5TH GENERATION END-TO-END NETWORK, EXPERIMENTATION, SYSTEM INTEGRATION, AND SHOWCASING

[H2020 - Grant Agreement No. 815178]

Deliverable D4.5

The Málaga Platform (Release B)

Editor I. González (UMA), P. Merino (UMA), A. Ríos (UMA)

Contributors Universidad de Malaga, Airbus, Telefónica I+D, Nemergent, Athonet, Eurecom, Atos, RunEl, Ayuntamiento de Málaga, Fogus, Cosmote

Version 1.0

Date January 31st, 2020

Distribution PUBLIC (PU)

List of Authors

ADS	AIRBUS DS SLC
Arthur Lallet	
ATH	ATHONET SRL
Daniele Munaretto, Fabio Giust	
ATOS	ATOS SPAIN SLC
Elisa Jimeno, Javier Melian, Sonia Castro	
COS	COSMOTE KINITES TILEPIKOINONIES AE
Fofy Setaki	
ECM	EURECOM
Florian Kaltenberger, Panagiotis Matzakos	
FOGUS	Fogus Innovations & Services
Dimitris Tsolkas	
MoM	Ayuntamiento de Málaga
Ricardo Fernández, José Manuel Moreno	
NEM	NEMERGENT SOLUTIONS SL
Eneko Atxutegi, Egoitz Alonso, Leire Eguia	
REL	RUNEL NGMT LTD
Israel Koffman	
TID	TELEFóNICA INVESTIGACIÓN Y DESSARROLLO S.A.u.
David Artuñedo, Daniel García, Alberto Flórez	
UMA	Universidad de Málaga
Pedro Merino, Álvaro Ríos, Bruno García, Almudena Díaz, Iván González, Francisco Luque, María del Mar Moreno	

Disclaimer

The information, documentation and figures available in this deliverable are written by the 5GENESIS Consortium partners under EC co-financing (project H2020-ICT-815178) and do not necessarily reflect the view of the European Commission.

The information in this document is provided "as is", and no guarantee or warranty is given that the information is fit for any particular purpose. The reader uses the information at his/her sole risk and liability.

Copyright

The 5GENESIS Consortium consists of:

NATIONAL CENTER FOR SCIENTIFIC RESEARCH "DEMOKRITOS"	Greece
AIRBUS DS SLC	France
ATHONET SRL	Italy
ATOS SPAIN SA	Spain
AVANTI HYLAS 2 CYPRUS LIMITED	Cyprus
AYUNTAMIENTO DE MALAGA	Spain
COSMOTE KINITES TILEPIKOINONIES AE	Greece
EURECOM	France
FOGUS INNOVATIONS & SERVICES P.C.	Greece
FON TECHNOLOGY SL	Spain
FRAUNHOFER GESELLSCHAFT ZUR FOERDERUNG DER ANGEWANDTEN FORSCHUNG E.V.	Germany
IHP GMBH – INNOVATIONS FOR HIGH PERFORMANCE MICROELECTRONICS/LEIBNIZ-INSTITUT FUER INNOVATIVE MIKROELEKTRONIK	Germany
INFOLYSIS P.C.	Greece
INSTITUTO DE TELECOMUNICACOES	Portugal
INTEL DEUTSCHLAND GMBH	Germany
KARLSTADS UNIVERSITET	Sweden
L.M. ERICSSON LIMITED	Ireland
MARAN (UK) LIMITED	UK
MUNICIPALITY OF EGALEO	Greece
NEMERGENT SOLUTIONS S.L.	Spain
ONEACCESS	France
PRIMETEL PLC	Cyprus
RUNEL NGMT LTD	Israel
SIMULA RESEARCH LABORATORY AS	Norway
SPACE HELLAS (CYPRUS) LTD	Cyprus
TELEFONICA INVESTIGACION Y DESARROLLO SA	Spain
UNIVERSIDAD DE MALAGA	Spain
UNIVERSITAT POLITECNICA DE VALENCIA	Spain
UNIVERSITY OF SURREY	UK

Version History

Rev. N	Description	Author	Date
1.0	Release of D4.5	ALL	31/01/20

LIST OF ACRONYMS

Acronym	Meaning
3GPP	3rd Generation Partnership Project
ANDSF	Access Network Discovery and Selection Function
API	Application Programming Interface
AS	Application Server/Service
CA	Consortium Agreement
CME	City Emergency Center
CORD	Central Office Rearchitected as Data Center
DHCP	Dynamic Host Configuration Protocol
DUT	Device Under Test
E2E	End to End
ELCM	Experiment Life-Cycle Manager
eMBMS	Evolved Multimedia Broadcast Multicast Service
EMS	Element Management System
EPC	Evolved Packet Core
ePDG	Evolved Packet Data Gateway
FCAPS	Fault, Configuration, Accounting, Performance and Security
GA	Grant Agreement
GUI	Graphical User Interface
HSS	Home Subscriber Server
IMS	IP Multimedia Subsystem
KPI	Key Performance Indicator
LTE	Long Term Evolution
MANO	Management and Orchestration
MCPTT	Mission Critical Push-to-Talk
MCS	Mission Critical Services
MME	Mobility Management Entity
MNO	Mobile Network Operator
MOCN	Multiple Operator Core Network
NFV	Network Function Virtualization
NFVI	Network Function Virtualization Infrastructure
NFVO	Network Function Virtualization Orchestrator

NMS	Network Management System
NSA	Non-StandAlone
OAI	OpenAirInterface
OAM	Operations, Administration and Management
OLT	Optical Line Termination
OSM	Open Source MANO
OSS/BSS	Operations Support System and Bussiness Support System
OTT	Over The Top
PCRF	Policy and Charging Rules Function
PGW	Packet Gateway
PNF	Physical Network Function
PoP	Point of Presence
QCI	QoS Class Identifier
QoS	Quality of Service
RAN	Radio Access Network
RRH	Remote Radio Head
SCPI	Standard Commands for Programmable Instruments
SDK	Software Development Kit
SDN	Software Defined Network
SDR	Software Defined Radio
SGW	Serving Gateway
SNMP	Simple Network Management Protocol
SoC	System on a Chip
SON	Self-Organized Network
TAP	Test Automation Platform
UE	User Equipment
VIM	Virtualization Infrastructure Manager
VLAN	Virtual Local Area Network
VNF	Virtualized Network Function
WAN	Wide Area Network
WIM	WAN Infrastructure Manager
X-PON	Any PON technology (G-PON, XGS-PON, NGPON2)

Executive Summary

5GENESIS project is building a 5G experimentation facility composed of six 5G platforms, distributed in Europe, with the major task of validating the 5G KPIs (Key Performance Indicators) defined by the 5G PPP[1]. The five main platforms are being developed in Athens, Berlin, Limassol, Málaga and Surrey, while the sixth one serves as a portable demonstrator. All of them are instances of a common reference architecture already defined in deliverable D2.2 "Initial overall facility design and specifications" in response to the project requirements, identified in deliverable D2.1 "Requirements of the facility". *This deliverable focuses on the specific instantiation of the reference architecture of the 5GENESIS Málaga Platform. It first presents the platform instantiation as expected to be by the end of the project and then reports the current status (platform release B), resulted after the second integration cycle of the project (December 2019).*

The 5GENESIS project is split into three integration cycles, each one lasting 6 months and followed by a testing cycle of 3 months. The platform result of an integration cycle is called a platform Release, named Release A, B and C for each integration cycle. Integration cycles are also named as phases, namely Phase 1, 2 and 3.

