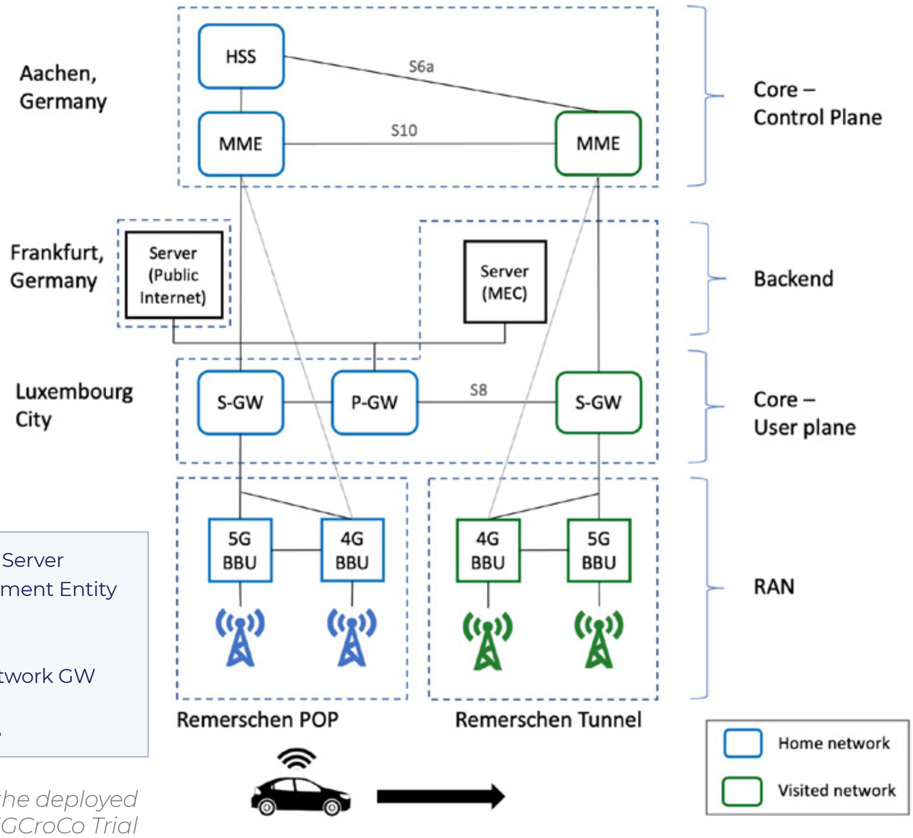


Figure 2: Architecture of the deployed networks for the 5GCroCo Trial

DEPLOYMENT

The 5GCroCo Trial was conducted on a rural road between the towns of Remerschen and Schengen (see Figure 3). Two Non Standalone (NSA) 5G networks were deployed (Remerschen POP 5G and Tunnel 5G). The user plane nodes of the two network cores (Home and Visited as in Figure 2) were deployed in Luxembourg City and the control plane nodes were located in an Ericsson lab in Aachen, Germany. The backend servers were physically residing in Frankfurt, Germany. Regarding the used spectrum, the 3.7 GHz band was used for 5G coverage with 40 MHz bandwidth in TDD mode while the 700 MHz band was used for the 4G anchor cells, which used 10 MHz for both the uplink and downlink.

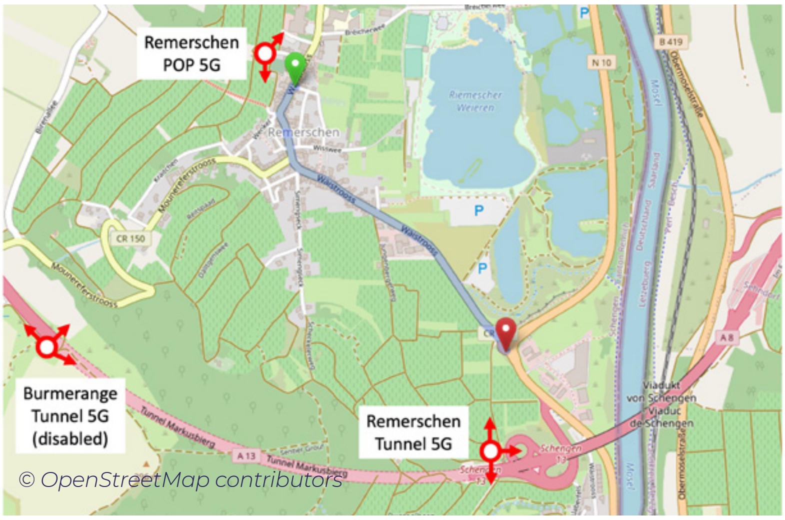


Figure 3: Path between Remerschen and Schengen Motorway Exit and location of the 5G cells (red circumferences with arrows)

RESULTS

This 5GCroCo Trial showed that cross-border service continuity is feasible. Specifically, it was successfully demonstrated for the HD Mapping and ACCA use-cases thanks to the developed cross-border/-MNO handover. For example, as shown in Figure 4, cross-border handover allowed for seamless service continuity for HD map download: the green/red tiles indicate successful/failed HD Mapping download, respectively. When cross-border/-MNO handover was enabled (left), there were no service interruptions, whereas when no cross-border/-MNO handover was enabled (right) the service was interrupted for about a minute. Further details on the Trials results can be found in the latest version of Deliverable D4.2, which is available for download from the 5GCroCo webpage (https://kutt.it/e1GvZ8).

