H2020 5G-TRANSFORMER Project

Grant No. 761536

Integration and proofs of concept plan

Abstract

This deliverable reports the refined plan of implementation, integration and demonstration of the 5G-TRANSFORMER platform. The main content of this deliverable is a detailed description of the updated integration progress of each individual use case; including a time plan with concrete milestones, expected KPIs to validate, technology and platform requirements, integration plan in the common testbed, as well as the integration progress of the individual 5G-TRANSFORMER components. Additionally, it provides the motivation for the selection of the individual use cases and an update of the status of the different testbed's sites.

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Disclaimer

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List of Acronyms

Acronym	Description
5G-PPP	5G Public Private Partnership
5GT	5G Transformer Project
5G-T CI	5G-TRANSFORMER Continuous Integration platform
5GT-MTP	5G-TRANSFORMER Mobile Transport and Computing Platform
5GT-SO	5G-TRANSFORMER Service Orchestrator
5GT-VS	5G-TRANSFORMER Vertical Slicer
AGV	Automated Guided Vehicle
AP	Action Point
CAGR	Compound Annual Growth Rate
CAM	Cooperative Awareness Messages
CI	Continuous Integration
CIM	Cooperative Information Manager
C-ITS	Cooperative Intelligent Transport Systems
CP/UP	Control Plane / User Plane
CR	Cloud Robotics
CTO	Chief Technology Officer
CUPS	Control / User Plane Separation
D2D	Device-to-Device (communication)
DC	Data Center
DENM	Decentralized Environmental Notification Message
E2E	End to End
EPC	Evolved Packet Core
EVS	Extended Virtual Sensing
HSS	Home Subscriber Server
HW	Hardware
ICA	Intersection Collision Avoidance
ICT	Information and communication technology
KPI	Key Performance Indicator
LTE	Long-Term Evolution
MANO	Management and Orchestration
MEC	Multi-access Edge Computing
MME	Mobility Management Entity
MNO/MVNO	Mobile Network Operator / Mobile Virtual Network Operator
MCPTT	Mission Critical Push to Talk
NBI	North-Bound Interface
NFV	Network Function Virtualization
NFV	Network Functions Virtualization
NFVI-PoP	Network Function Virtualization Point of Presence
NFV-NS	Network Service
NFVO	NFV Orchestrator
NSD	Network Service Descriptor
OTT	Over The Top media services
PNF	Physical Network Function
PoC	Proof-of-Concept
QoE	Quality of Experience
RAN	Radio Access Network
RSU	Road Side Unit
SGi	Service Gateway interface

SLA	Service Level Agreement
UC	Use Case
UE	User Equipment
UHD	Ultra High Definition
VA	Virtual Application
VDU	Virtual Data Unit
vCDN	virtual Content Distribution Network
vEPC	virtual EPC
VNF	Virtualized Network Function
VNFM	Virtual Network Functions Manager
VPN	Virtual Private Network
VSD	Vertical Service Descriptor
VxLAN	Virtual eXtensible Local Area Network
WIM	WAN Infrastructure Manager
WP1	5GT Work Package 1
WP2	5GT Work Package 2
WP3	5GT Work Package 3
WP4	5GT Work Package 4
WP5	5GT Work Package 5

Executive Summary

After defining and specifying the baseline 5G-TRANSFORMER architecture, the project has implemented the first release of its main components and it is now ready to start demonstrating and validating the technology components designed and developed by the project consortium. Work Package (WP) 5 coordinates and leads the efforts regarding the integration of the components provided by WP2 (5GT-MTP), WP3 (5GT-VS) and WP4 (5GT-SO), and their deployment in a common testbed. The first months of the project focused on the interconnection of the testbed, which is composed of four different physical sites, as described in D5.1 [1]. The next step has been for WP5 to define refined implementation, integration and demonstration plans for the tests and Proofs-of-Concept (PoCs) that will be developed showcasing selected use cases from the set identified by WP1.

The scope of this deliverable is mainly to provide a refined plan of implementation, integration and demonstration of the 5G-TRANSFORMER platform by conducting tests and PoCs based on the vertical-oriented use cases selected by the project. The key contributions and the associated outcomes of this deliverable are the following:

- The rationale followed to select the use cases, from the set identified by WP1, which will be used in the demonstration activities conducted by WP5.
- The final list of the demonstrations and PoCs that will be conducted, as well as their implementation and development roadmap. This roadmap is aligned with the implementation plans provided by the correspondent work packages, which are responsible for providing the 5G-TRANSFORMER platform components that will be used to deploy the use cases. The initial release of these components has just been made available in November 2018 and described in D2.2 [2], D3.2 [3] and D4.2 [4].
- An initial planning of the PoCs per use case, their description, the technologies and functional requirements demanded by these PoCs.
- An update on the different trial sites that compose the 5G-TRANSFORMER testbed, including updates regarding the end to end integration of the different components of the 5G-TRANSFORMER platform.

1 Introduction

5G-TRANSFORMER demonstrates and validates a series of 5G use cases and, importantly, the innovative components and concepts (such as vertical slicer, network slicing, service orchestration, infrastructure abstractions, etc.) specifically designed and developed within the project to meet their functional and technical requirements. WP5 leads and coordinates the integration of the different components designed in WP2, WP3 and WP4 onto one testbed distributed across four different sites.

D5.1 (Section 6) [1] introduced this testbed in detail and presented the activities carried out at the beginning of the project to interconnect the different sites and provision them with the relevant infrastructure resources to deploy the different 5G-TRANSFORMER system components. In particular, 5TONIC, EURECOM, CTTC and ARNO sites are interconnected via a Virtual Private Network (VPN) as illustrated in Figure 1 with an example deployment of different 5G-TRANSFORMER components. In addition, the same document (Section 5) presented an initial plan for the development of the Proof-of-Concepts (PoCs) selected in D1.2 [5]. Specifically, a descriptive set of Automotive, Entertainment, e-Health, e-Industry, and mobile (virtual) network operator use cases were introduced.

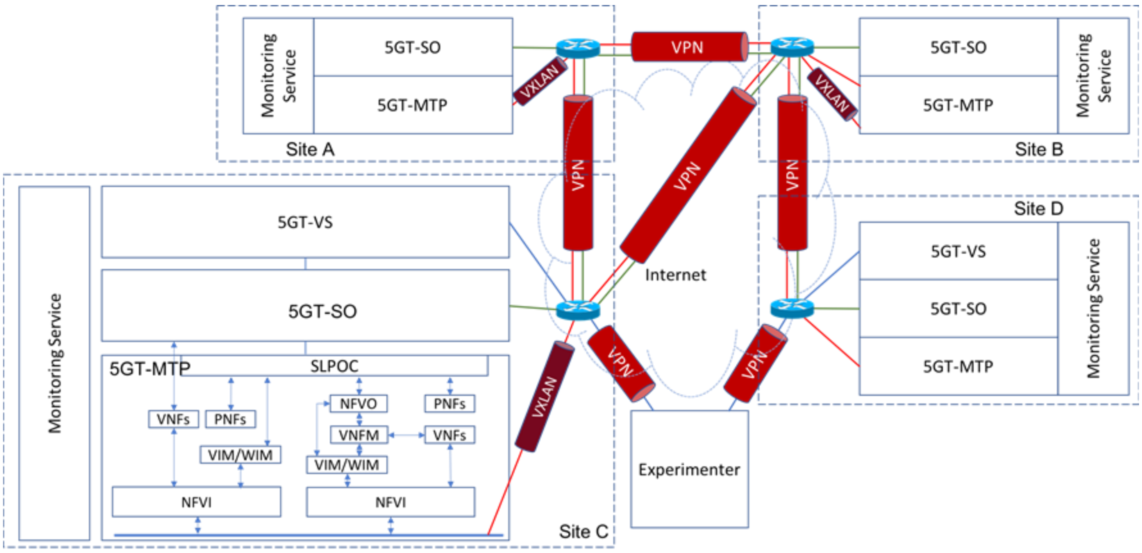

FIGURE 1: 5G-TRANSFORMER INTEGRATED TESTBED. EXAMPLE DEPLOYMENT (FROM D5.1 [1])

The main goal of this deliverable, D5.2, is to provide a refined plan for implementation, integration and demonstration of the 5G-TRANSFORMER platform that includes tests and PoCs based on such vertical-oriented use cases. In this way, Section 2 introduces the procedure we have implemented to select the specific use cases to be demonstrated in the final PoCs, including automotive (Extended Virtual Sensing services), entertainment (Smart Stadium - Fan Enhancement and OTT), e-Health (monitoring of life functions through wearables), e-Industry (cloud robotics) and mobile network operator (Mobile Core as a Service).

Section 3 provides a detailed development plan of each respective use case. This refined plan includes a time plan with concrete milestones, expected KPIs to validate their successful outcome, technology and platform requirements and integration plans in the common testbed. This plan is aligned with the different design and implementation activities being carried out in WP2, WP3 and WP4, which have already provided an initial release of their components in D2.2 [2], D3.2 [3] and D4.2 [4].

Section 4 is devoted to updates on the specific tasks executed so far for the maintenance of the common testbed across the four different sites mentioned above. In particular, the section briefs about the main integration work done so far in terms of the deployment of the 5G-TRANSFORMER components (5GT-VS, 5GT-SO, 5GT-MTP) across each site. Finally, based on the inter-site connectivity results presented in D5.1 [1] and the individual components deployed in each site, the section presents a plan to inter-connect each component to have a single end-to-end 5G-TRANSFORMER Continuous Integration (CI) platform. The 5GT-CI platform enables rapid integration, testing and evaluation of the developed software components.

The work carried out within WP5 is highly dependable on WP2, WP3 and WP4, which are responsible to release the software components according to a coordinated release time-plan which is summarized in Section 5. Specifically, there are two release milestones (Release 1 and Release 2) for each component and this section reports on the status of the work progress towards releasing and functional testing such releases.

Finally, this document is concluded in Section 6 with some final remarks and a brief summary highlighting the main achievements so far.

2 Selected use cases

This section describes the procedure we have implemented to select the specific use cases to be demonstrated in the final PoCs of the project.

The selection criterion of all the use cases was based on several factors, including the economic impact – describing the improvements made by the use case regarding the current situation, impact on society – focusing on the consumers of the service, and the innovation challenges aligned with the scope of the 5G-TRANSFORMER project.

The feasibility to develop each use case with the relevant resource requirements including software and hardware components is key, so it is certain that the selected use cases must be implementable with the resources of 5G-TRANSFORMER project. The selected use cases should also serve to highlight innovations of the project using the innovation radar to obtain the innovation challenges involved in each use case, and binding them with the technology offered by the 5G-TRANSFORMER project.

Last, the selected use cases also directly contribute to the definition of the 5G-TRANSFORMER KPIs, with a direct relation regarding the mapping between the KPIs and the PoCs.

In the following, we present the list of selected use cases based on this procedure.

2.1 Automotive

In D1.1 [6], a wide list of possible use cases for the Automotive Industry has been provided. The wide scope was to demonstrate how many different types of services could need the emerging 5G technology and to collect as many requirements as possible. After the initial analysis reported in D1.1 [6] and D1.2 [5], Extended Virtual Sensing (EVS) (initially referred to as Intersection Collision Avoidance (ICA)) has been selected as the use case for the final demonstration because of the potential benefit of the application to road safety, the alignment with governments' Cooperative Intelligent Transport Systems (C-ITS) application roadmaps, the maturity of the application from an implementation point of view and the possibility to demonstrate solutions to challenges for 5G-TRANSFORMER.