The main challenge of the Málaga site[2] is to build a 5G multi-technology, multi-domain End-to-End (E2E) platform that will be used to validate the 5G PPP KPIs for 3GPP Mission Critical Services (MCS) offered over E2E network slices. The main technologies combined for that are the 5G New Radio (NR), the edge computing at the Radio Access Network (RAN) and the flexible orchestration of network functions and services at the core of the network.

The 5GENESIS Málaga Platform is being deployed in two main areas of the city of Málaga: the campus of the University of Málaga (UMA), nearby the research Building Ada Byron; and the old historical center of the city, where the Police Department operates a number of surveillance cameras. Additionally, the City Emergency Center (CME), where those cameras are monitored, will serve as a support site for the platform. The sites are directly connected to the main data center and the core network at the UMA research building Ada Byron. Additional connections with the premises of a commercial Mobile Network Operator (MNO) in Madrid and with the 5GENESIS Athens platform through GÉANT are planned. The first one will allow to share the MNO network in the city centre with the Málaga Platform, while the second will allow the testing of two 5GENESIS platforms interconnected.

For the delivery of the release B of the platform, the integration of several infrastructure components located in the above-mentioned sites was required. All these integration activities are described in this document. The integration of the Coordination Layer, defined in deliverable D2.2, is described in detail, as it realises control and monitoring aspects that are necessary in order to automate the process of the experimentation, measure KPIs and implement full control and security aspects. One step beyond the individual description of the components developed in WP3 for all the platforms, the document includes technical characteristics and development choices specific to the Málaga Platform.

[1] https://5g-ppp.eu/kpis/
[2] https://5genesis.eu/malaga-platform/

The expected deployments and extensions for the support of experimentation use cases in big events are provided, serving as a reference point for the evolution of the Malaga Platform. The major target is Phase 3, when the Platform will be able to support trials related to MCS in which verticals and real end users will be involved.

Table of Contents

List of Figures

List of Tables

1. INTRODUCTION

1.1. Purpose of the document

This deliverable provides a detailed description of the layout and functionalities of the 5G experimental platform being built in the city of Málaga in the context of the H2020 project 5GENESIS. The project aims to validate the relevant 5G PPP KPIs over realistic 5G platforms and use cases. In previous deliverables, the project identified the specific requirements [1] to be satisfied by each of the platforms that compose the facility and its common reference architecture [13].

The document is the second of a series of three deliverables which main goal is to report on the status of the 5GENESIS Málaga Platform, in line with the three experimentation cycles defined in the project: April-June 2019, January-March 2020, October 2020-June 2021. These experimentation cycles target the validation of relevant 5G KPIs in a full end-to-end network and follow an integration cycle where new or upgraded components are integrated into the platform.

The following table shows the set of deliverables with which the present one shares dependence. It is advisable to check them to better understand the Málaga Platform status and evolution.

Table 1: Dependencies with previous 5GENESIS documents

id	Document Title	Relevance
D2.1 [1]	Requirements of the Facility	The document establish the ground for the first set of requirements to be supported by the testbed for the realisation of the planned Use Cases.
D2.2 [2]	5GENESIS Overall Facility Design and Specifications	The 5GENESIS facility architecture is defined in this document. The list of functional components to be deployed in each testbed is defined.
D2.3 [3]	Initial planning of tests and experimentation	Testing and experimentation specifications that influence the testbed definition, operation and maintenance are defined.
D3.1 [4]	Management and orchestration (Release A)	The document presents the MANO solutions that are integrated in the infrastructure. Interfaces and deployment options are also described.
D3.3 [5]	Slice management WP3 (Release A)	The document details the Slice Manager solution, its interfaces towards the MANO and NMS components.
D3.5 [6]	Monitoring and WP3 analytics (Release A)	The document details the Infrastructure Monitoring components and the interfaces with infrastructure elements.
D3.9 [7]	5G Core Network WP3 Functions (Release A)	The document details the 5G Core network functions and provides input on their integration with the infrastructure and management components.

D3.11 [8]	5G Access Components and User Equipment (Release A)	The document details the 5G Radio Access components and UE devices.
D4.4 [9]	The Málaga Platform (Release A)	This document summarizes the sites and components that will form the Málaga Platform and sets the ground for D4.5.
D5.1 [10]	System-level tests and verification (Release A)	Midterm report with detailed analysis of the results from the system-level tests and the verification trials.
D6.1 [11]	Trials and experimentation - cycle 1	This deliverable includes the trials and experimentation executed on the 5GENESIS platform as well as the initial results of the first integration cycle.

1.2. Structure of the document

The technical part of the document starts in Section 2. In the first subsection of Section 2, an overview of the sites that host the components of the Málaga Platform is provided. Then, the second subsection depicts the overall architecture of the platform in detail, splitting the characterization of the components in three logical layers, as per defined in the reference architecture:

- The Coordination Layer is the high-level component responsible for the synchronization of the rest of the elements including the monitoring tools of the platform.
- The Management and Orchestration (MANO) layer controls the configuration of the physical and logical elements of the setup and is responsible for the creation and management of the different slices.
- The low-level Infrastructure Layer is composed of all the physical components that provide service to the entire platform.

As a complement to Section 2, Appendix 1 includes the setup and the connections of the different subsystems that compose the platform, covering aspects that range from the indoor deployment of base stations inside the laboratory of the University of Málaga to the interconnection between the police cameras used in the use-cases through a commercial MNO network. Appendix 1 can be used as a reference point for those interested in the technical details of the components of the Málaga Platform.

Section 3 includes a description of the intended evolution of the platform in consecutive cycles, listing the current accomplishments and the milestones to reach in the deployment of the Release C.

Finally, Section 4 is devoted to the three use cases that will be tested in the final release of the platform, describing their components, the scenarios of utilization and the expected outcome.

1.3. Target Audience

This deliverable detailing the Release B of the Málaga Platform is the first public document depicting the platform status and the integration activities that took place until the present date. The target audience includes the European Commission and the general audience interested in the Málaga Platform for experimentation, as well as the 5GENESIS consortium itself.

This document will ease the task of the European Commission of evaluating the progress of the developments carried on in the platform, as its current scope and status, and its evolution from the last release. It will also allow the general public to understand what the platform offers and its possibilities in relation with 5G-oriented experimentation. Finally, the deliverable will be also helpful for the 5GENESIS project partners, since it will provide valuable inputs for analysis and decision making in relation with future developments, integration, experiments, requirements, and, in general, for improving the roadmap of this platform specifically and of the 5GENESIS framework as a whole.