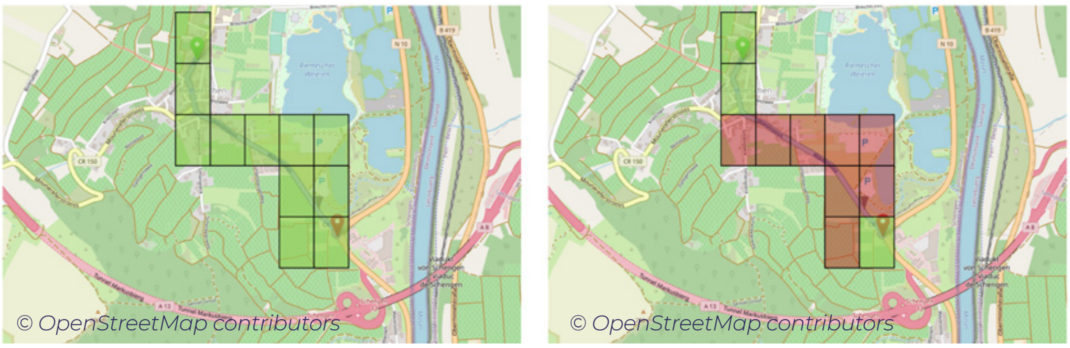


Figure 4: HD Map Service Continuity with (left) and without (right) Cross-MNO Handover

5G EMPOWERMENT

The main results / benefits brought by the 5G technology in this Trial, are mainly related to the reduced latency of 5G (e.g., 13 ms at percentile 99 in 5G compared to 30 ms in 4G for ACCA), the increased throughput of 5G through an increased spectral efficiency and available mid-band spectrum, and the adoption of MEC, which can further reduce latency. Other 5G key features that have been used in this Trial involve: (i) optimised 5G RAN configuration for the HD Mapping and ACCA use-cases, E2E QoS management, QoS prediction, precise positioning, cross-domain Management and Orchestration (MANO) and Software Defined Networking (SDN) together with network slicing. By leveraging the above-mentioned 5G technologies, this Trial has shown cross-border/-MNO handover to ensure service continuity.

5gcroco.eu

E2E TRANSPORT-AWARE ORCHESTRATION

5GROWTH

OVERVIEW

The 5Growth project validated, through field trials, the performance of 5G systems deployed on vertical premises. Significant advances were conceived by the interworking of 5G with a transport infrastructure under the direction of an orchestration platform. Cloud platforms were part of this synergy as radio functionalities and vertical applications migrate from dedicated platforms towards virtual machines running on commercial-off-the-shelf servers, located on the vertical premises (to preserve confidentiality and to reduce latency) or in the central office of operators. The 5Growth platform simplified the instantiation and operations of services and network slices over a virtualised view of the infrastructure.

All the potentialities of 5Growth were exploited in a pilot in Italy. Here, COMAU, Ericsson, TIM, Politecnico di Torino, Scuola Superiore S.Anna and Nextworks deployed three use-cases in the COMAU plant and in TIM central office. The experimental area was covered with 5G NSA. In June 2021, the pilot successfully demonstrated a cross-layer solution for the control of 5G slicing in support of end-to-end vertical services. The pilot iwa also linked to the 5G facilities deployed by the 5G EVE project.

ARCHITECTURE

The pilot architecture included: a shared transport network for running applications in a remote cloud platform and an E2E transport-aware orchestrator to handle 5G slicing in support of different QoS levels across radio, transport, and cloud infrastructures.

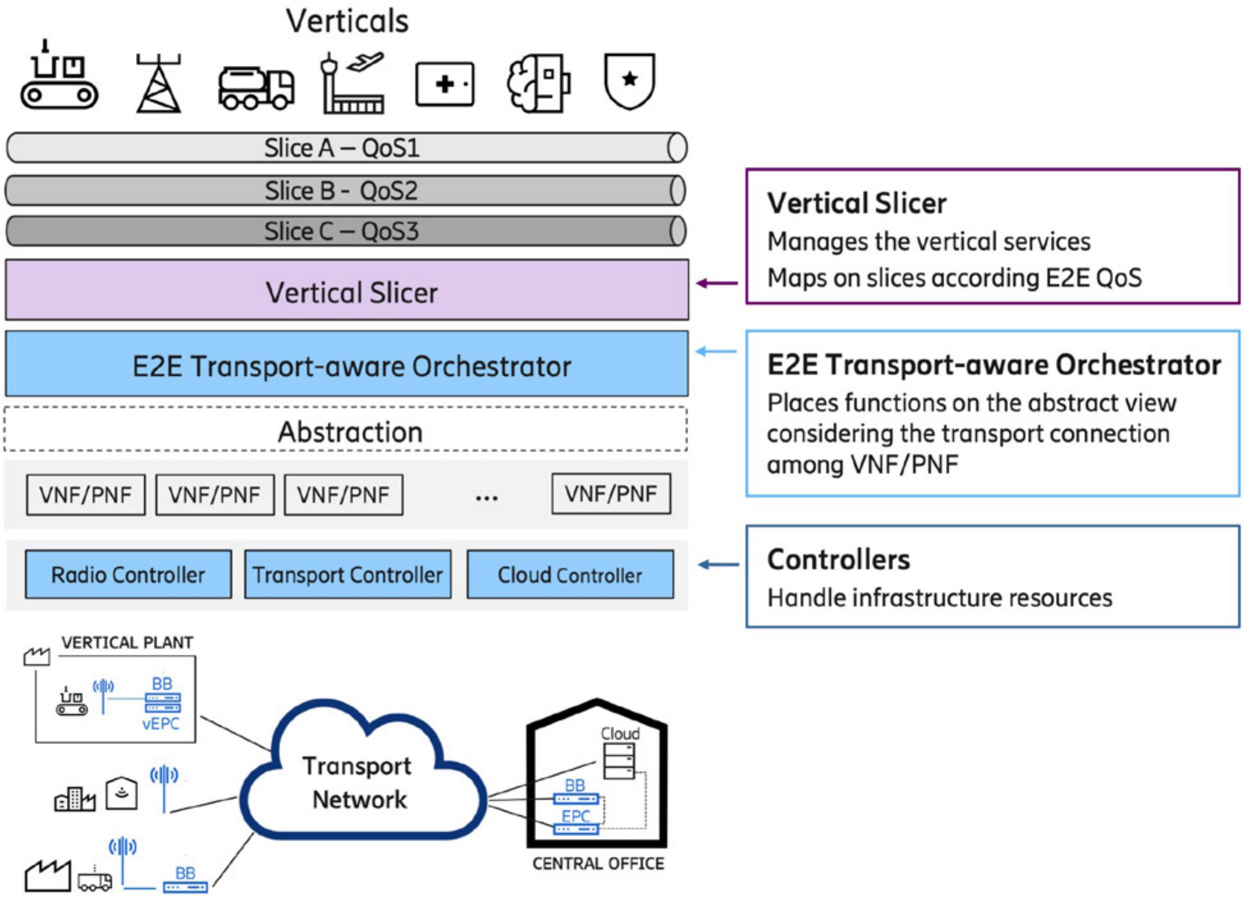


Figure 1: Architecture of the pilot including the E2E Transport-aware Orchestrator

The E2E orchestration was based on 3GPP RAN slicing model/ETSI MANO, suitably extended for the automatic placement of VNF/PNF considering transport characteristics. Hence, the QoS mapping on slices became transport aware and enables the cross-optimization of radio, transport, and cloud.