Relevant accident statistics, released by the European Commission, are used to establish a comparison of existing and future number of fatalities and serious injuries by year, in the absence of C-ITS technologies. The study [7] demonstrates that C-ITS technologies can considerably reduce the number of fatalities and serious injuries on the EU's roads (more than 50%). This is reflected also by reduced societal costs of €1,870,000 and €243,100 associated with a fatality and a serious injury, respectively.

Regarding the current economic impact, as described in [8], applications are focusing mainly on infotainment nowadays, but they are expected to cover also other use cases that have high requirements regarding secure interaction between applications and vehicle's sensors, which translates into new business models opportunities for the stakeholders. Standard business models are based on subscription (the user pays for a service provided by the application), but an approach of rewarding the driver for sharing the data could also be used. In this latter case the adoption of smart-connected vehicles would be incentivized. The business case for the Automotive Safety domain is still under consideration.

The main approach about EVS is to enhance the already matured and implemented ICA application (limited to the use of local vehicle sensors) with the capabilities expected from 5G technology, and therefore, extend the vehicle sensing capability beyond buildings and obstructions. To make EVS feasible, the 5G-TRANSFORMER architecture must guarantee low latency, which could be achieved using Multi-Access Edge Computing (MEC).

2.2 Entertainment

Atos Major Events has explored several technologies to support massive personalized content in venues to enhance our Smart Stadium - Fan Enhancement and OTT offering. In fact, PoCs have been run testing different vendors technology, combining different types of Wi-Fi infrastructure with specific software. The most promising solution before 5G-TRANSFORMER, was a combination of multicast, and Wi-Fi. Nevertheless, this solution did not cover all the needs, as explained below:

- There was a high cost associated to the deployment of the Wi-Fi infrastructure.
- Due to Wi-Fi limitations, even with an expensive Wi-Fi infrastructure the number of users was limited.
- When using multicast to optimize the Wi-Fi bandwidth, the personalization and interaction was limited.
- When mobile devices are connected to a Wi-Fi service, all data traffic is redirected to the Wi-Fi, which either overloaded the infrastructure or needed to block all content not related to the application, thereby disconnecting people from other applications.
- The need to deploy dedicated hardware within the venues required maintenance.

Although Atos Major Events recognizes that 5G technology could allow an evolution in many areas of the sports industry, such as sports results capture and massive local distribution, the decision was to focus on content consumption to provide the fan an immersive experience inside a sport venue. The aim is to take advantage of the 5G-TRANSFORMER platform capabilities and be able to deploy a service with 4K UHD video content without requiring any knowledge of the network services underneath as well as allocating the resources near the fans.

The 5G-TRANSFORMER platform will allow the virtualization of Content Distribution Networks with the possibility of extending the content delivery services better and with a flexible approach as well as allowing scaling of the services.

As soon as the possibility of participating in 5G-TRANSFORMER initiative arose, the Major Events department foresaw the opportunity to cover the need of providing a better fan experience to the users attending an event and guarantee a high-quality of content in venues, which has not been able to support earlier, preventing the provision of solutions to sports venues owners and clubs.

The decision of having On-site live event experience (UC E.01) and Ultra-high fidelity media (UC E.02) came out of the discussion between the Innovation Manager, the CTO and sales teams of the Atos Major Events department. There were two types of venues we wanted to evaluate with 5G technologies provided by 5G-TRANSFORMER project:

Open and close venues. Atos Major Events has selected use cases for open venues, because it was considered that this use case has the highest business potential.

The Entertainment use cases will help 5G-TRANSFORMER project validate the benefits of end-to-end latency reduction in the vCDN service as well as a decrease in bit rate and service creation time, being able to install service delivery applications on demand.

2.3 E-Health

In D1.1. [6], E-Health has been defined as the delivery of health services by means of information and communication technologies (ICT). The goal is to improve the information flow between the actors involved (e.g., patients, paramedics, hospitals, doctors, surgeons, etc.), supported by ICT.

Mobile health, which is a component of E-Health, is defined as a medical health practice supported by wireless devices, including wearable medical devices, patient monitoring devices and personal assistants [9]. Using small smart devices, the health of individuals can be analyzed and monitored using various parameters such as heart rate, blood pressure and so forth. In [10], the study shows that adults increasingly seek for health information online, which reflects into individual investments in mobile health devices. On the other hand, in [11] [12] it is stated that paramedics’ response time or more specifically the door-to-balloon time[1] of the most serious heart attack case is critical for saving a patient’s life.

With the emergence of 5G technologies, the network slicing concept can allow low-latency networks, allowing for performing remote interventions or deploying ad-hoc networks after disasters or emergencies have been detected. Technologies like MEC will help to provide E-Health services in emergency scenarios by providing localization information for patients or paramedics, triggering alarms and fast response to disaster scenarios. For that reason, the door-to-balloon time would be significantly decreased along with better logistic synchronization among paramedics in case of multiple emergencies scenarios.

In [6] we described the list of e-Health use cases. The heart-attack emergency use-case from the listed E-Health use cases is selected for demonstration. The use-case is composed of users wearing a smart wearable device (e.g., smart shirt) that can detect potential health issue (e.g., heart-attack, high blood pressure, etc.). The wearable periodically reports the health status to a central server. If the monitoring data shows a potential issue, the central server issues an alarm to the wearable device so the user can mark it as a false alarm, or the issue will be confirmed if there is no feedback for certain interval. In the case of a confirmed alarm (e.g., no feedback from the user), the central server request sending paramedics to the location of the user and request deployment of edge service closer to the user. Once the edge service is deployed (on a host close to the user), the edge application establishes connection to the user’s hospital, obtaining the health records and establishes connection with the paramedic teams that are involved in the emergency response. The paramedics can obtain the records from the edge service or in case it is needed, through the edge service the

[1] The time between the moment a patient with a possible acute heart-attack enters an Emergency Room and he/she undergoes balloon angioplasty surgery.

paramedics can establish video stream connection to a medical specialist (e.g., surgent) located at a remote site (e.g., hospital far away from the emergency location) to perform remote surgery or consultation. The edge service can also be used as video streaming hub to support Augmented and Virtual Reality applications supporting the emergency personnel deployed.

It can clearly demonstrate the benefits of deploying low-latency communication services on the edge of the network with the goal to lower the door-to-balloon time and potentially increase the probability of saving people’s life. As compared to the original use case, we have performed some modifications, without overlooking the vertical’s requirements. For example, D2D communication between users and paramedics are optional (so it might not be implemented, and we only use infrastructure-based communication).

2.4 E-Industry

E-Industry is predicted to fundamentally change industry. The connectivity envisioned by E-Industry implies that streams of data will flow to and from connected systems, placing stringent demands on the underlying communications platform. The ability of the next generation of mobile networks to meet the service requirements of the E-Industry vertical is paramount, and thus the motivation for including the E-Industry UC in the 5G-TRANSFORMER project.

The emergence of E-Industry, and the role of industrial robots in global production is increasing with a significant upward trend as more and more industrial tasks are accomplished with the use of robots. From 2018 to 2020, European robot installations are estimated to increase by at least 11% on average per year (CAGR) with total global sales reaching about 520,900 units in 2020. Globally, between 2017 and 2020, it is estimated that more than 1.7 million new industrial robots will be installed in factories around the world [13].

The future benefits of E-Industry include a more cost-efficient production model with the ability to adjust products more swiftly; it allows for predictive maintenance, thereby extending life cycles, reducing waste, and thus, cooperating with sustainability. To facilitate this, robots must be multipurpose and intelligent enough to adapt, communicate and interact with each other and with humans, based on a remote control that can globally manage a complete set of robot systems. The necessary increase in complexity of the control software requires more powerful computers for handling the tasks in real time. This has led to a push toward cloud robotics, with the “brains” (virtual controllers) of the robots in the cloud. The “brain” consists of a knowledge base, program path, models, communication support and so on, effectively transferring the intelligence of the controller into a remote virtual controller.

Communications among all the elements in a cloud robotics industrial setting must work in a challenging environment characterized by electromagnetic interferences and distributed over a large area that could span several buildings. While LTE connectivity is robust and capable enough to cope with that environment today, stringent network requirements will soon demand 5G connectivity. The networking requirements are largely driven by the performance requirements of the individual applications. Figure 2 presents a characterization of the network requirements for some robotic applications. Within the scope of 5G-TRANSFORMER, the ability to guarantee stringent requirements such as deterministic latencies and reliability to the cloud robotics use case, which features factory service robots and production processes that are remotely monitored and controlled in cloud, can be achieved and demonstrated through customized slices created and managed throughout a federated virtualized infrastructure. Out of these reasons, the cloud robotics use case was selected within 5G-TRANSFORMER.

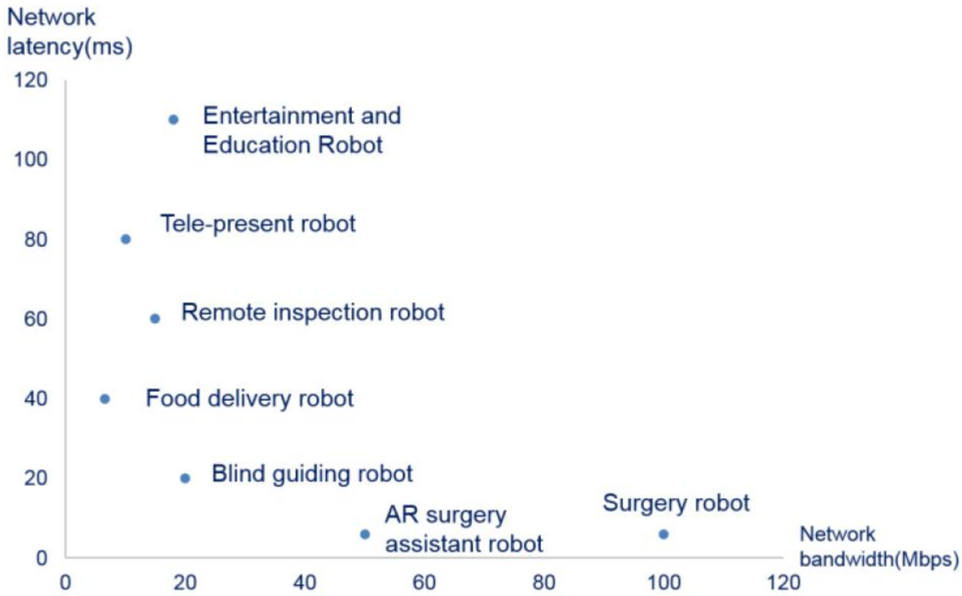

FIGURE 2: NETWORK REQUIREMENTS FOR ROBOTIC APPLICATIONS [14]

2.5 MNO/MVNO

Currently, mobile operator networks are composed by entities based on single-purpose devices that are deployed and configured according to some service needs. Hence, despite the intent of accomplishing services fitting the evolving demand, these static and monolithic environments make it difficult, when not impossible, to have the desired flexibility.

One of the most important 5G challenges is precisely the increasing of the flexibility in networks through the convergence of mobile networks and cloud infrastructure. In this way, Mobile Network Operators (MNOs) will have the ability of using Network Function Virtualization (NFV) concepts deployed on top of cloud-based infrastructure to decentralize and virtualized their network entities.

The concept of Mobile Virtual Network Operator (MVNO) already exists with different variants in terms of the functions and capabilities being performed by the Mobile Network Operator that enables it [15]. The new possibilities brought by network virtualization and programmability enable a more flexible and powerful environment for MVNOs, since the functionality needed for approaching the market can be easily tailored to the real demand, or even, specialized markets can be addressed in a more focused manner.

Many use cases were proposed in D1.1 [6], which could be used as a basis to serve different 5G network services in a slice. Similarly, other specific use cases were proposed in which the MVNOs built a Mission Critical Push to Talk (MCPTT) service.