2. MALAGA PLATFORM OVERVIEW

The 5GENESIS Málaga Platform is an extension of the previous 4G platform deployed at UMA and result of other European projects like FLEX, Fed4Fire, Fed4Fire+, TRIANGLE, Q4Health and NRG5. The latest instance of this previous platform is the testbed TRIANGLE[3], which became a platform for validation of KPIs of devices and applications over mobile networks. The TRIANGLE testbed has been the starting point for the 5GENESIS Málaga Platform development.

The new platform in 5GENESIS is composed of the resources coming mainly from UMA, Telefonica I+D, Police Department of Málaga City, ATOS, Athonet, RunEL and Eurecom. The platform is oriented to validate KPIs for verticals related to Mission Critical Communications, which require Enhanced Mobile Broadband and Low Latency Communications, and that are supported by Airbus and Nemergent in the context of 5GENESIS. The platform combines: a) the current indoor UMA instances of TRIANGLE testbed (one of the EU FIRE research testbeds, located in Ada Byron Research building); b) one outdoor deployment at the UMA campus); c) an outdoor deployment in the city centre of Málaga; d) Telefonica mCORD infrastructure to be deployed in Málaga; e) the orchestration solution provided by ATOS; and f) Athonet VNFs for LTE and 5G core network. Figure 1 depicts the main sites of the platform and how the major components are deployed in the field.

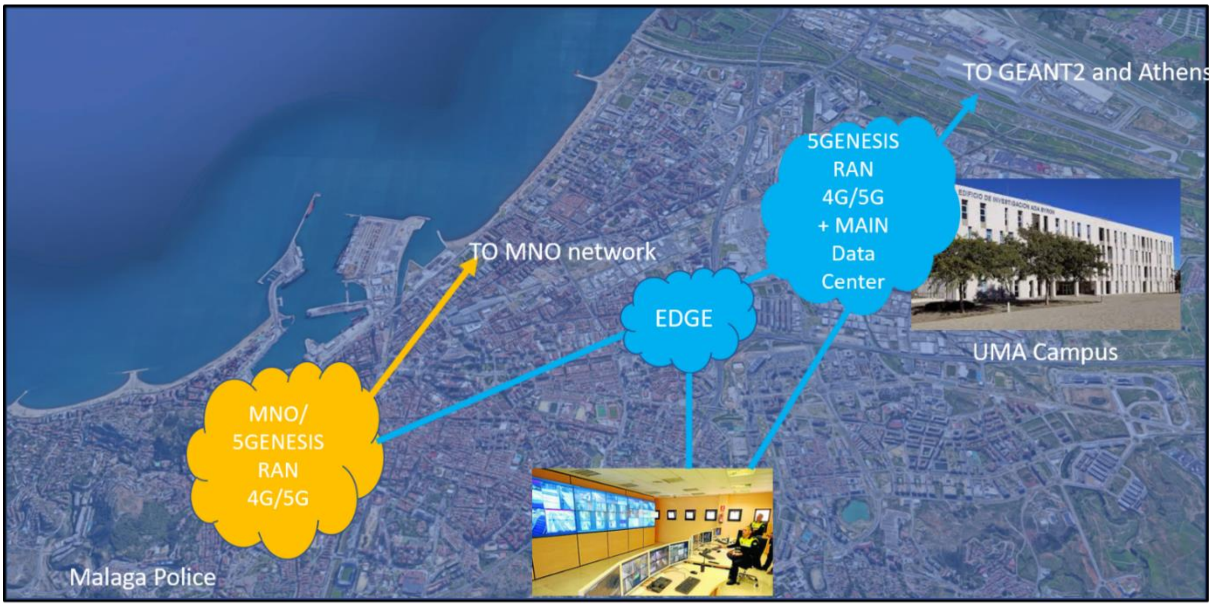

Figure 1: Picture of 5GENESIS Málaga Deployment

There are also plans to interconnect Málaga and Athens platforms for integration and connectivity experimentation purposes. A high capacity link from the Géant network will be used for this. The following figure shows a high-level overview of the whole network that will be implemented in the Málaga Platform by the end of the project.

[3] https:// www.triangle-project.eu

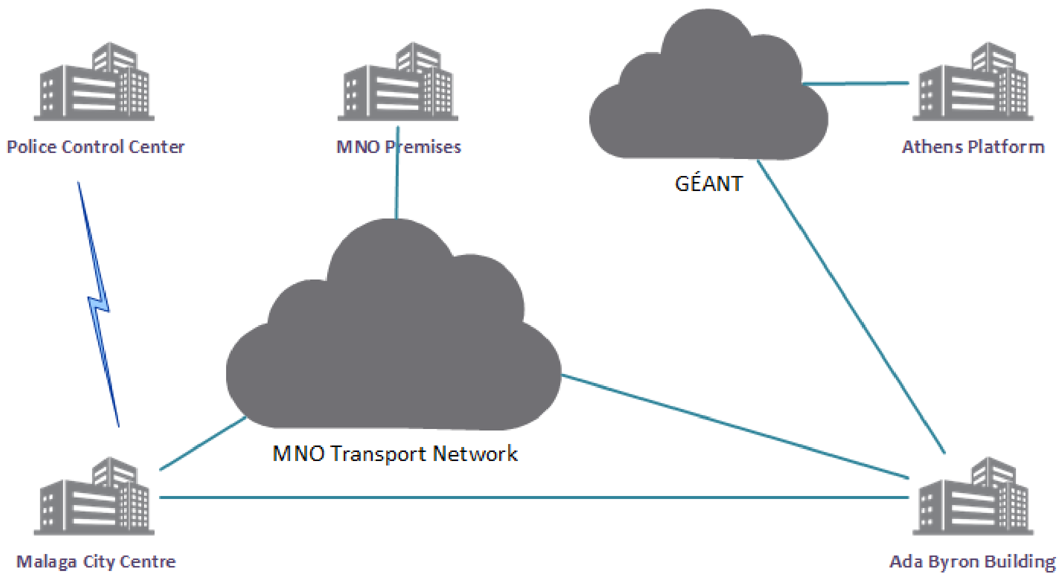

Figure 2: High-level Overview of the different Málaga Platform Sites

The interconnection between the different sites of the platform will be done using optic fiber links. The physical fibers are already installed between the cameras´ locations and the Police Control Center. From it, a connection with the MNO premises will be installed in order to split the commercial users from the experimental 5GENESIS ones using the same spectrum. The 5GENESIS users´ traffic will be routed to the Ada Byron building, where the core network is located. The user´s traffic will be then routed back to the Málaga City Centre and to the Police Control Center using a radio link between the two locations.

2.1. Platform Sites Overview

2.1.1. Overview

The Málaga Platform of 5GENESIS facility is physically distributed in three different locations, belonging to three different domains of the network:

- Ada Byron Research building hosts the core network and most of the equipment (OpenStack deployment, Edge infrastructure, experimental 5G radio) as well as part of the commercial 5G base stations of the platform.
- Málaga city centre, where the Police cameras to be used are already available. In collaboration with Telefonica, additional 5G cells will be installed in a hybrid commercial/experimental deployment. The police facilities across the city centre, which host wiring and other equipment, will also serve as a connection point between the cameras, the base stations and the MNO and the University network.
- The City Emergency Center, located on the outskirts of the city and connected through a fixed radio link with the police facilities, will take the role of the remote end-user that consumes the video from the cameras and assesses the performance of the entire platform in a real world public safety environment.