DEPLOYMENT

The pilot included an Ericsson 5G radio network, operating on TIM's spectrum, a transport network, systems for industry automation and IIoT platform by COMAU, and the E2E transport-aware orchestrator.

5G served three use-cases: (i) Digital Twin, requiring Ultra-Reliable Low-Latency Communications, (ii) Monitoring & Telemetry, requiring massive Machine-Type Communications, (ii) Remote Support, requiring enhanced Mobile BroadBand and exploiting a multi-domain solution linked to the 5G-EVE infrastructure.

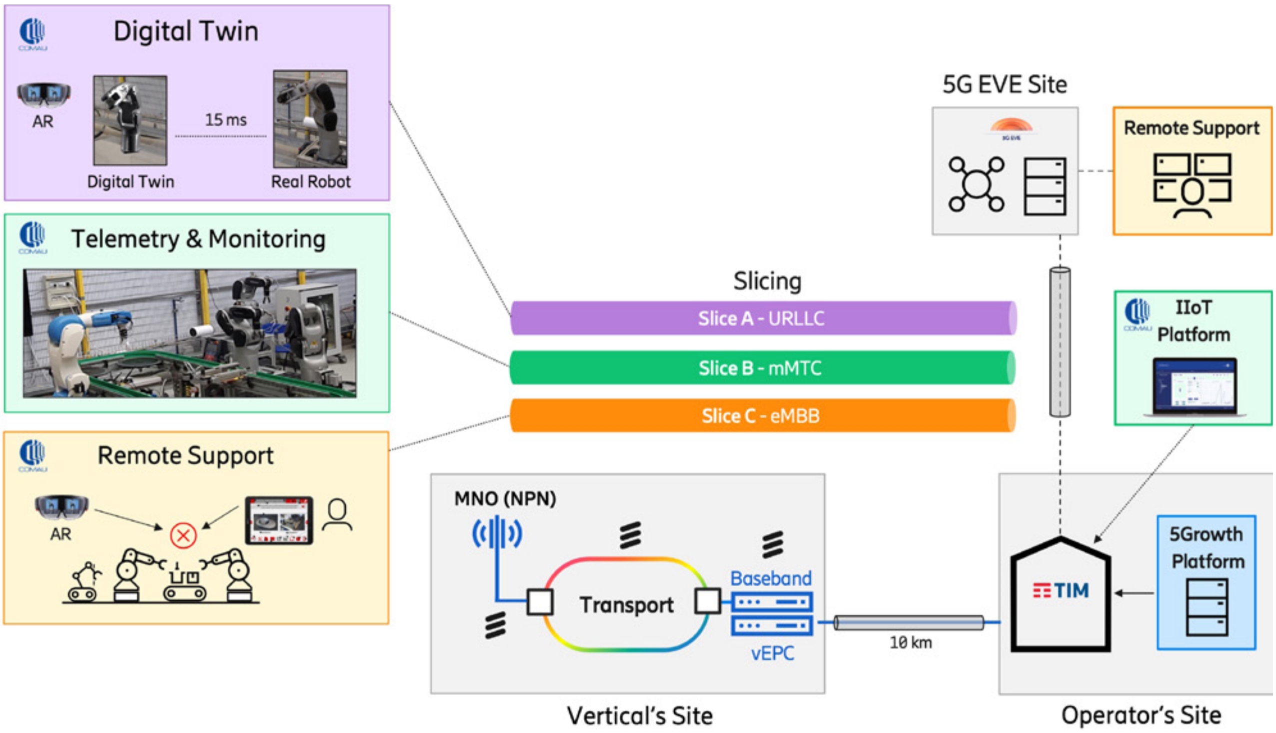


Figure 2: Deployment of the COMAU Pilot

RESULTS

To assess the implementation of 5G slicing, the execution time to manage the network slices was measured in the 5Growth stack, which runs as Docker containers on a Linux machine. Cloudify v5.1.0 was used as open-source NFVO for the service orchestrator.

The measure, obtained by repeating 20 times the slice instantiation and termination, showed that the delay introduced by the E2E orchestration is negligible (1 sec) w.r.t. the delay of the open-source NFVO (21 sec).

The additional overhead introduced to control the radio resources was also negligible if compared with the time required to instantiate and configure the virtual functions, with a global service provisioning time that was on the order of 23 sec.

5G EMPOWERMENT

5Growth has conducted an in-depth business analysis for the COMAU pilot considering the application of the solution to a reference plant of 7700 m2 and serving 44 robots + a support team of 10 people. 5G enables more efficient service provisioning and operation, a faster change of production line and the predictive maintenance, loading towards hitless production. These represent the main advantages. However, the largest saving comes from the advanced predictive maintenance enabled by 5G. This means increasing the number of sensors fitted to equipment from one or two to measuring dozens of different parameters and ensuring that data is always reliably collected in real-time. Minimizing the interruptions means obtaining impressive savings.

5growth.eu

INDUSTRY 4.0: REMOTE OPERATION OF METROLOGY MACHINERY OVER 5G

OVERVIEW

According to VDI (the German engineering association), industry and metrology 4.0 will evolve into fast, accurate, reliable, flexible and holistic processes. Digitisation and 5G are essential tools for quality control paradigm transformation. To this aim, the 5Growth architecture and technology are vital enablers for more autonomous human-machine-information interactions over 5G networks.