After a study on the proposed use cases in D1.2 [5], EPC as a Service (EPCaaS) was selected because vEPC perfectly captures the network slicing concept as defined in 3GPP TS 28.530 [16] in terms of business service types. Accordingly, an MNO will offer to its (vertical) clients, i.e. the MVNOs, 5G access services shaped like a Network Slice as a Service offering. Furthermore, MVNOs can be able to provide their own and specific services on top of the vEPC services.

EPC as a Service is defined as virtualized implementation of the Evolved Packet Core (EPC) over a virtualization infrastructure, providing it in an as-a-service fashion. Figure 3 represents this service offering. Then, the more direct and first realization of EPCaaS consists of a cloud-enabled mobile operator constituting an MVNO. In contrast, an MNO owns a mobile network infrastructure, which includes implementation of all relevant network entities, including the EPC itself, the auxiliary platforms used to manage and charge the services offered to the end-users, and the infrastructure needed to deliver services going beyond pure connectivity. The cloudification of EPC creates the opportunity for an operator to move to a completely different network paradigm, where the network functions that used to be implemented on physical devices and deployed on specific points of presence (PoP). Hence, with the advent of network slicing, EPCaaS becomes not only an interesting opportunity for MNOs and MVNOs, but also a network and business enabler for verticals targeting specific markets (i.e., specific communities of individuals, like sports fans, retail customers, etc.).

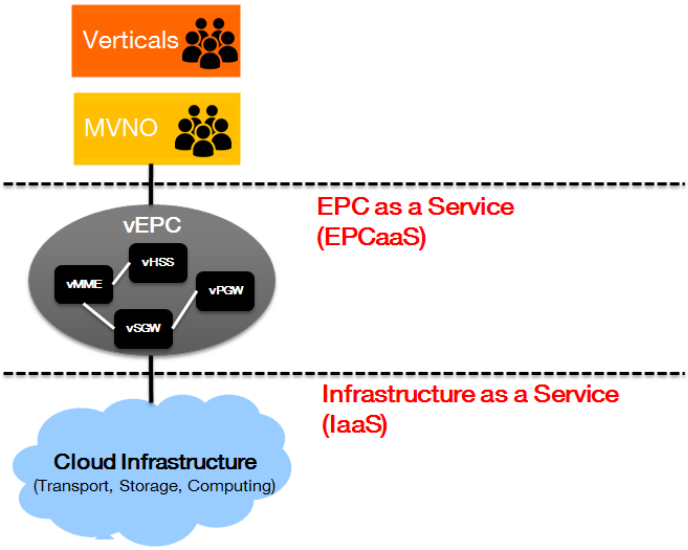

FIGURE 3: EPC AS A SERVICE WITH FULL VIRTUALIZATION OF EPC ENTITIES

3 Proofs of concept

This section presents a description and mapping of the different PoCs of the use cases describing how they will be deployed and validated with the 5G-TRANSFORMER platform in the different testbed sites. The testing of the different technologies and functionalities of the PoCs will grant the demonstration of the identified use cases. Each vertical provides the following information:

- An updated plan for each PoC including a description and relevant observations.
- The mapping between the high-level KPIs and the different PoCs.
- The mapping between the required technologies, the associated PoCs and the testbeds that will be used to demonstrate them.
- The mapping between the platform functionalities and the different PoCs of each vertical.
- The planning of the demonstration of the PoCs and the integration with the testbed sites including the associated software release.

3.1 Automotive

The scope of the Automotive PoCs is to implement an Extended Virtual Sensing Service, previously known as Intersection Collision Avoidance Service, which will allow (thanks to the communication among the vehicles and infrastructure) to calculate the probability of collision and react accordingly.

3.1.1 Updated plan

The updated plan (from D5.1 [1]) for the Automotive PoCs is shown in the following table, considering the objectives mentioned above.

TABLE 1: UPDATED PLAN FOR AUTOMOTIVE POCS

PoC ID	Description	Observations	Month
1.1	The vehicle exchanges messages (CAM, DENM) with an RSU deployed on a MEC host. A video streaming service is deployed in the MEC host and delivered to the vehicle UE.	Required traffic flows from the vehicle to the RSU.	M16
1.2	CIM (in the MEC host) processes the messages from the vehicle and the traffic simulator (basic implementation).	Required traffic flows between the MEC and all involved entities.	M18
1.2+	Integration of real radio equipment.	Required E2E latency (radio protocol contribution between modem and the SGi interface, transport contribution of the SGi interface and MEC algorithm processing time.	M20
1.3	CIM receives the messages from the vehicle and the traffic simulator.	CIM receives as input data from traffic simulator. Communication between VAs in	M20

	The Extended Sensing in the MEC host processes context data from CIM and computes a decision (special message) to be notified to the vehicle.	MEC host. Required latency and impact of Extended-Sensing algorithm.	
1.4	In vehicles integration and instantiation of a concurrent slice (e.g., video streaming/back-ends).	End to End communication among all service components.	M26
1.5	Increase the amount of connected vehicles and traffic to be supported by slices, and adapt the amount of resources accordingly.	Monitoring the assigned resources.	M28

The final integrated demo will be performed in a different step in M28, after 1.5.

3.1.2 KPIs

The following table addresses the mapping among the PoCs, and the high-level KPIs introduced in D1.1 [6] to provide a quantifiable output of the Automotive EVS.

TABLE 2: AUTOMOTIVE MAPPING: POCS AND HIGH-LEVEL KPIS

KPI	PoCs	Observations	Month
LAT	1.1*, 1.2, 1.2+, 1.3, 1.4, 1.5	Measuring RTT latency (time in which the vehicle sends the CAM and receives the DENM).	M16, M18, M20, M26, M28
REL	1.1*, 1.2, 1.2+, 1.3, 1.4, 1.5	Measuring the percentage of messages sent and received correctly.	M16, M18, M20, M26, M28
MOB	1.5	Measuring the service availability, considering different car speeds (>50 km/h).	M28
DEN	1.1*, 1.5	Measuring the maximum number of vehicles in considered areas, where reliability is >99%.	M16, M26, M28
TRA	1.1*, 1.2, 1.3,1.4, 1.5	Measuring the amount of data transmitted from and to the vehicles.	M16, M18, M20, M26, M28

*preliminary measurements

3.1.3 Requirements

3.1.3.1 Technology requirements

The following table addresses the mapping between the required technologies [1], PoCs, and the testbed sites used for the automotive EVS. Several technologies are used in multiple testbed sites. In particular, 5TONIC will be used for infrastructure KPI measurement done by Ericsson (1.2 plus). ARNO will be used for serving the whole UC hosting APPs to be deployed close to the testing area. Turin will be used for local testing and the final demo with vehicle (MEC App should be located close to the running vehicles). CTTC will be used for the scalability measurement (i.e. MOBILITY and DENSITY) realized in PoC 1.5 with simulation.

TABLE 3: AUTOMOTIVE MAPPING: TECHNOLOGIES, POCS, AND TESTBED SITES

Technologies	Functions	Associated PoC	Vertical site	Month
T1.a (R)	5G, LTE-A, Wi-Fi interworking capabilities	1.1*, 1.2+, 1.4, 1.5	5TONIC, Turin test site, CTTC	M16, M20, M26, M28
T1.d (R)	Core Network	1.1*, 1.2+, 1.4, 1.5	5TONIC, Turin test site, CTTC	M16, M20, M26, M28
T2.a (R)	End-to-End network slicing with predictable performance isolation	1.4, 1.5	ARNO, Turin test site	M26, M28
T2.b (R)	Network Functions Virtualization (NFV) of 5G Networks	1.3, 1.4, 1.5	Turin test site, CTTC	M20, M26, M28
T2.d (R)	NFV service scaling procedures	1.2+, 1.3, 1.4, 1.5	5TONIC, Turin test site	M20, M26, M28
T2.f (R)	End-to-end control of reliability & performance	1.2+,1.4, 1.5	Turin test site	M20, M26, M28
T2.h (R)	Cross NFV_NS Data Base	1.4, 1.5	ARNO, Turin test site	M26, M28
T2.i (R)	Vertical Specific VNF	1.4	Turin test site	M26
T3.b (R)	Multi-access Edge Computing	1.1*, 1.2*, 1.2+, 1.3, 1.4, 1.5	Turin test site	M16, M18, M20, M26, M28
T5.b (R)	Platforms for mission critical (group) communications (voice, data, video)	1.4, 1.5	ARNO, Turin test site	M26, M28

*with Open Air Interface [20].

3.1.3.2 Platform requirements

The following table addresses the mapping among the application of platform technologies and the PoCs of the Automotive EVS.

TABLE 4: AUTOMOTIVE MAPPING: PLATFORM FUNCTIONALITIES AND POCS

Platform Functionalities	Associated SW release	Associated PoC	Architectural component
Abstraction support	R1	1.4	5GT-MTP
Resource allocation	R1	1.4	5GT-MTP
Monitoring support	R2	1.5	5GT-MTP
MEC and Radio support.	R2	1.5	5GT-MTP
Fully integrated monitoring platform supporting lifecycle management and service assurance operations through the SLA manager	R2	1.5	5GT-SO
Final integration with 5GT-MTP	R2	1.5	5GT-SO

supporting the full set of operations			
Final integration with 5GT-VS supporting the full set of NBI REST API operations	R2	1.5	5GT-SO
SLA Manager supporting service assurance and auto-scaling operations on NFV-NSs leveraging Monitoring Platform	R2	1.5	5GT-SO
MEC support through plug-in in Cloudify [17] (client side) interworking with 5GT-MTP (server side) for resource allocations	R2	1.5	5GT-SO
Basic integration with 5GT-SO	R1	1.4	5GT-VS
Translator: integration of enhanced algorithms, support of service decomposition in multiple NSDs	R2	1.5	5GT-VS
Enhanced arbitration mechanisms	R2	1.5	5GT-VS
Lifecycle management of Network Slices, Network Slice Subnets, composite Vertical Services and groups of Vertical Services	R2	1.5	5GT-VS
Support of monitoring functions	R2	1.5	5GT-VS

3.1.4 Testbed integration

The final PoC will be demonstrated in Turin, and all implemented MEC applications should run close to the final test-bed site (due to latency). The initial prototypes are implemented using Open Air Interface (OAI) and, as soon as the final version of the EVS application is available, the 5G-TRANSFORMER platform will be integrated in the PoC. In particular, for the PoC 1.4, the demonstration of the Automotive UC is planned integrated in the vehicles, using the available infrastructure. Finally, the goal of PoC 1.5 is to go beyond the limitations encountered in previous versions of the Automotive PoCs, exploring the benefits of the 5G-TRANSFORMER functionalities (to achieve targets for the KPIs, e.g. mobility, density). CTTC site will be used for the PoC 1.5.

TABLE 5: AUTOMOTIVE MAPPING: POC AND TESTBED INTEGRATION

	2018									2019										
	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N
	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Automotive				1.1																
							1.2													
								1.2+												
									1.3											
													1.4							
																1.5				
																		Demo		
5GT-VS																R1		R2		
5GT-SO																R1		R2		
5GT-MTP																R1		R2		

3.2 Entertainment

The Entertainment PoCs provide the sports fan an immersive and interactive experience in sports venues, known as fan engagement, demonstrating the on-site live event experience (UC.E01) and ultra-high fidelity media (UC.E02) UCs. The UCs aim to provide a better fan experience and guarantee a high-quality content experience for closed and open venues. To achieve these objectives, a sports media player will be provided, which will allow following the competition progress in real time and interacting with additional services of the venue, as well as improving the spectator experience as for fans, it is quite difficult to follow the competition (specially in open venues). Moreover, the sports media player will be able to replay a live feed, choose a specific camera that will allow watching live views from another position and providing facts and figures, as well as insights of the event.