Additionally, commercial UEs in the city centre are connected to premises of the MNO in Madrid, as explained in the following section 2.1.6. This also allows the evaluation of the impact of Edge infrastructure on the network.

A brief description of the sites involved in Málaga Platform follows. Specific diagrams detailing the architecture of all the sites and the setups, along with Main Data Center and Edge Data Center diagrams, can be seen in Appendix 1.

2.1.2. Site 1: Indoor UMA Lab

The MORSE research group of Universidad de Málaga operates the TRIANGLE testbed, which is the result of the H2020 project TRIANGLE. TRIANGLE testbed was one of the examples considered as 5G European platforms in the 5G-PPP Trials Roadmap Version 2.0[4]. The testbed offers a realistic experimentation environment covering LTE, LTE-A and 5G features, and it is based on commercial off-the-shelf solutions (both in the radio and core network), software defined radio equipment and conformance testing equipment.

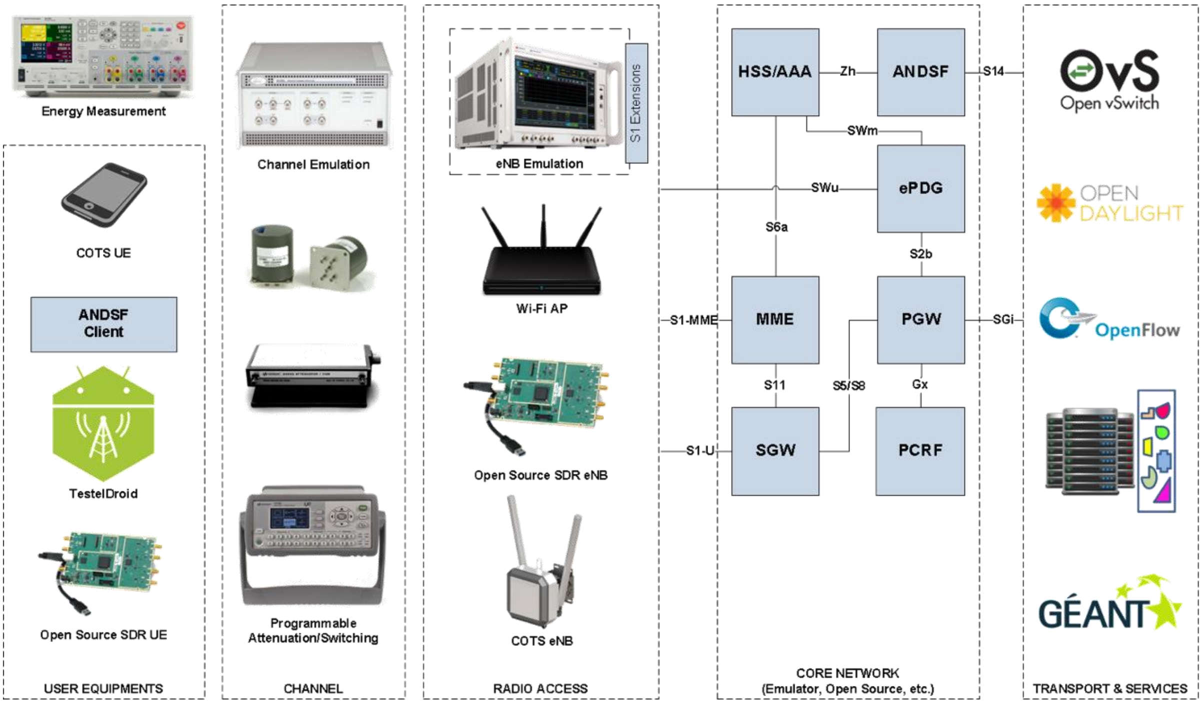

Figure 3: UMA Lab Testbed Components

Figure 3 depicts the different components of the testbed per category, whereas Figure 4 shows part of the actual indoor laboratory. Details regarding the equipment currently available are provided in Section 2.2.1.

[4] https://5g-ppp.eu/5g-trials-roadmap/

Figure 4: Part of Indoor UMA Testbed

Besides the TRIANGLE testbed components, Málaga Platform also integrates 5G NR radio access equipment, 5G compatible UEs, 5G NSA compatible EPC and different services to support the use cases. This components will be described accordingly in section 2.2. Some of them can be seen in Figure 5.

Figure 5: 5G setups at UMA Testbed

2.1.3. Site 2: UMA Outdoor deployment

UMA has extended the indoor lab to cover an outdoor area around the Ada Byron research building as represented in Figure 6. A further extension might be considered during the project lifetime if it is required from external verticals using the platform. The current extension has consisted in the deployment of small cells or remote heads (RRH) with the latest radio release available. Such equipment has been provided by vendors through a public procurement launched by UMA, including both 5GENESIS and UMA specific budget. The spectrum is provided by Telefónica that also supply the required equipment. The Spanish regulator is also willing to authorize the use of spectrum for mmWave. Details on the specific components for the outdoor deployment are provided in section 2.2.1.3. .