This trial deployed 5G connected quality control services for workers 4.0, connecting anywhere, anytime, the M3 metrology software with the Coordinate Measurement Machine (CMM) and video system. This enabled personalised, remote decision, and quality control assistance. The trial was recorded for the 5Growth technical review in February 2021. The involved partners are Innovalia, Ericsson, Telefónica, UC3M, CTTC, IMDEA Networks, Telcaria Ideas, Nextworks, Mirantis, NEC and Nokia.

ARCHITECTURE

The vertical user interacted with the Vertical Slicer component of the 5Growth stack to instantiate and manage services in the form of network slices. Then, all required network services and resources were deployed and configured leveraging the multi-domain orchestration innovation to connect the 5G EVE platform deployed at 5TONIC site, as illustrated in Figure 1. The M3 edge application was deployed on the edge cloud with the 5Growth stack. The Interworking Layer component of the 5G-EVE platform coordinated the orchestration operations at the different domains. To reach the application, the 5G network (either NSA or SA), configured by the Radio Controller component of the 5G-EVE platform, provided the desired connectivity to the devices.

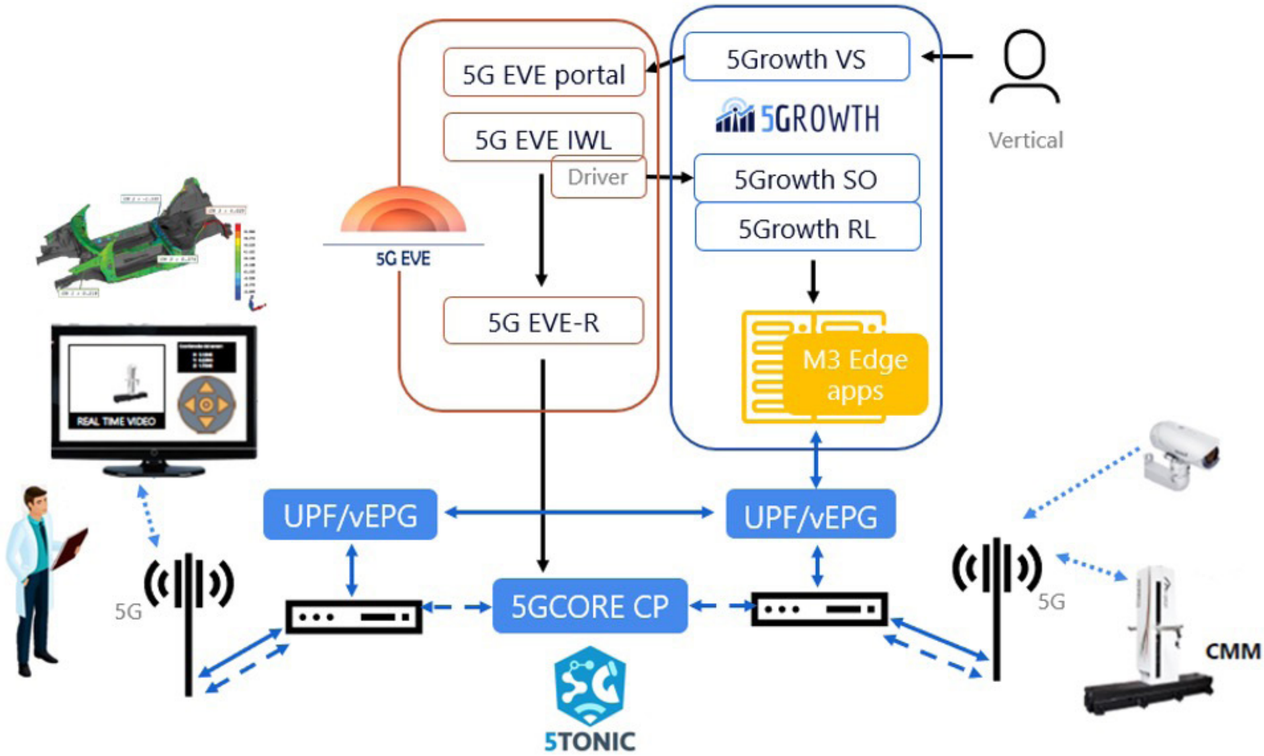


Figure 1: Pilot architecture

DEPLOYMENT

Figure 2 shows the field implementation. The devices on the left of the image, belong to the remote-control area and are connected to CPE 1. The scanning area is on the right of the image. The devices on that side are connected to CPE 2. The radio conditions are: (i) 3.5 GHz frequency band, (ii) 50 MHz 5G + 20 MHz 4G bandwidth, (iii) TDD pattern 7:3. For more detailed information: https://youtu.be/EBLm0l32iTQ

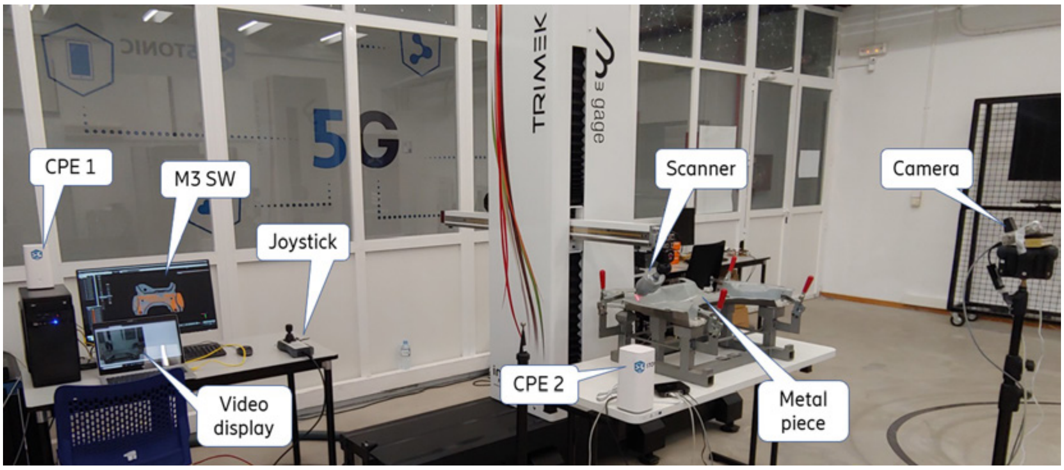


Figure 2: Pilot deployment at 5TONIC site

RESULTS

The radio segment offers UL peaks of 90 Mbps and below 10 ms one-way delay added to the TCP flow. Co-located device-to-device measured traffic metrics show: (i) video streaming constant demand of 20 Mbps and average RTT latency about 45 ms, (ii) irregular traffic patterns between M3 and CMM with peaks of 7 Mbps and average RTT latency about 30 ms. Also, the distance between sites has been emulated. Service QoE turns bad beyond 3000 km. Thus, feasibility and I4.0 competitive advantages are proved.