Another PoC that will be demonstrated shows the allocation of resources near the fans with MEC integration, federation and video service distribution, reducing bottlenecks in the network and the latency perceived by the user.

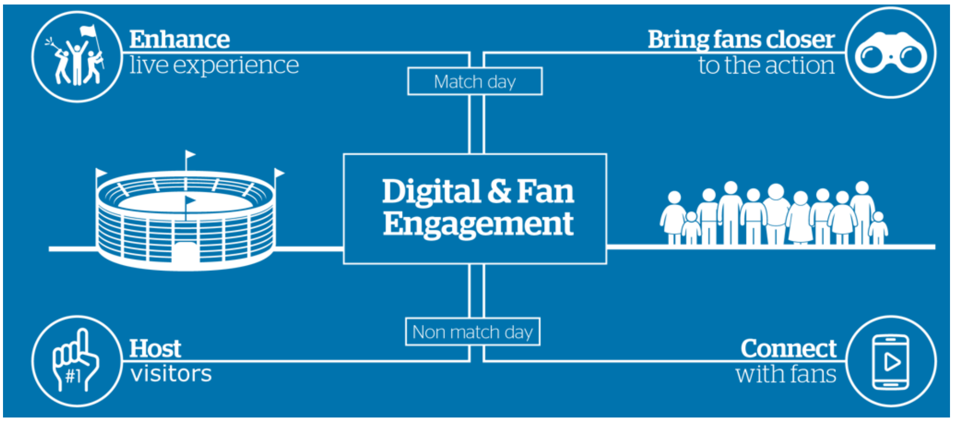

FIGURE 4: FAN ENGAGEMENT

3.2.1 Updated plan

The updated plan for the PoCs is shown in the following table, considering the objectives mentioned above.

TABLE 6: UPDATED PLAN FOR ENTERTAINMENT POCS

PoC ID	Description	Observations	Month
2.1	A MEC platform instantiates the NSDs of a vertical service and the system provides an UHD video to the spectator app.	Demonstrated in: 5G network slices for media vertical services (https://youtu.be/sRH4m_eQ6NM).	M14
2.2	Connecting the video distribution service with a PNF providing live stream.	No observations.	M16
2.3	Instantiating a separate vertical service (e.g., providing video metadata), and connecting it to the service instantiated in PoC 2.1.	Demonstrated in: 5G network slices for media vertical services (https://youtu.be/sRH4m_eQ6NM).	M18
2.4	Interconnection of a secondary datacenter for backup source.	No observations.	M20
2.5	Instantiating the video service over multiple administrative domains.	Demonstrated in: Using Cloudify [17] and public and private clouds to deploy an entertainment service (https://youtu.be/MhxpLNuTOEE).	M22
2.6	Increasing the number of connected devices. The service instance resources should be increased to adapt to the new requirements.	Demonstrated in: 5G network slices for media vertical services (https://youtu.be/sRH4m_eQ6NM).	M24

2.7	Smart placement of virtual appliances at the edge of the network.	Demonstrated in: 5G network slices for media vertical services (https://youtu.be/sRH4m_eQ6NM). Using Cloudify and public and private clouds to deploy an entertainment service (https://youtu.be/MhxpLNuTOEE).	M24
2.8	Provision of transparent abstraction of the network and automatic provisioning of intercloud connectivity and configurations.	Demonstrated in: Using Cloudify and public and private clouds to deploy an entertainment service (https://youtu.be/MhxpLNuTOEE).	M25

3.2.2 KPIs

The following table addresses the mapping between the PoCs that will be demonstrated and the high-level KPIs introduced to provide a quantifiable output of the Entertainment UCs.

TABLE 7: ENTERTAINMENT MAPPING: POCS AND HIGH-LEVEL KPIS

KPI	PoCs	Observations	Month
LAT	2.1, 2.7, 2.8	Measuring latency in the vCDN service	M14, M24, M25
UDR	2.8	Measuring the bit rate of the vCDN application	M25
SER	2.8	Measuring the instantiation time of the vCDN service	M25

3.2.3 Requirements

3.2.3.1 Technology requirements

The following table maps the technology requirements with the associated PoCs and the vertical testbeds that will be used to demonstrate them, regarding the Entertainment UCs.

TABLE 8: ENTERTAINMENT MAPPING: TECHNOLOGIES, POCS, AND TESTBED SITES

Technologies	Functions	Associated PoC	Vertical site	Month
T1.a (R)	LTE-A, Wi-Fi	2.1, 2.2, 2.3, 2.4, 2.5, 2.6	5TONIC	M14, M16, M18, M20, M22, M24
T1.d (R)	Core Network	2.1, 2.2, 2.3, 2.4, 2.5, 2.6	5TONIC	M14, M16, M18, M20, M22, M24
T2.a (R)	Openstack	2.1, 2.2, 2.3, 2.4	5TONIC	M14, M16, M18, M20
T2.b (R)	VNFs implementing network components	2.1, 2.2, 2.3, 2.4, 2.5, 2.6	5TONIC	M14, M16, M18, M20, M22, M24
T2.c (R)	ETSI	2.3, 2.5	5TONIC	M18, M22

	OpenSource MANO v2			
T2.f (R)	End-to-End performance control and measurements	2.1	5TONIC	M14
T3.b (R)	MEC platform	2.1	5TONIC, EURECOM	M14

3.2.3.2 Platform requirements

The table below maps the platform functionalities and technologies with the entertainment PoCs.

TABLE 9: ENTERTAINMENT MAPPING: PLATFORM FUNCTIONALITIES AND POCS

Platform Functionalities	Associated SW release	Associated PoC	Architectural component
Abstraction support	R1	2.5, 2.6	5GT-MTP
Resource allocation	R1	2.5, 2.6	5GT-MTP
Resource termination	R1	2.5, 2.6	5GT-MTP
MEC support	R2	2.1, 2.7	5GT-MTP
Monitoring support	R2	2.6	5GT-MTP
NS Id creation	R1	2.5, 2.8	5GT-SO
NS instantiation	R1	2.5, 2.8	5GT-SO
NS termination	R1	2.5, 2.8	5GT-SO
NS query operational status	R1	2.5, 2.8	5GT-SO
Extended SO	R2	2.5, 2.6	5GT-SO
Basic integration with SO	R1	2.5, 2.1, 2.3, 2.7	5GT-VS
Extended REST-based NBI	R2	2.5	5GT-VS

3.2.4 Testbed integration

TABLE 10: ENTERTAINMENT MAPPING: POC AND TESTBED INTEGRATION

<table>
<tr><th></th><th colspan="9">2018</th><th colspan="11">2019</th></tr>
<tr><td></td><td>A</td><td>M</td><td>J</td><td>J</td><td>A</td><td>S</td><td>O</td><td>N</td><td>D</td><td>J</td><td>F</td><td>M</td><td>A</td><td>M</td><td>J</td><td>J</td><td>A</td><td>S</td><td>O</td><td>N</td></tr>
<tr><td></td><td>11</td><td>12</td><td>13</td><td>14</td><td>15</td><td>16</td><td>17</td><td>18</td><td>19</td><td>20</td><td>21</td><td>22</td><td>23</td><td>24</td><td>25</td><td>26</td><td>27</td><td>28</td><td>29</td><td>30</td></tr>
<tr><td rowspan="7">Entertainment</td><td colspan="4">2.1</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
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<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="3">2.5</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
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<tr><td>5GT-VS</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>R1</td><td></td><td></td><td></td><td></td><td>R2</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>5GT-SO</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>R1</td><td></td><td></td><td></td><td></td><td>R2</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>5GT-MTP</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>R1</td><td></td><td></td><td></td><td></td><td>R2</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

3.3 E-Health

3.3.1 Updated plan

The E-Health PoCs have been defined as the service of monitoring the life functions of patients through wearable devices, in order to detect failures on the vital signs in time to act early on emergency cases.

TABLE 11: UPDATED PLAN FOR E-HEALTH POCS

PoC ID	Description	Observations	Month
3.1	The wearable transmits information towards the eServer, which analyses the information. When an issue is detected, the eServer contacts the wearable to confirm or discards the alert.	Wearable off and on → alarm and cancel. Wearable off → alarm and confirmation.	M14
3.2	An edge server is deployed over the E-Health network slice close to the emergency.	Required traffic flows between the MEC and all involved entities.	M21
3.3	After an alarm is confirmed, the eServer requests that the configuration of a network slice among all involved entities is instantiated.	Traffic flows between all involved entities using the network slice.	M25

All these PoCs will be integrated after PoC 3.4 in M28.

3.3.2 KPIs

TABLE 12: E-HEALTH MAPPING: POCS AND HIGH-LEVEL KPIS

KPI	PoCs	Observations	Month
LAT	3.1, 3.3	Measuring the latency between the eServer and the access point (AP)	M14, M25
REL	3.1, 3.2, 3.3	Measuring the availability of the service (%) for the duration of time (e.g., day, week, month)	M14, M21, M25
A-COV	3.1, 3.2, 3.3	Measuring the percentage of users from which we receive regular/periodic monitoring data in a certain area (covered by an edge server).	M14, M21, M25
DEN	3.1, 3.2, 3.3	Measuring the maximum number of users that are connected to the service in a certain area (of the edge server).	M14, M21, M25
POS	3.1, 3.3	Measuring the reported position from the user's device and the actual position of the user that the ambulance detects once it arrives to the emergency site.	M14, M25
TCD	3.1, 3.2, 3.3	Measuring the total connected devices to the E-Health service (in multiple areas).	M14, M21, M25
SER	3.2, 3.3	Measuring the instantiation time of the E-Health service (eServer and network connections established upon emergency).	M21, M25

3.3.3 Requirements

3.3.3.1 Technology requirements

TABLE 13: E-HEALTH MAPPING: TECHNOLOGIES, POCS, AND TESTBED SITES

Technologies	Functions	Associated PoC	Vertical site	Month
T1.a	LTE-A,Wi-Fi interworking capabilities	3.1	5TONIC	M14
T1.d	Core Network	3.1	5TONIC	M14
T2.a	End-to-End Network Slicing with predictable performance isolation	3.3	5TONIC	M25
T2.b	Network Functions Virtualization (NFV) of 5G Networks	3.3	5TONIC	M25
T2.c	SDN/NFV-based Management and Orchestration (MANO) 5G Networks across multiple administrative network domains.	3.3	5TONIC	M25
T4.a	Encryption and other Privacy-enhancing technologies	3.1	5TONIC	M14
T4.d	Trust management for citizens, patient, families, care givers, etc.	3.1	5TONIC	M14
T5.b	Platforms for mission critical (group) communications (voice, data, video)	3.3	5TONIC	M25
T7.a	Network based location services	3.3	5TONIC	M25

3.3.3.2 Platform requirements

Table 14 presents the platform requirements of the E-Health use-case for each PoC. The platform functionalities provided by the architectural components are mapped to the PoCs:

TABLE 14: E-HEALTH MAPPING: PLATFORM FUNCTIONALITIES AND POCS

Platform Functionalities	Associated SW release	Associated PoC	Architectural component
Basic integration with SO	R1	3.3	5GT-VS
Extended REST-based NBI	R2	3.3	5GT-VS, 5GT-SO
Lifecycle management	R2	3.1, 3.2, 3.3	5GT-VS
Monitoring support	R2	3.1	5GT-VS, 5GT-MTP
Instantiate Composite-NS	R2	3.2, 3.3	5GT-SO
Terminate Composite-NS	R2	3.2, 3.3	5GT-SO
Scaling Composite-NS	R2	3.3	5GT-SO
Federation of nested-NS	R2	3.2, 3.3	5GT-SO
Resource orchestration management	R2	3.2, 3.3	5GT-SO
NFV-NS management and support	R2	3.2, 3.3	5GT-SO
Resource allocation	R1	3.2, 3.3	5GT-MTP
Resource termination	R1	3.2, 3.3	5GT-MTP
Abstraction support	R1	3.3	5GT-MTP
5GT-MTP placement algorithm	R2	3.2	5GT-MTP

3.3.4 Testbed integration

The PoC demonstration will take place after Release 2 of the 5G-T software development. All PoCs will be deployed on the 5TONIC testbed site. The PoC development takes the top-down approach. First, we define the blueprints and the VSDs for PoC 3.1, 3.2, and 3.3. Then, we proceed with deploying composite NFV-NS to local and federated domain. The deployment of the PoCs is detailed in the Table 15.