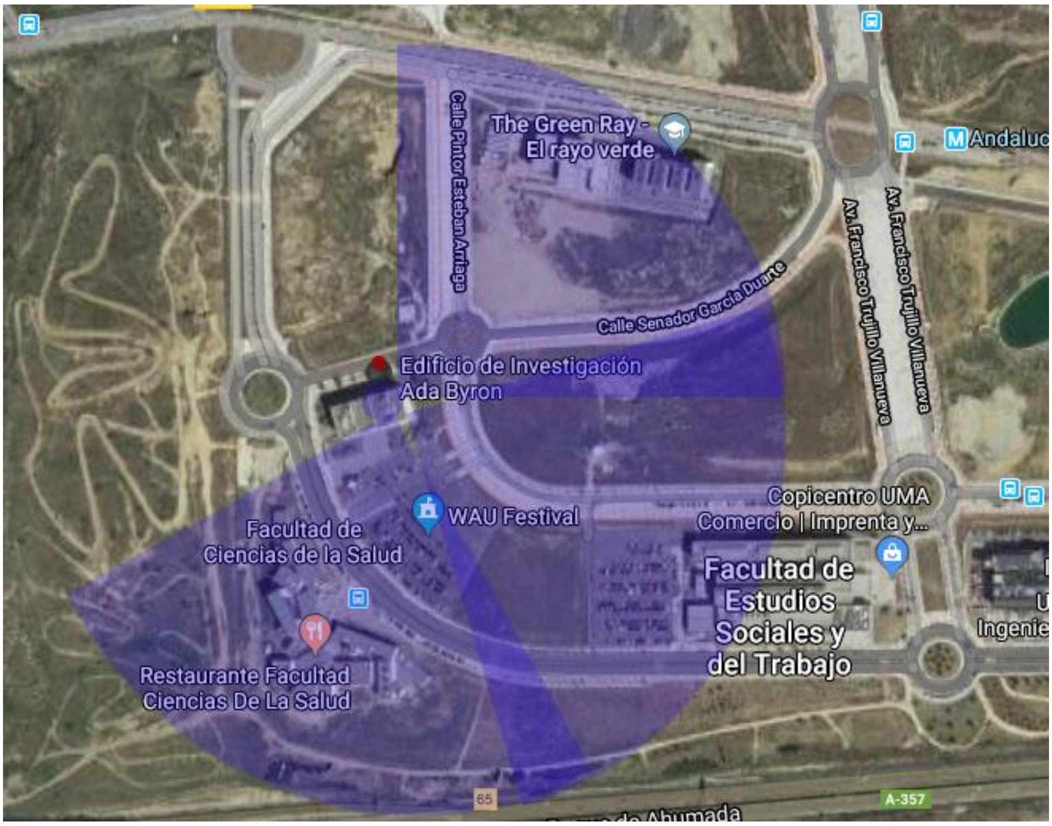

Figure 6: UMA Outdoor Testbed and Ada Byron building location

2.1.4. Site 3: Málaga City Centre

The testbed at UMA has also been extended to cover the area of Málaga City centre to support the validation of Mission Critical Communications in the context of both periodic big events (i.e. annual fairs, parades or shopping holidays) and singular events in dense areas. Málaga city provides locations for small cells with backhaul and energy supply. The provision and installation of those small cells has followed the same approach as in UMA campus. Figure 7 depicts some of the locations (blue area) that are being used now and the connection of this area with the CME.

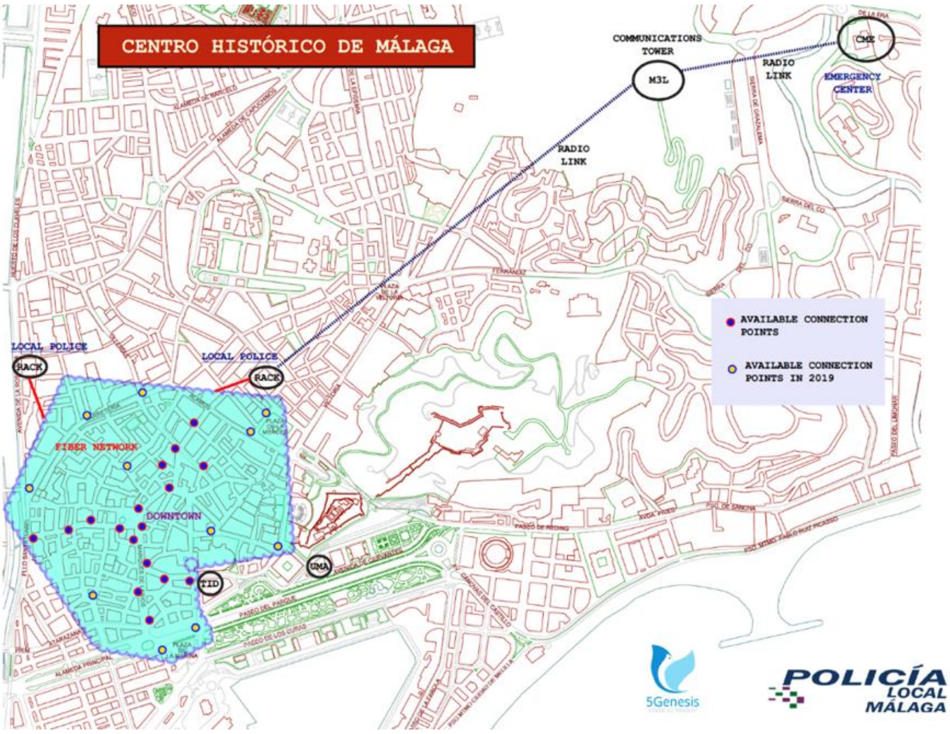

Figure 7: Area of Málaga City Centre with locations for Small Cells

2.1.5. Site 4: Málaga Police Emergency Centre

Málaga Police department has a control room in the Málaga CME to monitor and control the existing cameras in the city (Figure 8). Currently, all the cameras are connected with a fiber network to a central point at Plaza de la Merced square (mentioned previously as police facilities across the city). There is no direct fixed connection between the Emergencies Centre and Plaza de la Merced, two radio links are now in place (Figure 9).

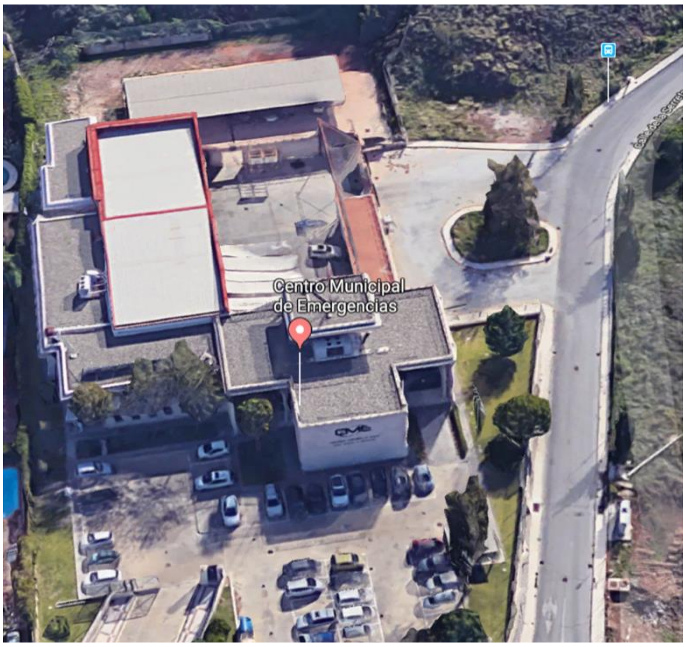

Figure 8: Málaga Emergency Centre

Figure 9: Radio Link Repeater close to Emergency Centre

2.1.6. Site 5: Telefonica I+D lab in Málaga/Madrid

Telefonica will provide their mCORD-like installations in Málaga to provide Edge functionality. In addition, the team from Telefonica I+D will connect this to 5Tonic lab at IMDEA in Leganés (Madrid). The 5Tonic infrastructure is expected to be used in order to deploy specific components that are part of the use cases defined for the Malaga Platform. Thus, KPIs values could be extract for components interconnecting several hundreds of kilometers away and be compared with the ones obtained when using Malaga Platform resources exclusively.

5Tonic permanent infrastructure includes:

- Data center infrastructure including racks for each 5Tonic members and communications infrastructure;
- Virtual EPC provided by Ericsson, to evolve to NGC;
- LTE Radio Access infrastructure, provided by Ericsson and CommScope, to be evolved to NR;
- Virtualization, processing and transport infrastructure.
- ONLIFE Data Center for Edge Computing testing, similar to the one deployed at UMA 5Genesis Malaga Platform.