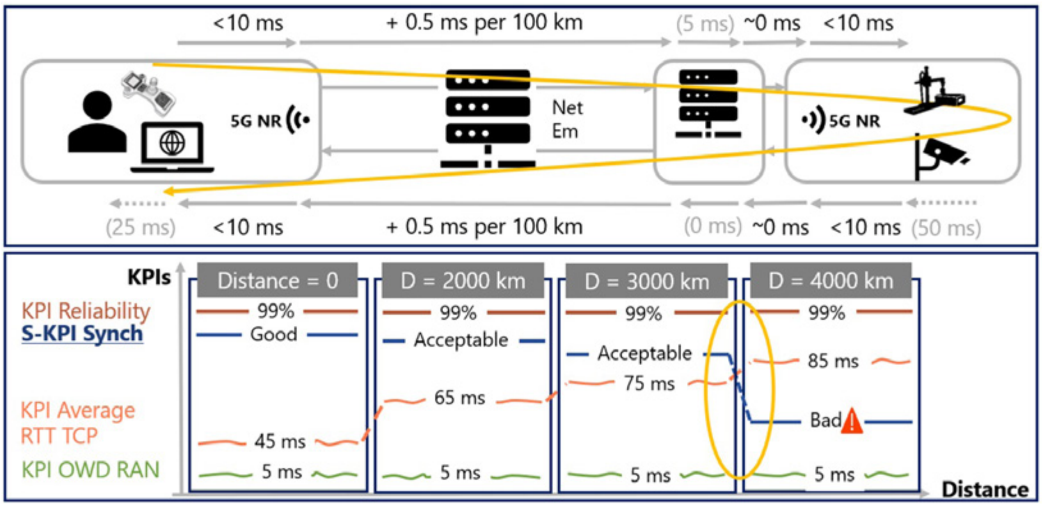


Figure 3: Experiment Results

5G EMPOWERMENT

5G NR provides a reliable high-throughput performance, with a consistently low latency, improving previous mobile generations. The lower latency in the radio segment leaves a higher margin for operating the machines from far distances. The vertical application is deployed on the network edge of the 5G architecture, and only when needed. This saves costs for the verticals, as they do not need to maintain the hardware and the application at all their customers' premises. Industries will benefit from the ubiquity of 5G commercial networks connectivity, that will allow to instantly connect the devices anywhere, in a faster, cheaper and more flexible way than cable. For all these reasons, the 5G solution is well suited for industrial SMEs.

COOPERATIVE MEDIA PRODUCTION

OVERVIEW

5G-SOLUTIONS is a 5G PPP project supporting the EC's 5G policy aiming to validate that 5G provides prominent industry verticals with ubiquitous access to a wide range of services with orders of magnitude of improvement over 4G, thus bringing the 5G vision closer to realisation. Cooperative Media Production became the new standard for production companies.

Wireless At-Home/Cloud Production solutions allow broadcasters to reduce costs producing live shows from a centralised studios instead of on-site production. At-home production solves inefficiencies and reduced support of live events allowing sending only the camera and audio teams to the field, whereas the production is done in the professional studio facility. In this use-case several cameras are each connected in the field to cellular transmission devices, including bonding devices to provide the utmost reliability and bandwidth.

LiveU was used as the bonding server for video encoders-transmitters. It used its Precision Timing feature to support the synchronization of the video streams. Video quality was up to 4K from each camera provided by Fothnet-NOVA.The partners that participated in the trials are: LIVEU, Forthnet-NOVA, University of Patras (UoP), Centre Tecnològic de Telecomunicacions de Catalunya (CTTC) and Nokia. Trials were held between Oct. 2020 and Jun. 2021.

ARCHITECTURE

The use-case architecture using bonding equipment and 4K cameras is illustrated in Figure 1.