TABLE 15: E-HEALTH MAPPING: POC AND TESTBED INTEGRATION

	2018									2019										
	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N
	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
E-Health	3.1																			
														3.2						
														3.3						
																	demo			
5GT-VS									R1					R2						
5GT-SO									R1					R2						
5GT-MTP									R1					R2						

3.4 E-Industry

3.4.1 Updated plan

The E-Industry Cloud Robotics PoC (CR) simulates factory service robots and production processes that are remotely monitored and controlled in the cloud, exploiting wireless connectivity (5G) to minimize infrastructure, optimize processes, and implement lean manufacturing. The objective of the demonstrator is to verify allocation of suitable resources based on the specific service requests to allow the interaction and coordination of multiple (fixed and mobile) robots controlled by remote distributed services, satisfying strict latency and bandwidth requirements.

The demonstrator will show that, when a CR service request arrives, the required resources are correctly selected and configured. Latency will be measured to optimize the positioning of the vEPC and consequently identify the most suitable selection of resources.

Different level of virtualization of the control functionality will be implemented to verify if the system is able to meet latency requirements in realistic scenarios.

Moreover, a fault on the transport domain will be simulated to verify the ability of the 5G-MTP platform to recover from faults without impacting on the abstraction exposed to the 5GT-SO.

The basic block components of the demonstrator consist of:

- LTE radio + vEPC (Ericsson radio equipment).
- eXhaul network [18] (transport network for 5G developed in 5G Crosshaul) + 5GT-MTP, 5GT-SO, 5GT-VS functionalities.
- Cloud robotic factory model (1 Automated Guided Vehicle (AGV), 2 robotic arms, 1 door, 1 rotating plate, user interface tablet, and 1 server, as shown in Figure 5.

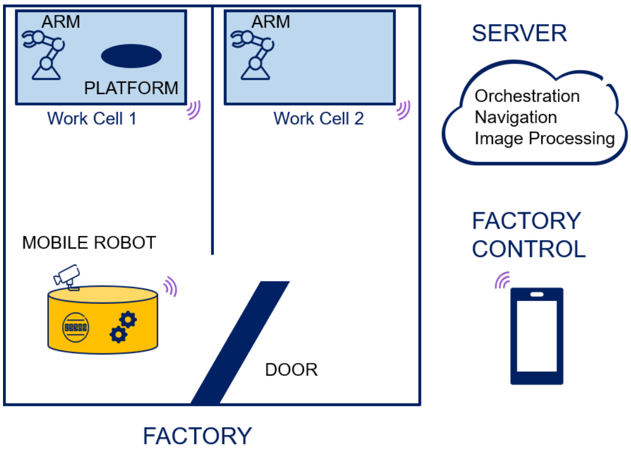

FIGURE 5: SCHEMATIC OF THE ERICSSON CLOUD ROBOTICS DEMONSTRATOR

The updated plan for the PoC is shown in the following table, considering the objectives mentioned above.

TABLE 16: UPDATED PLAN FOR E-INDUSTRY POCS

PoC ID	Description	Observations	Month
4.1	Preparatory experiment for CR service activation.	Verify the latency requirements and service isolation. Demonstrated in https://youtu.be/-Ox14nzRHu0	M15
4.2	CR service activation	Check if latency requirements are met in different virtualization scenario and different (v)EPC location.	M20
4.3	Monitoring of failures on the transport domain	5G-MTP perform the monitoring for enabling recovery.	M26

3.4.2 KPIs

The following table performs the mapping between the PoCs and the high-level KPIs introduced to provide a quantifiable output of the E-Industry CR.

TABLE 17: E-INDUSTRY MAPPING: POCS AND HIGH-LEVEL KPIS

KPI	PoCs	Observations	Month
LAT	4.1, 4.2, 4.3	Measuring RTT latency in different virtualization scenarios and different (v)EPC locations.	M15 (Fig.3) M20 M26
REL	4.2	Measuring the availability of the service (%) for duration of a factory task(s) (e.g. pallet transfer, navigation, etc.).	M20 M26
SER	4.2, 4.3	Measuring the instantiation time of the CR service.	M20, M26

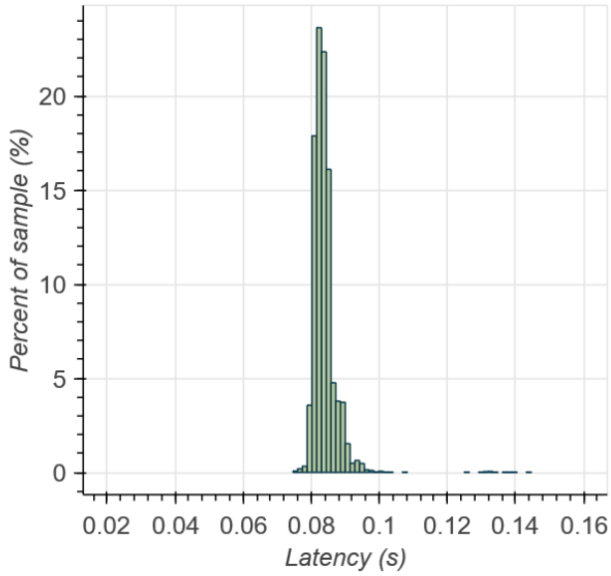

FIGURE 6: ROUND TRIP-TIME (RTT) LATENCY, THE TIME IN SECONDS OF THE PATH FROM THE CORE NETWORK TO THE SERVICE ROBOTS AND BACK

The KPI RTT latency measurement for PoC ID 4.1 (Preparatory experiment for CR service activation) is shown in Figure 6. The associated demonstration can be viewed at https://youtu.be/-Ox14nzRHu0. The purpose of the KPI measurement in context of PoC 4.1 is only to demonstrate the ability of measurement in the CR. The mean value of the distribution is 83.88 ± 0.05(statistical error) ±2 (systematic error) ms.

3.4.3 Requirements

3.4.3.1 Technology requirements

The following table addresses the mapping between the required technologies, PoCs, and the testbeds used for the E-Industry CR.

TABLE 18: E-INDUSTRY MAPPING: TECHNOLOGIES, POCS, AND TESTBED SITES

Technologies	Functions	Associated PoC	Vertical Testbed	Month
T1.a (R)	5G,LTE-A,Wi-Fi interworking capabilities	4.1, 4.2	5TONIC	M15
T1.d (R)	Core Network	4.2, 4.3	5TONIC	M20
T2.b (R)	Network Functions Virtualization (NFV) of 5G Networks	4.1	5TONIC	M15
T4.a (R)	Encryption and other Privacy-enhancing technologies	4.2, 4.3	5TONIC	M20
T6.b (R)	Efficient ultra-low latency scheduling of small data packets (few bytes payload)	4.2, 4.3	5TONIC	M20

3.4.3.2 Platform requirements

The following table addresses the mapping between the application of platform technologies and the PoCs of the E-Industry CR.

TABLE 19: E-INDUSTRY MAPPING: PLATFORM FUNCTIONALITIES AND POCS

Platform Functionalities	Associated SW release	Associated PoC	Architectural component
Abstraction support	R1	4.2, 4.3	5GT-MTP
Resource allocation	R1	4.2, 4.3	5GT-MTP
Resource termination	R1	4.2, 4.3	5GT-MTP
Radio support	R2	4.3	5GT-MTP
Monitoring support	R2	4.3	5GT-MTP
Integration with 5GT-MTP	R1	4.2, 4.3	5GT-SO
Instantiate NS	R1	4.2, 4.3	5GT-SO
Terminate NS	R1	4.2, 4.3	5GT-SO
Integration with 5GT-VS	R1	4.2, 4.3	5GT-SO
Basic integration with 5GT-SO	R1	4.2,4.3	5GT-VS
Extended REST-based NBI	R2	4.3	5GT-VS

3.4.4 Testbed integration

Following the platform release plan of the 5GT-MTP, 5GT-SO, and 5GT-VS (detailed in D2.2 [2], D3.2 [3], and D4.2 [4]), the CR use case will be integrated using a bottom up approach. First, by implementing the relevant 5GT-MTP plugins and verifying functionality of the domain configure, allocate, and terminate infrastructures. Second, integrating the 5GT-SO, performing the placement NFVO orchestration, and NFVM manager operation. Finally, the 5GT-VS will be deployed, which will define the service. All the operations will follow the specifics detailed in the respective software release. The dates for the development of the functionalities (2 stages) and the PoCs are detailed in table below.

TABLE 20: E-INDUSTRY MAPPING: POC AND TESTBED INTEGRATION

<table>
<tr><th></th><th colspan="9">2018</th><th colspan="11">2019</th></tr>
<tr><td></td><td>A
11</td><td>M
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<tr><td rowspan="4">E-Industry</td><td colspan="5">4.1</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
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<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="4">demo</td><td></td><td></td></tr>
<tr><td>5GT-VS</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="2">R1</td><td></td><td></td><td></td><td colspan="2">R2</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>5GT-SO</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="2">R1</td><td></td><td></td><td></td><td colspan="2">R2</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>5GT-MTP</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="2">R1</td><td></td><td></td><td></td><td colspan="2">R2</td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

3.5 MNO/MVNO

3.5.1 Updated plan

The MNO/MVNO PoCs consists of instantiating a 5G network by sending a 5GT-VS order to the 5GT-SO in order to create a network service instance. The result will be the deployment of an end to end network slice which contains a vEPC network service. This network slice will provide end-users with multi connectivity (4G/5G/Wi-Fi), homogeneous QoE and unified authentication.

The updated plan for the MNO/MVNO PoCs is shown in the following table.

TABLE 21: UPDATED PLAN FOR MNO/MVNO POCS

PoC ID	Description	Observations	Month
5.1	MNO requests the instantiation of a specific 5G network with local access to the infrastructure, in a split vEPC mode (CUPS).	5GT-VS order sent to 5GT-SO for network service instance creation	M15
5.2	End to end network slice set up and vEPC network service are instantiated, connected to local small cells and Wi-Fi APs. User Plane VNF and PNF are configured in the local area infrastructure. Control Plane VNF in the Central DC.	VNFs are up and running. The end to end slice provides the network service through local and central infrastructure and operator’s services own infrastructure (HSS, …).	M20
5.3	End-users are provided with multi connectivity (4G/5G/Wi-Fi), homogeneous QoE and unified authentication.	UE connectivity via Cellular access and WiFi access toward Internet.	M20

3.5.2 KPIs

The goal is to measure the time required to create and activate a network slice based on the performance requirements expected by the customer (UE bearer establishment rate). To achieve this goal, we establish a profile of the VNFs to determine their resource consumption according to the committed performance. Using these profiles, we are able to measure the overall delay of the commissioning phase according to the network slice performance requirements based on the resources derived for the deployment.

Similarly, by leveraging on the profiles of the VNFs, it is possible to characterize the cost of a deployed service. This cost depends both on the amount of resources requested and the type of the cloud (private or public) providing the virtualized infrastructure and the pricing model of VNFs. Here we propose to assess the cost of a deployed service depending on a required level of performance.