The current status of the permanent 5Tonic network infrastructure is represented in the following figure.

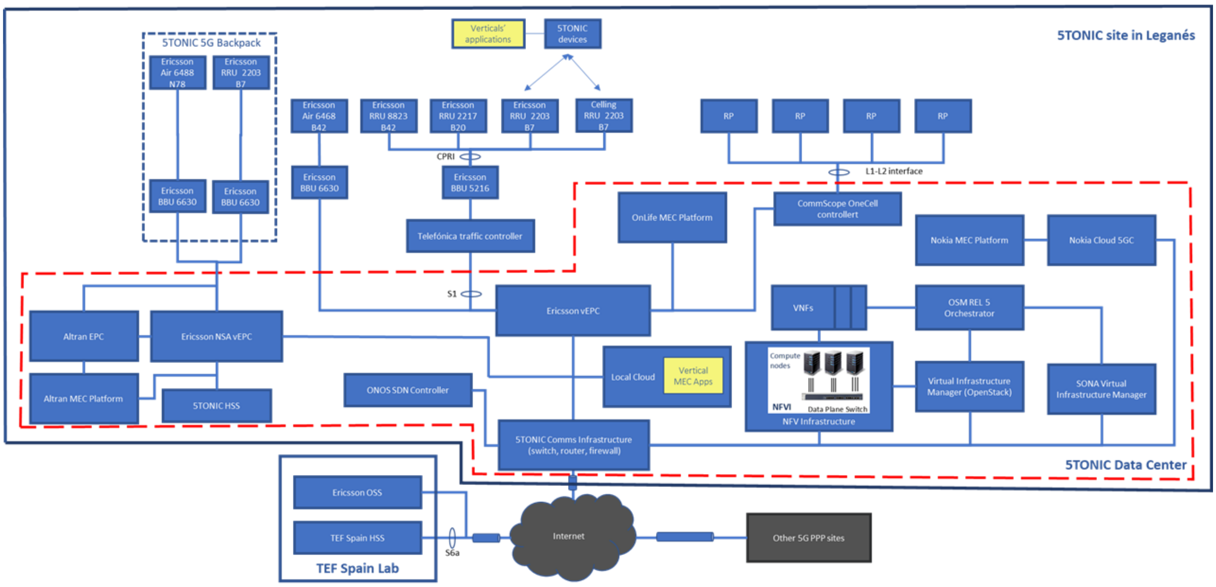

Figure 10: 5Tonic Lab deployment

This infrastructure is connected to Rediris network, same as University of Malaga, so the target is to connect 5Genesis Málaga Platform with 5Tonic Lab using Rediris Network.

2.2. Target Deployment Topology

Figure 11 below shows a schematic distribution of the target physical deployment for the Málaga Platform at the end of the project, which includes the functional components of the different sites involved. Most of those components are implemented in the Release B of the platform, as will be described in the following subsections.

This section explains the components integrated in the platform up to its Release B, highlighting the new components and the ones that have been upgraded. The section is structured in three subsections, each one dedicated to one of the three different layers of the platform architecture, as defined in D2.2 [2].

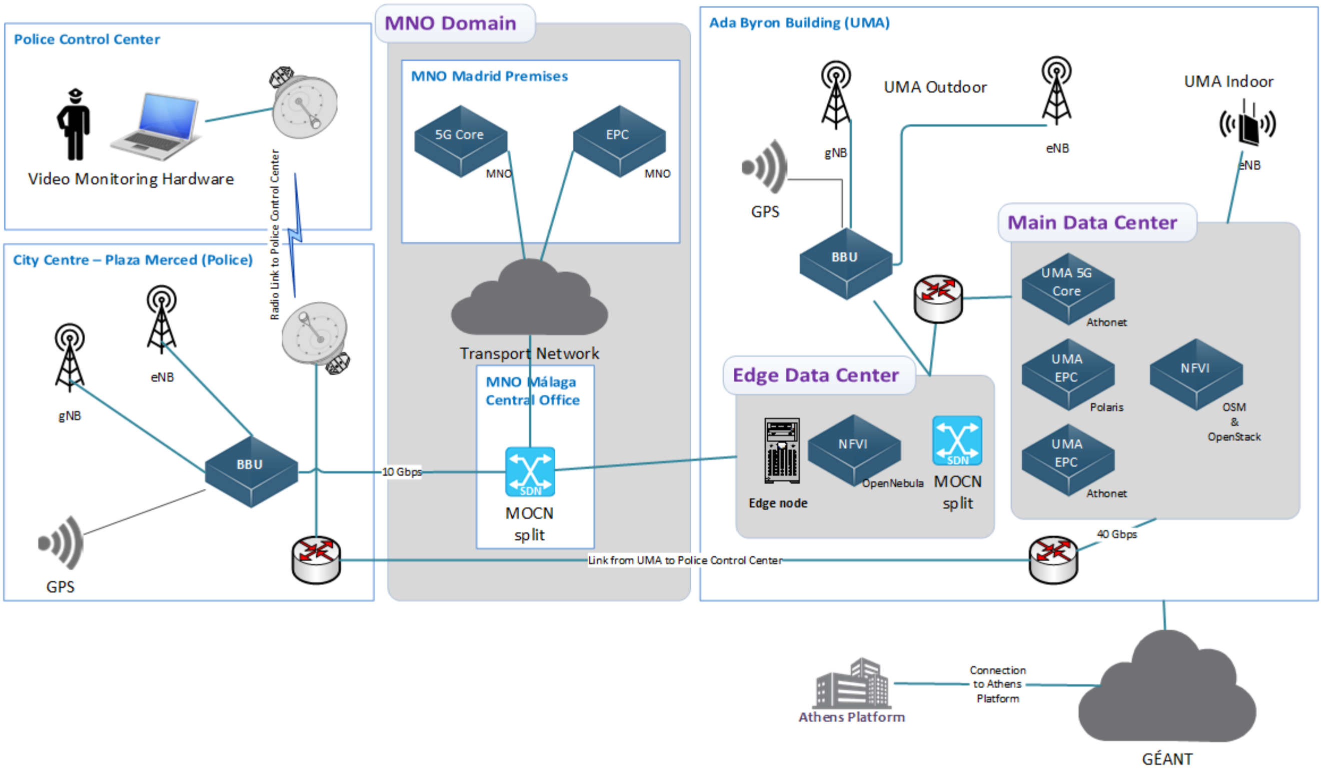

Figure 11: Overview of the Málaga Platform Infrastructure

2.2.1. Infrastructure Layer

This section is focused on the physical components used to provide the services of the platform, and the devices and networking elements that form the core infrastructure used for experimentation. Each part of this layer is described in a dedicated subsection of this section. The table below acts as an overview of all those parts that compose the infrastructure layer:

Table 2: Infrastructure Layer Technologies

Component	Product/Technology	Mode of Implementation
Main Data Center	Commercial servers	OpenStack
Edge Data Center	TID Edge solution	OpenNebula
RAN – LTE	Nokia small cells deployed indoor and outdoor Commercial LTE smartphones	LTE base station and UEs
RAN – 5G	Nokia Airscale System and 5G micro RRHs deployed outdoor Prototypes from REL and ECM Commercial 5G smartphones	5GNR prototypes, base stations and UEs

Mobile Core Network	ATHONET's EPC Polaris' Rel. 15 EPC solution for Edge environment	Instances of the core network with different capabilities
Monitoring & Measurements	Custom traffic and functionality probes	Distributed tools across all the layers of the stack, controlled by a single monitoring entity

2.2.1.1. Main Data Center

The main data center is used for the physical composition of the NFVI. We have chosen to extend the minimum configuration (i.e. one server that contains everything) to a more distributed one, where each server has its own functionality. Adding an extra server for storage relieves the load of the controller, taking care of the volumes of persistency which might also be useful for the next phases in case we want to enhance the platform capabilities with instance migration, redundancy or we need to deploy services that require volume persistence. For such reason, the server that is dedicated to host the volumes has been equipped with extra storage.