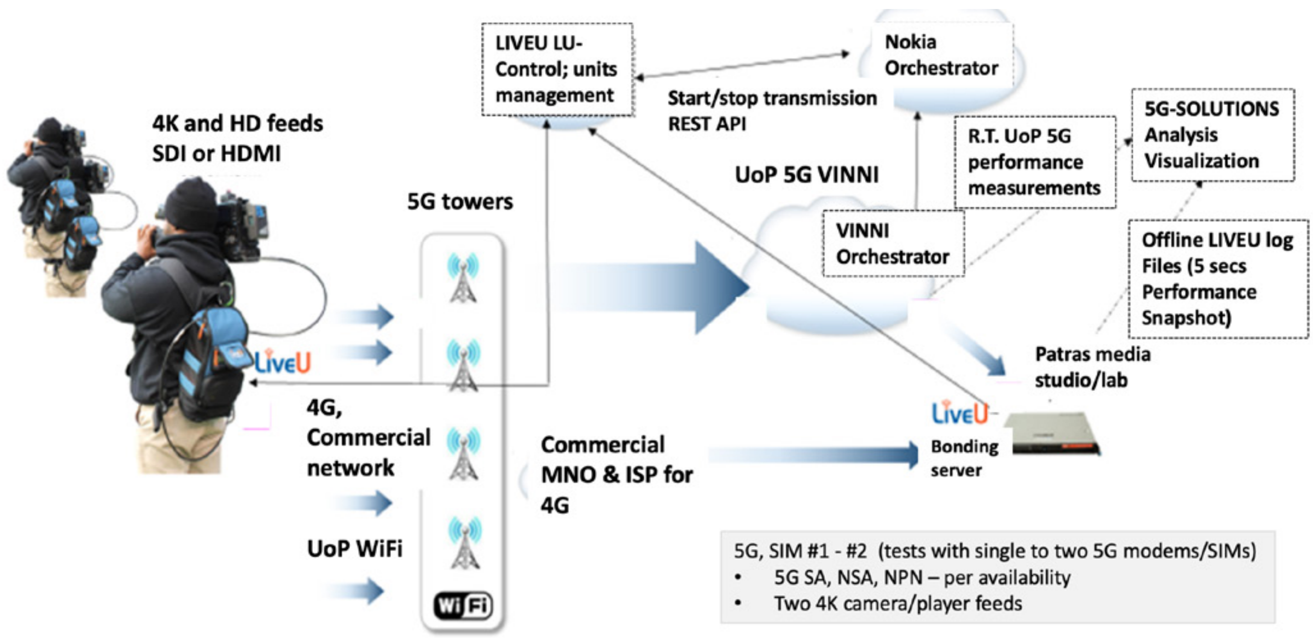


Figure 1 High Level Architecture

The use-case included LIVEU units, Forthnet-NOVA cameras, the 5G-VINNI tested on the University of Patras, Nokia's Cross Domain Service Orchestrator (CSDO), and APP-ART's Visualization System (VS) to collect the trial KPIs.

DEPLOYMENT

The use-case aimed at measuring uplink bandwidth and latency under different conditions and sub-scenarios. Multi-camera feeds at low (<0.6 sec to allow remote interviews), consistent latency and uplink bandwidth validate and evaluate 5G-bonding using multi-link bonding, multi-link with WiFi, multi-link of 5G with 4G, etc. combinations the uplink contribution at various network conditions such as cell-edge, and impact of uplink congestion on said performance.

Several products were used – LU600 and LU800 which have multi camera built-in capabilities.

Figure 2: LiveU Deployment Setup and LiveU unit and 5G base station at University of Patras

RESULTS

In the table below the key service KPIs are illustrated. All target values were met during the trials.

	Trial Target	Measurement Method
5G latency	< 20 ms	Measure 5G RAN + network latency
E2E Uplink stream latency	< 0,6 s	Including video capture, compression, and transmission to cloud/studio and decoding.
5G latency sustainability	< ~1% fluctuations over > 3 hours continuous transmission durations	Application and network parameters at various scenarios
Uplink Bandwidth per camera	> 40 Mbps, consistent over > 3 hours transmission	Transmission with LiveU LU800, single and bonded 5G (same operator, as this is what's available at VINNI)

5G EMPOWERMENT

5G is required in order to solve issues of the current on-site production allowing the production to be done remotely while sending to the field only the cameras and the cameramen. 5G is expected to provide higher uplink bandwidth, consistency, latency sustainability and overall uplink guaranteed SLA/QoS for multiple uplink cameras/feeds. This is expected to be done with SA with slices/services, PN and NPN networks. In this UC 5G can turn the impossible to possible. High upload bandwidth is required for live multi-camera production at high quality video (full HD, 4K and 8K). Latency stability is required to support this synchronization as well as to allow the remote production studio to output the live streams in confidence.

DIGITAL MOBILITY:
PUBLIC SAFETY, SECURITY AND INFOTAINMENT

5G VICTORI

OVERVIEW

5G-VICTORI project addresses the technical validation of several vertical's use-cases, including the 5G Digital mobility trial. In the Romanian facility, Alba Iulia Municipality (AIM), it has been deployed in 2021 a 5G pilot to increase safety and comfort for citizens structured around two components: infotainment and public safety.

The trial system enabled two 5G services, as seen in Figure 1. Infotainment in public buses (top), containing municipality services media streaming and social networking. For public safety, a high-resolution video streaming (bottom) is delivered over 5G to AIM C&C server, allowing through AI automated and real time threats identification using a 5G network that is allocating the appropriate QoS for emergency services.

The involved partners are Orange RO and FR, EURECOM and AIM.

Figure 1: Infotainment services in dense areas (top) and AI recognition of emergency situation (bottom)

ARCHITECTURE

The main project trial components were: (i) Facility Services Web Portal, (ii) Orchestrator, managing the use-case service slices and resources, 5G-EVE French Cluster ONAP, (iii) IaaS, multitenant in AIM and Bucharest, following the ETSI MANO framework, (iv) Physical network Infrastructure: radio, computing servers and transmission networks, (v) Mobile Edge Computing (MEC) & Analytics application for threats identification, (vi) Command and Control Center, initiating the emergency procedures, (vii) 5G RAN and Core components (5G NSA Option3x), software components for 5G services communication.