TABLE 22: MNO/MVNO MAPPING: POCS AND HIGH-LEVEL KPIS REQUIREMENTS

KPI	PoCs	Observations	Month
CST	5.1, 5.2	Establish the cost models of the infrastructure based on the cloud hosting type (private or public). In the case of a private cloud, the datacenter size and the supported non-functional services (redundancy, support, and disk performance) are impacting on the virtualized resource cost. By public cloud hosting, several pricing models such as on-demand instance, resource reservation and spot instance models are taken into account in the cost evaluation of a vEPC performance level.	M25
SER	5.1, 5.2	Measure the time to create and activate a network slice based on the performance requirements expected by the customer (number of UE attach procedures per second). The approach is to deploy the vEPC with different flavours by scaling either horizontally in terms of the number of VDUs for the VNFs (for instance MME), or vertically by increasing the size of the VDU itself. The scaling is not a dynamic scaling nor changes of deployment flavours during the NS instantiation lifetime. The scaling will be realized by VNF sizing through several deployments. We will measure the commission time according to the different flavours.	M25

3.5.3 Requirements

3.5.3.1 Technology requirements

The following table addresses the mapping between the required technologies, PoCs, and the testbeds used for the MNO/MVNO UC.

TABLE 23: MNO/MVNO MAPPING: TECHNOLOGIES, POCS, AND TESTBED SITES

Technologies	Functions	Associated PoC	Vertical Testbed	Month
T1.a (R)	eNodeB	5.2	5TONIC	M23
T2.a (R)	OpenStack	5.1, 5.2	5TONIC	M20
T2.b (R)	WEF	5.2, 5.3	BCOM	M20
T2.c (R)	OSM R4	5.2	5TONIC	M20
T4.a (R)	SGi LAN	5.3	5TONIC	M23

3.5.3.2 Platform requirements

The following table addresses the mapping between the application of platform technologies and the PoCs of the MNO/MVNO UC.

TABLE 24: MNO/MVNO MAPPING: PLATFORM FUNCTIONALITIES AND POCS

Platform Functionalities	Associated SW release	Associated PoC	Architectural component
Lifecycle management	R2	5.1, 5.2	5GT-VS
Resource allocation	R1	5.1, 5.2, 5.3	5GT-MTP
Resource termination	R1	5.1, 5.2, 5.3	5GT-MTP
Abstraction support	R2	5.1, 5.2, 5.3	5GT-MTP
REST-based NBI offering deployment functions	R1	5.1, 5.2	5GT-VS
Tenants, groups, and SLAs management	R1	5.1, 5.2, 5.3	5GT-VS
Service Orchestration functions leveraging manually on-boarded catalogues	R1	5.1	5GT-SO

3.5.4 Testbed integration

The PoC demonstration will take place after the Release 2. Following the platform release plan of the 5GT-VS, 5GT-SO, and 5GT-MTP (WP3, WP4 and WP2, respectively), the MNO/MVNO UC will be integrated using the top-down approach. Firstly, we define the VSB and NSD for the vEPC and implement the network slice manager in PoC 5.1. Secondly, we deploy the vEPC on the infrastructure and test the end to end connectivity in PoCs 5.2 and 5.3.

The following table summarize the information below and give the duration time of each PoC.

TABLE 25: MNO/MVNO MAPPING: POC AND TESTBED INTEGRATION

	2018									2019										
	A 11	M 12	J 13	J 14	A 15	S 16	O 17	N 18	D 19	J 20	F 21	M 22	A 23	M 24	J 25	J 26	A 27	S 28	O 29	N 30
MNO/MVNO									5.1											
													5.2/5.3							
														demo						
5GT-VS														R2						
5GT-SO														R2						
5GT-MTP														R2						

3.6 Summary

Within the activities reported in this deliverable, the 5G-TRANSFORMER project continued the work on KPI definition and measurement. In particular, a set of steps were defined with the aim of identifying how the project contributes to the 5G-PPP contractual KPIs. The steps are as follows:

1. Definition of the 5G-TRANSFORMER KPIs and their methods of measurement derived from the vertical use case requirements analysis.
2. KPIs classification and identification of their relevance with regards to the project objectives.
3. Mapping between 5G-T KPIs and 5G-PPP KPIs.
4. Translation of the vertical service performance KPIs to the SLA requirements for the 5G-T service provider.
5. Definition of the KPI measurements through PoC test-bed experiments, emulations or simulations.
6. Evaluation of KPI including comparison with benchmark solutions.

Steps 1 to 3 were included already in D1.1 and their results are repeated here for convenience. Moreover, based on the KPIs defined by the verticals we need to harmonize some definitions with respect to D1.1 and map them in measurable performance KPIs to better reflect the PoC development.

The results of step 1 are reported in the previous sections of this document where the different PoCs reported the performance KPIs to be considered in the vertical use case performance evaluation. The future work to be done in WP5 will be to map those KPIs to measurable harmonized, if needed, performance KPIs.

In D1.1, 5G-TRANSFORMER addressed already step 2 by assigning a relevance to the 5G-PPP contractual KPIs as represented in Table 26. The aforementioned PoCs have shown how their KPIs contribute to the 5G-PPP contractual KPIs.

TABLE 26: RELEVANCE OF 5G-PPP CONTRACTUAL KPIS TO 5G-TRANSFORMER

KPIs		Relevance (High / Medium / Low)
P1	Providing 1000 times higher wireless area capacity and more varied service capabilities compared to 2010.	High
P2	Saving up to 90% of energy per service provided.	High
P3	Reducing the average service creation time cycle from 90 hours to 90 minutes.	High
P4	Creating a secure, reliable and dependable Internet with a “zero perceived” downtime for services provision.	Low
P5	Facilitating very dense deployments of wireless communication links to connect over 7 trillion wireless devices serving over 7 billion people.	Medium

Concerning step 3, an initial mapping between 5G-TRANSFORMER KPIs and 5G-PPP contractual KPIs was already provided in D1.1. However, during the WP5 activities such mapping has been slightly modified and it is reported in Table 27.

TABLE 27: MAPPING BETWEEN 5G-T KPIS AND 5G-PPP CONTRACTUAL KPIS

	5G-PPP KPIs					
5G-TRANSFORMER KPIs		P1	P2	P3	P4	P5
	LAT				X	
	REL				X	
	UDR	X				
	A-COV					X
	MOB					X
	DEN					X
	POS					X
	CON				X	
	INT				X	
	A-RES				X	
	TRA	X				
	RAN					X
	INF					X
	NRG		X			
	CST		X	X		
	SER			X		

As shown above, the 5G-TRANSFORMER KPIs will be able to contribute to all the 5G-PPP KPIs.

In future activities, the three remaining steps will be tackled by the project. In particular, each PoC will be required to define SLAs that will then be mapped into performance KPIs. Such KPIs will be measured by means of simulation or emulations. Based on the achieved results, if the required SLAs are not fulfilled, the vertical service architecture and deployment will be modified. Finally, it will be shown how the 5G-TRANSFORMER architecture improves some KPIs by considering benchmark solutions.

4 Testbed integration updates

4.1 5TONIC

4.1.1 Technology updates

The 5TONIC site has been upgraded based on the requirements of the different PoCs. No additional hardware has been added with respect to what was reported in D5.1 [1], although there are extensions scheduled and we will perform an additional check to assess if more resources are needed.

Conversely, we have restructured both the resources and the software to be prepared for the PoCs. An illustration of the site is depicted in Figure 7. As shown by the figure, NFV/SDN infrastructure A is now composed of 3 OpenStack compute nodes plus one controller node (OpenStack Rocky release) which will be complemented with additional compute nodes by the time the experimentation starts. The Management and Orchestration (MANO) infrastructure now supports Cloudify [17] in addition to OSM.

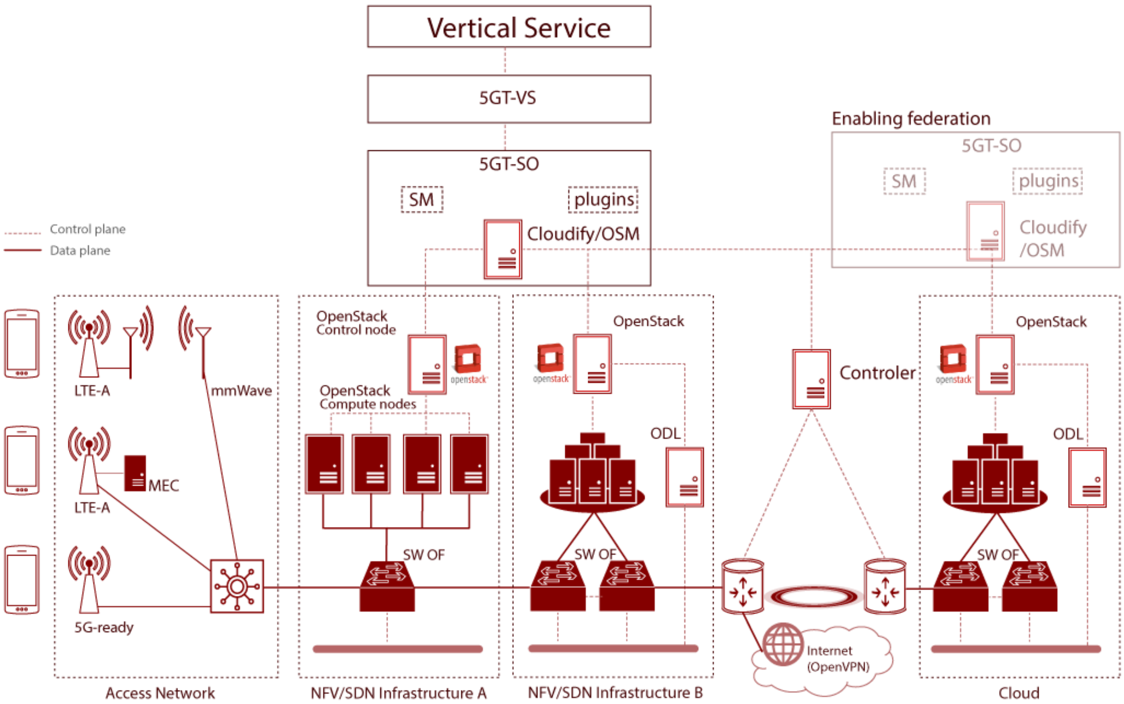

FIGURE 7: UPDATES ON 5TONIC INFRASTRUCTURE WITH ADDITION OF 5G-T PLATFORM COMPONENTS

Regarding the restructuring of hardware components, the connections to external test sites enable multi-domain federation. In addition to the option of external connections to other sites, the 5TONIC test site can additionally restructure the components by adding a new MANO controller on top of the Cloud or NFV/SDN Infrastructure B. As a result, the 5TONIC infrastructure can be split in two administrative domains, which enables showcasing federation features within the 5TONIC test site.

4.1.2 Platform integration updates

The 5G-TRANSFORMER platform components developed for Release 1 (R1) have been deployed on the 5TONIC test site. Figure 7 illustrates how the 5GT-VS and 5GT-SO are deployed over the infrastructure. Each platform component is running on a single VM (e.g., 5GT-VS is deployed as an individual VM, 5GT-SO is deployed as another VM). All platform components or VMs are deployed manually. In the future, the 5G-T CI platform will be deployed on the 5TONIC infrastructure. More details regarding the 5G-T CI platform is explained in Section 4.4.1.