Connectivity between the different elements of the Main Data Center and also with the rest of the platform, outlined in Figure 37(Appendix 169), will use high-capacity OpenFlow switches with a base bandwidth of 10 Gbps for general interconnections and specific 40 Gbps links for the backhaul between remote sites.

2.2.1.2. Edge Data Center

The infrastructure of the Edge Computing domain follows the CORD architecture. It has a Data Center architecture with three fundamental components:

- **Compute Infrastructure**. It consists of a number of Compute Nodes (Servers) based on x86 architecture, with RAM Memory and Storage Capacity (per server or on a separate storage cabinet).
- **Switching Fabric.** It consists of a number of switches disposed in a CLOS fabric configuration to guarantee redundant physical connectivity.
- **Optical Access.** Optical equipment to connect access network devices. Namely, this is the Optical Line Transmission equipment (OLTs) to connect GPON or XGSPON fiber as fronthaul connection for Mobile Network infrastructure.

The infrastructure will be adapted to be connected directly to the HL4 router from a Telefónica Central Office to get the traffic from the Mobile Network infrastructure. The Edge Data Center infrastructure consists of the following layers and elements:

- **Computation Layer**. All routing and network control functions are virtualized and, therefore, implemented by software programs that run on the server nodes of the Edge compute layer, or part of them, destined to end users, following the edge computing model (Edge Computing).

- **Switching Layer.** It is the layer that passes the traffic from the optical access layer to the different services and outputs of the Edge server forming a CLOS fabric of switches.
- **GPON Optical Access Layer**. Formed by the elements that receive user traffic at the optical level.
- **Management switch.** It allows access to all the edge components through the management network.

The following diagram shows graphically the layout and physical interconnection of the different elements of the Edge Node architecture with the connections to the 5GENESIS Málaga Platform (core network and mobile infrastructure).

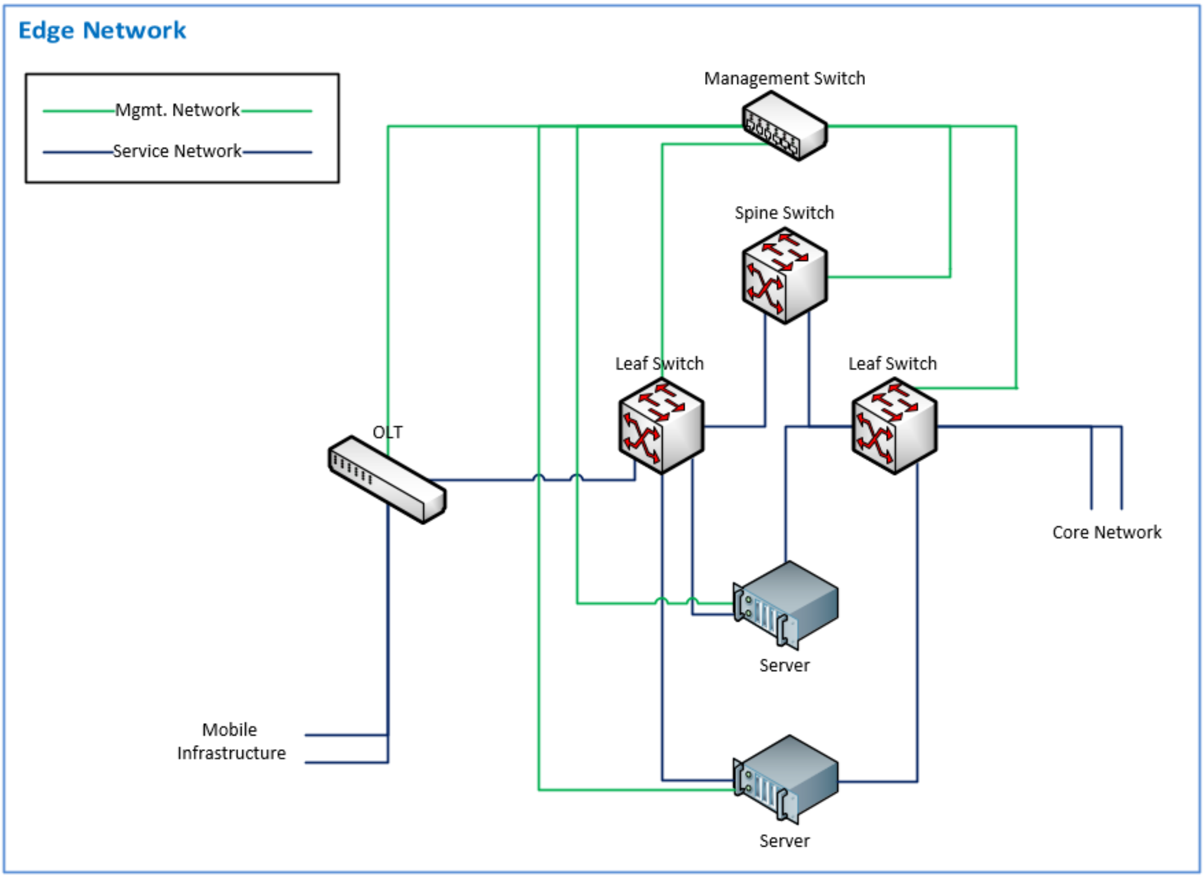

Figure 12: Edge Overview

The traffic comes into the Edge node from the Mobile Infrastructure, connects to Services running in the compute nodes of the Edge node, and leaves the node towards the core network at UMA 5GENESIS Platform.

Details about the Edge Data Center components and networking can be read in Appendix 1.

2.2.1.3. Mobile Network Technology

The platform will integrate radio equipment coming from different sources and delivering different setups. The use of these different setups will allow the incremental validation of KPIs from LTE to 5G NR and from very controlled indoor environments to unpredictable outdoor scenarios.

The following Table 3 depicts the roadmap for the different radio setups planned for the Málaga Platform. Setups 1 to 5 are already available in the platform, while setups 6, 7 and 8 are still a work in progress. Setup 8 is partially deployed, since the outdoor 5G deployment is already in place, as will be shown in the corresponding section.