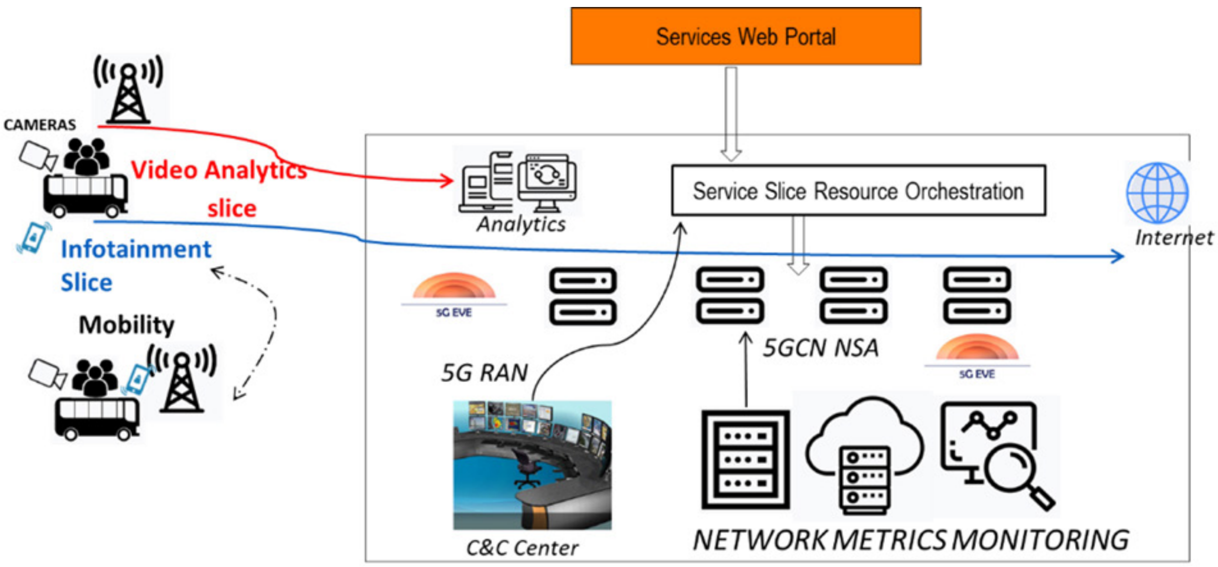


Figure 2: Trial Use-case architecture

The trial components are described in Figure 2 and provide the 5G communication for the two media applications, with proper traffic prioritization for the video analytic service.

DEPLOYMENT

Trial deployment and configuration integrated the 5G-EVE solution framework, three clusters are involved in experiment deployment: (i) French cluster for ONAP orchestration connected through IPsec to Bucharest, (ii) Bucharest 5G experimentation cluster, (iii) AIM cluster facility for use-case demonstration.

Figure 3: Pilot deployment results

The 5G service was instantiated through 5G-EVE framework, pilot results described in Figure 3 in which the network video service slice was instantiated and traffic was sent to AIM C&C analysis.

RESULTS

Using this configuration for the testing campaign, the results demonstrated the creation of the network slices that seamlessly converge with available networking technologies and provide a highly reliable, mission-critical, interoperable public safety communication supported by 5G systems.

This pilot provided infotainment services for citizens and public safety service over 5G, end-to-end deployment and instantiation, immediate service setup time, in-life management and automation.

The key achievements and performance KPIs were reflected by trial measured values, E2E latency and prioritised uplink data traffic for public safety services (20 ms RTT and 10 Mbps UL), network service instantiation (15 s RAN and Core service instantiation), Command and Control (C&C) Centre real time data visualization.

5G EMPOWERMENT

The trial of simultaneous 5G service slice deployment has demonstrated the creation and implementation of an end-to-end communication service over a 5G infrastructure for Digital Mobility use-case, assuring, through mainly the access radio, the slice resources prioritization and the service KPIs (bandwidth, latency).

The previous technologies were not capable the provide the needed network service control nor to support the specific traffic characteristics. Without the enhanced 5G performance the trial would not be possible. 5G enables new use-cases that legacy technologies cannot support and brings significant business benefits, rapid time to market delivery, reduced infrastructure cost, and improved service level management.

5g-victori-project.eu

5G EMPOWERMENT AND COLLABORATIONS

The 5G Infrastructure PPP Programme has allocated significant efforts to develop innovative solutions for multiple vertical industries. As highlighted in the 5G PPP White Paper "Empowering Vertical Industries through 5G Networks - Current Status and Future Trends"[1], the 5G PPP Key Achievements Version 3.0[2] and Version 3.1[3] and the 5G PPP White Paper "Service Performance measurement methods over 5G experimental networks"[4], the 5G Infrastructure PPP prototypes, trials and pilots have demonstrated the real empowerment that 5G networks bring into the vertical sectors. Complementarily, interested readers can also have a quick glance on how vertical services KPIs can be mapped into network KPIs[5] which, again, substantiates the need for 5G networks. The improved technological KPIs (e.g., throughput, delay reliability...), together with the native network flexibility and the short service deployment time have created the perfect environment for service developers to design and deliver services and applications that will have a significant impact in/for the European economy and the everyday life of citizens. In the context of the 5G Infrastructure PPP, tangible results from the experimentation platforms are now being systematically collected from multiple projects and are analysed to demonstrate the clear benefits of 5G networks, and to indicate what also remains open for further research activities towards 6G networks[6].

The Trials & Pilots included in this Brochure n°3 address the following verticals: Industry 4.0, Health, Transportation, Smart City, Tourism, Media and Public Safety. Note that in relation to the different verticals sectors, very relevant achievements and results are also captured in recent Programme and Projects PPP White Papers and Webinars.

The key 5G features described in the latest version of the PPP Architecture White Paper "View on 5G Architecture" (currently in consultation)[7] and the PPP White Paper "Empowering Vertical Industries through 5G Networks - Current Status and Future Trends" include Network Slicing, Mobile Edge Computing, Functional Split in RAN, Advanced Security, Smart Network Management, Location Services & Context Awareness, 5G NR Capabilities, Softwarisation, Service Chaining, Traffic Steering, Spectrum and Coverage and Guaranteed QoS.

Some of the key 5G enabling features demonstrated in the Brochure n°3 Trials & Pilots include:

- Effective delivery of highly demanding applications, with different KPIs requirements, over a single communication infrastructure and fully isolated different slices.
- Enabling of cloud-based services through high-capacity, stable low-latency, and reliable 5G two-way connectivity.
- Reduced network service creation time and multitenant deployments.

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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/wp-content/uploads/2021/06/Service-performance-measurement-methods-over-5G-experimental-networks_08052021-Final.pdf*

[5] *https://5g-ppp.eu/wp-content/uploads/2021/06/Service-performance-measurement-methods-over-5G-experimental-networks_short_version_08052021-Final.pdf*

[6] *https://5g-ppp.eu/wp-content/uploads/2021/08/TMV-Results-Explanation-White-Paper-V1.0.pdf*

[7] *https://5g-ppp.eu/wp-content/uploads/2021/08/Architecture-WP-v4.0_forPublicConsultation.pdf*