4.2 CTTC

4.2.1 Technology updates

The CTTC site has been extended to integrate and support the specific functionalities provided by key elements being designed and implemented within the 5G-T architectural solutions. Those elements are the 5GT-VS, 5GT-SO and 5GT-MTP. From a data plane perspective (see Figure 8), the experimental infrastructure follows the same description as the one provided in D5.1 [1]. In a nutshell, up to four Network Function Virtualization Infrastructure Point of Presence (NFVI-PoPs) numbered by #1, #2, #3 and #4) managed by three different VIMs (based on OpenStack) can be interconnected to support demanded network services via a multi-domain and multi-technological WAN domain. The WAN combines wireless (involving both Wi-Fi and mmWave), packet switching nodes (IP/MPLS) equipped with DWDM transceivers and a DWDM optical network infrastructure[2]. The WIM is based on a resource orchestrator, referred to as parent Application Based Network Operations (p-ABNO), which automatically coordinates underlying controllers to provide end-to-end connectivity through the aforementioned network technologies. Further details and features of the p-ABNO interactions with the underlying controllers (i.e., Wireless SDN controller and client ABNO, cABNO) were reported in D5.1 [1].

[2] The layout of NFVI-PoPs at the wireless domain can be rearranged according to needs.

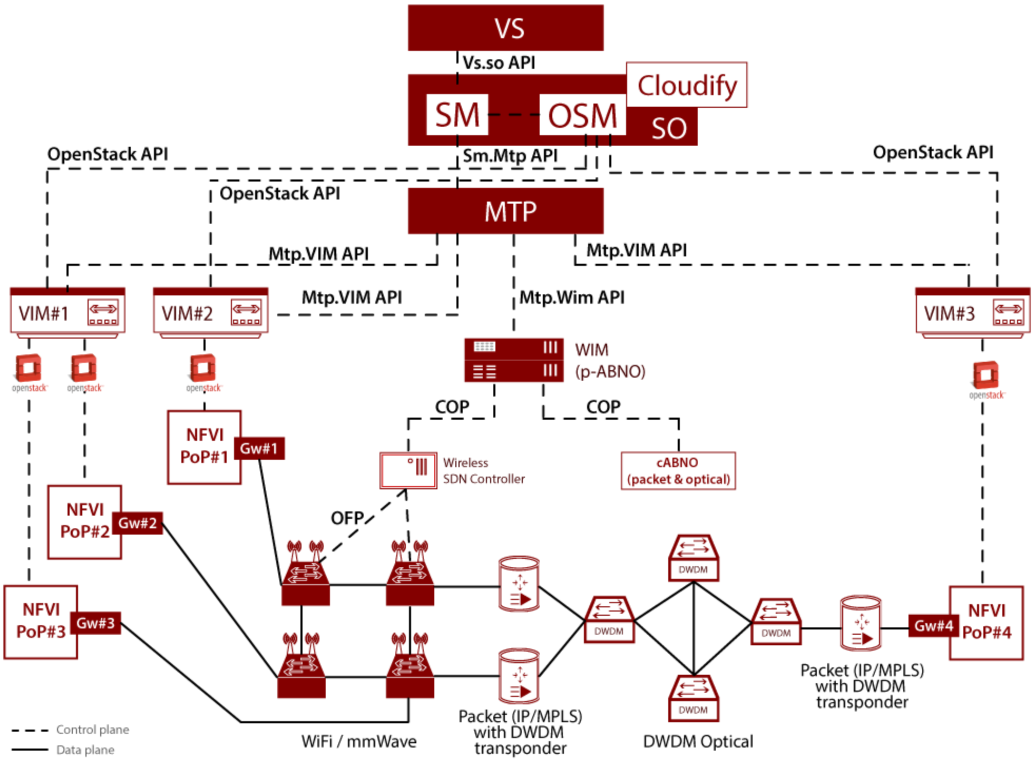

FIGURE 8: UPDATES ON CTTC SITE WITH ADDITION OF 5G-T PLATFORM COMPONENTS

4.2.2 Platform integration updates

To support the functionalities provided in the 5GT Platform Release 1 (R1), required updates have been deployed on top of the CTTC experimental platform. In this regard, the 5GT-SO functions are fully supported considering the VS - SO interworking (via the 5GT-T Vs.So API). Additionally, the OSM (with support to both releases 3 and 4) has been integrated to orchestrate cloud resources through multiple NFVI-PoPs which can be managed by multiple VIMs. There is also the availability of a Cloudify Platform, which is in process of integration in the CTTC experimental platform.

The integration between the SM and the 5GT-MTP throughout the defined 5G-T Sm.Mtp API has been also deployed and validated. Currently, it is being deployed the interaction between the MTP and CTTC WIM (i.e., pABNO) to provide abstracted WAN resource information and enabling the allocation and termination of WAN resources required to transport the targeted network services between NFVI-PoPs.

4.3 ARNO

4.3.1 Technology updates

The ARNO site, shown in Figure 9, has extended its software defined radio portfolio with two Ettus X310 (https://www.ettus.com/product/details/X310-KIT). When equipped with daughterboard Ettus X310 can provide up to 160MHz bandwidth per daughterboard and cover DC (Direct Current) to 6 GHz of carrier frequencies.

Required resources to host the 5G-TRANSFORMER platform (i.e., 5GT-VS, 5GT-SO, and 5GT-MTP) have been allocated in the ARNO Data Center. Moreover, Openstack has been installed in a Virtual Machine hosted by the Data Center. From a data plane perspective, the experimental infrastructure follows the same description as the one provided in D5.1 [1]. It consists of Data Center servers where the 5G-TRANSFORMER platform in containers and an instance of Openstack running in a Virtual Machine are deployed. The Openstack environment manages one NFVI-PoP. Such setup can be replicated to host more NFVI-PoPs. The Data Center is connected through an Open Virtual Switch (OVS) network emulated by means of Mininet. The Data Center network is connected to a Reconfigurable Add and Drop Multiplexer (ROADM) network that is, in turn, connected to the aggregation network based on commercial (HP) OVS and OVS installed in PCs. The aggregation network is connected through a commercial XGS-PON (Calix) to the USRPs hosting the Open Air Interface (OAI) software. Commercial dongles (Huawei) can be connected to the USPRs through coaxial cable to transmit in licensed bands. Two WIMs are available for the OVS network and the Optical network. Currently the two additional WIMs are under development for the XGS-PON and the Radio Network. Thus, currently, for 5GT purposes the USRPs are connected directly to the aggregation network.

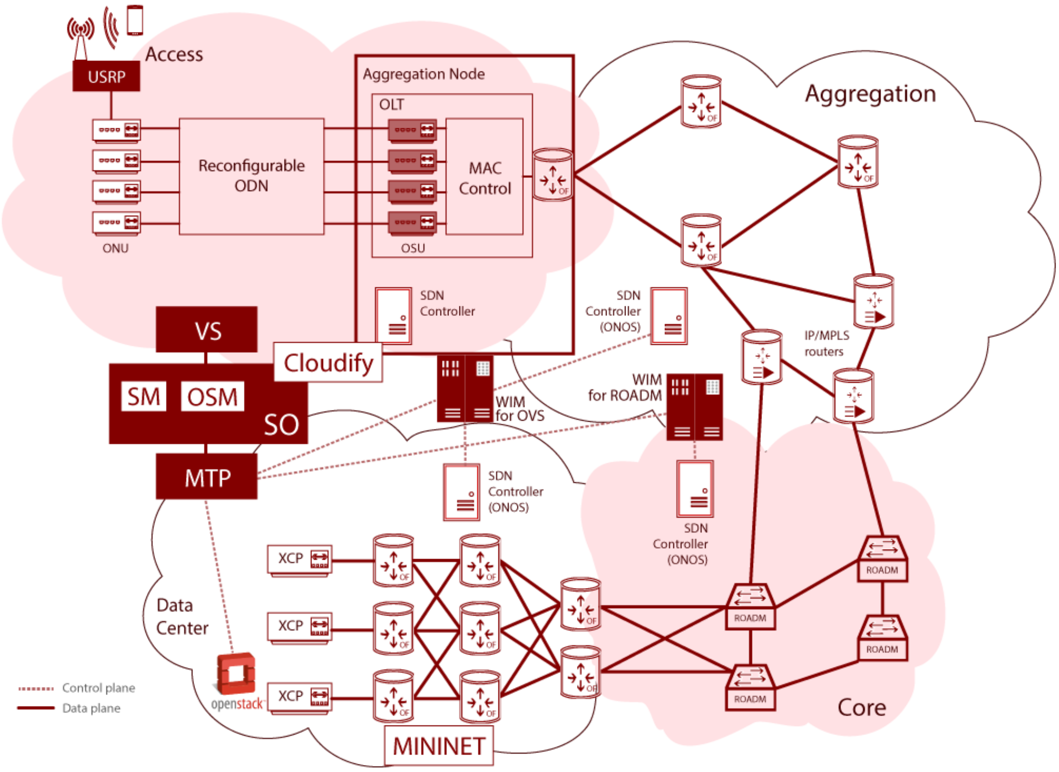

FIGURE 9: ARNO SITE TECHNOLOGIES

4.3.2 Platform integration updates

The containerized 5G-TRANSFORMER CI platform (5G-T Platform Release 1) composed by different repositories (i.e. 5GT-VS, 5GT-SO, 5GT-MTP) has been installed in the ARNO site through Jenkins. The platform is hosted in one of the Data Center servers as depicted in Figure 9.

Two plugins for the 5GT-MTP and WIM for OVS and WIM for ROADM have been developed [2]. They are referred to as Transport Controller WIM Plugin in D2.2 [2]. The plugins are implemented in Java. The plugins allow to allocate resources in both the OVS and ROADM-based networks that are controlled by ONOS (https://onosproject.org/). The plugins are based on extension of the ETSI NFV IFA 005 interfaces. Testing of plugins integrated with the 5GT-MTP is ongoing. During the current testing phase, the plugins have been proven to successfully allocate, release, and retrieve information about the considered networks.

Similar plugins for the XGS-PON and the Radio Network based on OpenAir Interface are under development. Their release is planned for the platform R2.

4.4 EURECOM

4.4.1 Technology updates

An OpenStack (Queens version) node with collocated controller and compute functionality has been installed on a four-core Intel i5 host with 16 GB of RAM, which will act as a MEC host for application instances to be deployed.

The MEC platform software has been extended to appropriately support traffic offloading services towards OpenStack instances. Moreover, a version of the MEC system building on lxd[3] is under development and testing. This version will allow for containerized MEC applications, which will be running directly on top of the MEC host as *Linux containers* controlled by a lightweight management layer.

Figure 10 shows our local testbed featuring an OAI LTE cell where the OAI eNodeB and EPC software have been extended to support communication with the MEC platform (MEP) for managing traffic offloading and making RAN information available to the MEP Radio Network Information Service (RNIS) and in turn to subscribing MEC application instances. In this setup, the OAI EPC components are hosted in two qemu/kvm virtual machines directly on top of a kvm hypervisor. A modified OVS version that supports GTP packet matching is installed inside the S/P-GW VM and acts as the SGW-U (following the control-user plane separation approach). The MEP can be deployed directly (natively) on the host where the virtualized EPC is running, as a virtual machine/container, or as a virtual instance on the OpenStack node. The testbed can be connected to the other trial sites over VPN.