- Faster change of production line and maintenance.
- Automatic management of end-to-end network services in multiple administrative domains while satisfying vertical requirements.
- Efficient infrastructure usage derived from the automation of network service deployment and the constant optimization of network and computational resources.
- Orchestration of 5G-ready applications over a programmable infrastructure that allows the dynamic adaptations of network topologies and resources.
- End-to-end orchestration of services across a distributed cloud involving edge and central sites.
- Enabling multiple service providers to offer end-to-end services inside a single slice, allowing seamless integration of currently siloed corporate networks and rapid service deployment.
- Transport network technologies and orchestration systems enabling the deployment of shared architectures which ensure the right balance between cost and revenues for all stakeholders.
- E2E transport-aware orchestration for QoS slices in support of vertical services.
- Identification of scheduler configuration for reducing latency.
- Dedicated isolated network slice for critical communications with high requirements on security and availability as well as QoS differentiation.
- Onboarding of third-party applications and security-as-a-service into the Network Slice for vertical customer.
- Support of advanced services like the collaborative collision avoidance that require challenging network KPIs and additional technological breakthroughs such as QoS prediction, precise positioning and cross-domain management and orchestration.
- Enabling the realisation of advanced air quality monitoring services for smart cities and taking advantage of 5G infrastructure in order to support the accurate identification of polluted atmosphere and the immediate notification of the interested parties.
- Feasibility of 5G neutral hosting solutions for a more efficient use of 5G virtualisation infrastructures, especially in 5G-enabled cities: Multitenancy and isolation guarantees have been demonstrated with multiple live network slices, and very short (< 1min) service creation times, thus opening to broader stakeholder ecosystems beyond Telcos.
- 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.

Finally, this Brochure n°3 clearly demonstrates the impacting and successful implementation of the PPP Programme and projects, showing the tight interconnections and interworking between the various projects. The PPP Heritage Figure Version 1.0[8] released in June 2020 summarised the direct projects follow-ups, the components (re-)use between projects and the utilisation of (ICT-17) Platforms projects by the (ICT-19) Verticals Pilots projects. Version 2.0 (under development) will include the overall panoramic perspective over the 92 PPP projects.

Many PPP Phase 3 Trials and Pilots are currently under further development leveraging on Phase 3 (ICT-19) Verticals Pilots projects using Phase 3 (ICT-17) Platforms projects. Their outcomes will be included in forthcoming editions of this Brochure.

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

CONCLUSIONS & NEXT STEPS

Evaluating the 5G Infrastructure PPP projects outcomes, it is clear 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. Obviously, 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. During the following years, the 5G Infrastructure PPP Initiative will continue its work to provide a solid bridge towards 6G networks and the Smart Networks and Services (SNS) era.

This Brochure n°3 has provided a summary overview of 10 outstanding Trials & Pilots. While Phase 2 projects completed their work, Phase 3 projects further address key vertical industries, and the Trials & Pilots aim to measure how 5G can and will impact the performance and the overall operation of vertical industries in the path to full digitisation. Many PPP Phase 3 Trials are currently running and producing further significant results.

This Brochure n°3 will certainly encourage readers to look for more information and details, visit the PPP and projects websites, watch the Trials & Pilots videos, read the related documents, interact with PPP participants in meetings, workshops, and conferences.

As the 5G Infrastructure PPP has reached its peak point, many new achievements are expected in the coming months through the further development of the Phase 3 projects. A fourth edition of the Brochure is planned to be ready in Spring 2022.

So, please, stay tuned...

EDITORS & CHAMPIONS

The editors of this PPP Trials & Pilots Brochure n°3 are Didier Bourse (Nokia), Alexandros Kaloxylos (5G-IA), Carles Anton (CTTC), Miguel Alarcón (Martel) and Frédéric Pujol and Carole Manero (IDATE).

The following Table summarises the key PPP champions involved in the 10 Trials & Pilots highlighted in this Brochure n°3.

TRIALS & PILOTS	TRIALS & PILOTS CHAMPIONS
5GCity: 5G Neutral Hosting	Gino Carrozzo *(Nextworks)*, Shuaib M. Siddiqui *(i2CAT)*, Elian Kraja *(Nextworks)*, Adriana Fernandez Fernadez *(i2Cat)*, Mariano Lamarca Lorente *(IMI, Ajuntament de Barcelona)*, Luca Falsiroli *(Comune di Lucca)*, Dimitra Simeonidou *(University of Bristol), Antonio Garcia (Accelleran)*, David Pujals Avila *(Cellnex)*, Michele Paolino *(Virtual Open System)*, Antonio Albanese *(Italtel)*, Ricardo Vitorino *(Ubiwhere)*, Gabriele Baldoni *(ADLINK)*, Maria Rita Spada *(WindTre)*
5G-EVE: Public safety and environment protection	Panagiotis Demestichas *(WINGS), Vassilis Foteinos (WINGS)*, Vaggelis Kosmatos *(WINGS)*, Christos Ntogkas *(WINGS)*. Ioannis Belikaidis *(WINGS)*, Kostas Tsagkaris *(WINGS)*, Yiannis Kyriopoulos *(Ericsson Hellas)*, Kostas Kravariotis *(Ericsson Hellas)*, Velissarios Gezerlis *(Hellenic Telecommunications Organization)*
5G-EVE: Industry 4.0: Autonomous Vehicles	Enrique Sierra *(ASTI Mobile Robotics)*, Manuel Lorenzo *(Ericsson)*, Jaime García Reinoso *(University Carlos III Madrid)*, Luis Miguel Contreras *(Telefónica I+D)*, Ignacio Berberana *(IMDEA Networks)*
5G-VINNI: Network Slicing Norwegian Defence	Pål Grønsund *(Telenor)*, Kashif Mahmood *(Telenor)*, Andres Gonzalez *(Telenor)*, Terje Rød *(Ericsson)*, Tom Kristian Berg *(Nokia)*, Antonios Dimitriadis *(Nokia)*, Tirthankar Ghosh *(Nokia)*, Geir Nevjen *(Huawei)*, Kennet Nomeland *(Norwegian Defence Material Agency)*
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Design by Martel Innovate

This material has been designed and printed with support from the Full 5G project and the 5G Infrastructure Association. The Full 5G Project has received funding by the European Commission's Horizon 2020 Programme under the grant agreement number: 856777. The European Commission support for the production of this publication does not constitute endorsement of the contents, which reflects the views only of the authors, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

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