[3] https://linuxcontainers.org/lxd/introduction/

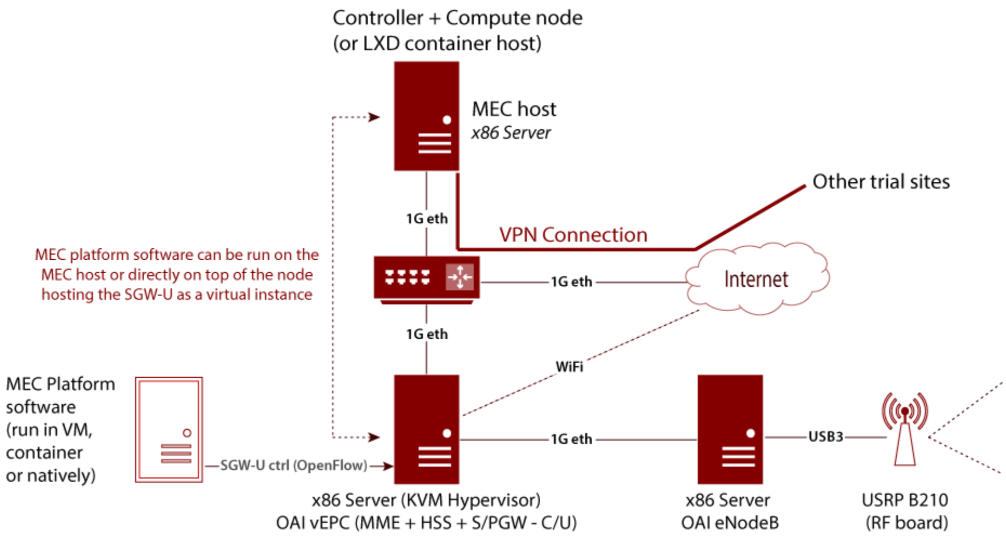

FIGURE 10: EURECOM OAI-BASED MEC SITE

4.4.2 Platform integration updates

Tests to verify that the MEC platform can appropriately apply traffic redirection towards MEC instances that are deployed on the OpenStack compute node have been carried out. Efforts related with the interconnection of the MEC platform and host with other trial sites over VPN are ongoing.

4.5 End to End integration plan

Previous sections 4.1, 4.2, 4.3, 4.4 explain all the updates performed on the testbeds. In D5.1 [1] we performed inter-site measurements and elaborated an initial integration plan. The connection between the sites can be established through VPN tunneling or implementing the VxLAN connectivity.

Due to variety of software 5G-TRANSFORMER components, their distributed and independent development process, integration of the 5G-T platform becomes a challenging task. As a result, the consortium decided to introduce a Continuous Integration platform (5GT-CI) which enables rapid integration, testing and evaluation of the developed software components. In a nutshell, the 5G-T CI platform is based on Jenkins and implements pipelines mechanism to build 5G-TRANSFORMER software components (5GT-VS, 5GT-SO, 5GT-MTP), configure required settings and deploy them at the given testbed. Thus, in the integration pipeline there are 4 stages, including: Bootstrap, Build, Deploy and Verify stage. Bootstrap stage installs docker[4] software (if required) on a remote node (VM). At the Build stage, 5G-T sources are cloned from the git repository, compiled and appropriate docker images are built. These images are then pushed to the local docker registry. During the Deploy stage, specified docker images are downloaded from the local registry and started on the target machine (VM). At the Verify stage, a set of integration tests is executed to ensure that containers are up and running at the remote node (VM) and 5G-T components are

[4] https://www.docker.com/

working as expected. At this moment, only integration tests for the 5GT-SO are implemented, while tests for other components are still under development

At this point, manual integration of specific platform components is enabled (5GT-VS, the SOE of the 5GT-SO, Cloudify orchestrator). For the next release (R2), the goal is to have an automatic integration and deployment of all 5G-T software components. Additionally, at R2 relevant integration tests will be available for e2e platform testing and the 5G-T CI platform will perform automatic unit and integration testing during each platform deployment cycle.

Once the 5G-T CI platform is finalized, the software components can be deployed and updated on each test site in the automatic manner. Through the previously established connections between the trial sites, the multi-domain deployment of a NFV-NS can be enabled using service or resource federation.

5 5GT component functional validation

5GT components are delivered in two main releases R1 and R2. Each of the releases includes features as described in the deliverables D2.2 [2] and D.3.2 [3] and D4.2 [4] for the 5GT-MTP and 5GT-VS and 5GT-SO, respectively.

Based on these deliverables, Table 28 shows, for each functionality:

- the actual progress status: done (D), on-going (O), to be completed (T),
- the location: internal labs, test sites, and
- the purpose description (demo event, integration tests, …) of the functional verifications that were performed.

TABLE 28: PROGRESS STATUS (DONE (D), ON-GOING (O), TO BE COMPLETED (T)), THE LOCATION (INTERNAL LABS, TEST SITES) AND THE PURPOSE DESCRIPTION (DEMO EVENT, INTEGRATION TESTS) OF THE FUNCTIONAL VERIFICATIONS

	Platform Functionalities	Status	Where (Test site, to be validated or in labs)	How (How the functionality was validated)
5GT-VS	REST-based NBI for administrative functions • Tenants, groups, and SLAs management • Retrieval of NSIs • Loading of VSBs	D	5TONIC and ARNO	Corresponding use cases demonstrated at technical review, ECOC18 and ICT18 for vEPC and vCDN services
	REST-based NBI for operational functions • Retrieval of VSBs • Definition of VSDs • Management of VSIs	D	5TONIC and ARNO	Corresponding use cases demonstrated at EuCNC18, technical review, ECOC18 and ICT18 for vEPC and vCDN services
	Authentication and per-tenant authorization at NBI	D	5TONIC and ARNO	Part of login procedures
	Web-based GUI for system administrators and verticals	D	5TONIC	GUI used in demos at technical review and ICT18 for vEPC and vCDN services
	Basic translation between VSDs and Network Service Descriptors (NSDs), deployment flavours (DF) and instantiation levels (IL)	D	5TONIC and ARNO	VSB with parameter (amount of users) for vEPC and vCDN services. Selection of correct DF/IL as part of overall workflow demonstrated at EuCNC18, technical review, ECOC18 and ICT18
	Basic arbitration mechanisms • SLA verification based on resources consumed by each tenant • One-to-one mapping between VSIs and NSIs	D	5TONIC and ARNO	Part of overall workflow demonstrated for vEPC and vCDN services in demos at EuCNC18, technical review, ECOC18 and ICT18

	Lifecycle management of simple Vertical Services and Network Slices (without service decomposition)	D	5TONIC and ARNO	Part of overall workflow demonstrated for vEPC and vCDN services in demos at technical review and ICT18
	Basic integration with Service Orchestrator	D	5TONIC	Demonstrated at ICT18
5GT-SO	REST-based NBI offering deployment functions • NFV-NS Id creation • NFV-NS instantiation • NFV-NS termination • NFV-NS query operational status	D	CTTC	QA tests validating the different operations of the NBI REST-API
	Service Orchestration functions leveraging manually on-boarded catalogues and supporting NFV-NS deployment-related operations • NFV-NS Id creation • NFV-NS instantiation • NFV-NS termination • NFV-NS query operational status	D	CTTC	Using on-board script for NSDs and VNFDs and using HTTP requests to query the NBI REST-API through dedicated python scripts
	Resource Orchestration functions supporting • placement decisions provided by a Placement Algorithm (PA) based on a stand-alone component • resource allocation and release operations triggered by NFV-NS instantiation and termination interworking with Cloudify orchestration platforms	D	CTTC and ATOS	CTTC has tested one PA through its REST-API interface using curl [5]commands. CTTC has tested the instantiate and release operations with the OSM orchestration platform by instantiating and terminating an NS.
	Three Placement Algorithm (PA) engines supported, integrated as stand-alone components	D	CTTC	Testing by integrating the PA in the instantiation workflow and checking the correctness of the algorithm output.
	Cloudify wrapper to provide automation in NFV-NS operations while involving the Cloudify orchestrator in supported 5GT-SO workflows	D	5TONIC	Demonstrated at ICT18.
	OSM Wrapper to provide automation in NFV-NS	D	CTTC	Requesting service instantiate and terminate operations from

[5] Curl: http://manpages.ubuntu.com/manpages/trusty/man1/curl.1.html

	operations while involving the OSM orchestrator in supported 5GT-SO workflows (stand-alone component)			the 5GT-SO NBI and checking the deployment of NFVs in Openstack.
	Monitoring platform as stand-alone component	D	NXW lab, ARNO and 5TONIC	Tests in lab with Prometheus exporters for OpenStack and OpenDaylight SDN controller.
	Resource Orchestration Execution Entity acting as the client to 5GT-MTP for resource query, deployment and terminate operations • query of networking and computing resources from the 5GT-MTP • requests for allocation and release of networking and computing resource operations	D	CTTC / MIRANTIS lab	CTTC has tested the query, the allocation and release of transport resources with a stub 5GT-MTP NBI server.
	Initial integration with Mobile and Transport Platform (5GT-MTP) supporting a basic set of operations • allocation and release of computing and networking resources in the cloud	D	MIRANTIS lab	At the 5G-T SO level special southbound plugin was developed to communicate with 5G-T MTP for compute and network resource allocation and termination. Validation was performed to verify APIs compatibility and interaction, using MTP working in the stub mode, without any hardware on the infrastructure level.
	Initial integration with Vertical Slicer (5GT-VS) supporting a basic set of NBI REST API operations • NFV-NS Id creation • NFV-NS instantiation • NFV-NS termination • NFV-NS query operational status	D	5TONIC	Demonstrated at ICT18 with the Entertainment Use Case
5GT-MTP	Abstraction support • Abstraction Computation • Advertisement to 5GT-SO via NBI	D	TEI lab/ CTTC / MIRANTIS lab / ARNO / BCOM lab	Validation using dummy plugin (stub with no hardware). Validate in TEI lab using Crosshaul hardware for WIM and XenServer as VIM. Ongoing validation using Openstack VIM plugin (in Mirantis/BCOM lab) and ONOS and Optical WIM plugin (in SSSA premises) domains.

				Validation is done retrieving via REST the abstracted NFVI-PoP and logical links computed by the software
	Resource Allocation • Allocation of resources for VIM domains • Allocation resources for WIM domains	D	TEI lab/ CTTC / MIRANTIS lab / ARNO / BCOM lab	Validation using dummy plugin (stub with no hardware). Validate in TEI lab using Crosshaul hardware for WIM and XenServer as VIM. Ongoing validation using Openstack VIM plugin (in Mirantis/BCOM lab) and ONOS and Optical WIM plugin (in SSSA premises) domains. Validation is done requesting via REST the allocation of a resources for logical link and resources in abstracted and a positive answer is sent with all the info of the allocated resource software
	Resource Termination • Termination of resources for VIM domains • Termination of resources for WIM domains	D	TEI lab / CTTC / MIRANTIS lab / ARNO / BCOM lab	Validation using dummy plugin (stub with no hardware). Validate in TEI lab using Crosshaul hardware for WIM and XenServer as VIM. Ongoing validation using Openstack VIM plugin (in Mirantis/BCOM lab) and ONOS and Optical WIM plugin (in SSSA premises) domains. Validation is done requesting the termination of a previously allocated resource in logical link or abstracted NFVI-PoP and obtain a positive answer

6 Summary

This deliverable has provided a refined plan of implementation, integration, and demonstration of the 5G-TRANSFORMER platform. This plan includes conducting tests and PoCs based on the vertical-oriented use cases selected by the project in a common testbed. The motivation for the individual use cases (Automotive, Entertainment, E-Health, E-Industry, and MNO/MVNO) was provided in Section 2 followed by the updated progress of each individual use case in Section 3, including a time plan with specific milestones, expected KPIs to validate their success, technology and platform requirements, and integration plan in the common testbed.

The integration progress of the 5GT components provided by WP2 (5GT-MTP), WP3 (5GT-VS) and WP4 (5GT-SO), and their deployment in the common testbed have been described in Sections 4 and 5.

In addition, Section 4 provided an update on the progress of the individual test sites which interconnect to form the common testbed.

Section 5 reported on the different tests and actions conducted to assess a functional validation of the different 5G-T platform components. Most of the R1 versions of the components have been used already in demonstrations involving integrated components such as EuCNC 2018 (June 2018) and ICT 2018 (December 2018).

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