Table 3: 5GENESIS Málaga Platform 5G Technology and roadmap

	#	Description	Mobile Core Product	Radio Access Products	UE	3GPP Option
Phase 1	1	TRIANGLE testbed	Polaris EPC	Keysight 4G Emulator	Commercial 4G	LTE
	2	Indoor E2E	Athonet EPC	Nokia eNodeB	Commercial 4G	LTE
	3	Indoor 5G ECM no core	-	OAI gNodeB	OAI	Only basic DL
Phase 2	4	Indoor 5G REL no core	-	RunEL gNodeB	RunEL UE Emulator	Only basic DL
	5	Full E2E 4G with VIM	Athonet EPC	Nokia eNodeB	Commercial 4G	LTE
	8.1	Full E2E 5G (including outdoor)	Athonet EPC Rel 15 Polaris EPC Rel 15	Nokia gNodeB	Commercial 5G	NSA
Phase 3	6	Indoor 5G ECM NSA	Athonet EPC Rel. 15	OAI gNodeB	OAI	NSA
	7	Full E2E Indoor 5G	Athonet 5G Core	RunEl gNodeB	OAI 5G UE	SA
	8.2	Full E2E 5G (including outdoor)	Athonet 5G	Nokia gNodeB	Commercial 5G	SA

TRIANGLE Testbed components

The equipment that forms the TRIANGLE Testbed as part of the indoor UMA laboratory is available as part of the 5GENESIS Málaga Platform, acting as baseline components and extending the possibilities of the platform. A brief description of the TRIANGLE components follows:

Conformance Testing Units. T2010 unit is a conformance testing equipment formerly implemented by AT4 Wireless and now part of Keysight Technologies. The unit is designed to provide conformance testing both at protocol and physical level of LTE user equipment of Release 8. This technology belongs to "eNB Emulation" present in Figure 3.

Keysight UXM. A very-high-performance LTE-A emulator, supporting functionality like carrier aggregation (4CC DL and 2CC DL) with data rates of up to 600Mbps. The unit has been extended over the course of the TRIANGLE project to support the standard S1 interface, thereby enabling experiments involving commercial core networks. As in the Conformance Testing Units case, this belongs to "eNB Emulation" part in Figure 3.

LTE Small Cells. Pico-cells of Athena Wireless working in band 7 with a maximum transmission power of 2W. The cells can be configured via a standard configuration interface (TR-069). The testbed also features indoor Nokia Small Cells working on band 7. The cells integrate Wi-Fi access and offer carrier grade performance, being part of the deployment of many different Tier 1 mobile operators.

Channel Emulation. The Spirent Channel Emulator SR5500 emulates complex wideband channels characteristics like time-varying, multi-path, delay spread, fading and channel loss offering a programmable SCPI (Standard Commands for Programmable Instruments) interface.

Radio interconnection infrastructure. The testbed also features programmable RF switches and attenuators, which can be used to have variable attenuation and RF outputs, useful to generate controlled handover scenarios.

LTE core network. Polaris core network implements the basic LTE core network elements (MME, SGW, PGW, HSS, PCRF) plus functionality to support Wi-Fi offloading (ePDG and ANDSF). The EPC supports features like negative testing, protocol monitoring and advanced KPIs. This core network supports all the standard functionality and can be used to deploy multiple instances of any of the available components, which enables very complex scenarios. The EPC components can be deployed as VNFs.

LTE User Equipment. Málaga University has many User Equipment samples working in different frequency bands, and covering several UE speed categories supporting from IoT devices to high performance connections. Additionally, there are several SDR cards that can be used to provide UE functionality deploying OpenAirInterface (OAI) or srsUE.

Power Analyzer and other instrumentation. The power analyzer unit N6715B can act as a 2-quadrant DC voltage and current source, but it's also able to generate arbitrary waveforms. It features an integrated oscilloscope and a remote programming interface, which can be used to mimic certain special behavior like battery chargers or even a battery emulator to connect to the DUT (Device Under Test).

Automation and measurement support. UMA has developed a web portal and several automation tools to control the experiments in the testbed in order to ensure their repeatability in the same conditions. This feature, that can be exploited remotely, is very valuable to measure KPIs and to compare technologies.

Radio Access Network

As a summary, the following Radio Access components are currently deployed as Release B of the Málaga Platform:

Table 4: Málaga Platform radio access equipment deployed

Site	Deployed Radio Access Equipment
UMA Lab indoor	• 4 FlexiBTS Nokia 4G Small Cell • Keysight T2010 and UXM LTE eNB emulators • Prototype 5G RAN setups from OAI and RunEL
UMA Lab outdoor	• 4 Nokia 5G Micro RRH 5GC001274 • 4 Nokia 4G Micro RRH 474147A • Nokia Airscale BBU
Málaga City Centre	• 6 Nokia 5G Micro RRH 5GC001274 • 5 Nokia 4G Micro RRH 474147A • Nokia Airscale BBU

Indoor LTE deployments

The Málaga Platform uses an existing 4G deployment for integration, experimentation and KPI baselines extraction. It consists of two different sets of devices:

- Two successive generations of the Keysight UE Conformance Testing Equipment for 4G networks, pictured in Figure 13. This is the kind of equipment that manufacturers use to test new radio and baseband chipsets before launching them to market. It acts as an eNodeB to the UE, giving complete control of the signaling and the radio stack to the operator. Thanks to its configurability, it is possible to test different frequency bands, bandwidth and resources assigned to the UE in the standard conditions stablished by 3GPP (clean or noisy environment, static or moving UE with different speeds, etc.)[12][13].

Figure 13: Conformance Testing Equipment available in the Málaga Platform

- Alongside the conformance testing equipment, a number of indoor commercial 4G small cells from Nokia are also used in order to obtain realistic baselines for the KPIs analyzed during the entire project. These base stations, depicted in Figure 14, provide the same characteristics and performance available to commercial MNO, and some advanced features like eMBMS support or carrier aggregation that will be used for the use cases.

Figure 14: FlexiBTS Nokia 4G Small Cell

Indoor 5G deployments

OpenAirInterface RAN (OAI-RAN) solution provided by Eurecom is an open-source software and hardware platform providing a standard-aligned implementation (3gpp Rel. 10/14) for the LTE UE and eNB. Currently, OAI is being extended to support 5G-NR UE and gNB [14], as per Rel.15 standards.

The Málaga Platform has integrated the OAI 5G-NR UE component, which will be interoperable with the gNB provided by RunEL to perform end-to-end experimentation and KPIs measurement collection. Until the interoperability with RunEL is ready, the platform will use an OAI 5G gNB that has been integrated to allow testing. The currently OAI setup integrated in the Málaga Platform can be seen in Figure 15. The protocol stack extensions for both 5G-NR UE and gNB are becoming gradually available throughout the different phases of 5GENESIS, starting from the physical layer (phase 1) and continuing with the rest of the RAN protocol stack (MAC, RLC, RRC, PDCP). The OAI UE can be launched and configured easily through a Command Line Interface (CLI). Based on this CLI, the UE can also be controlled remotely through external software.

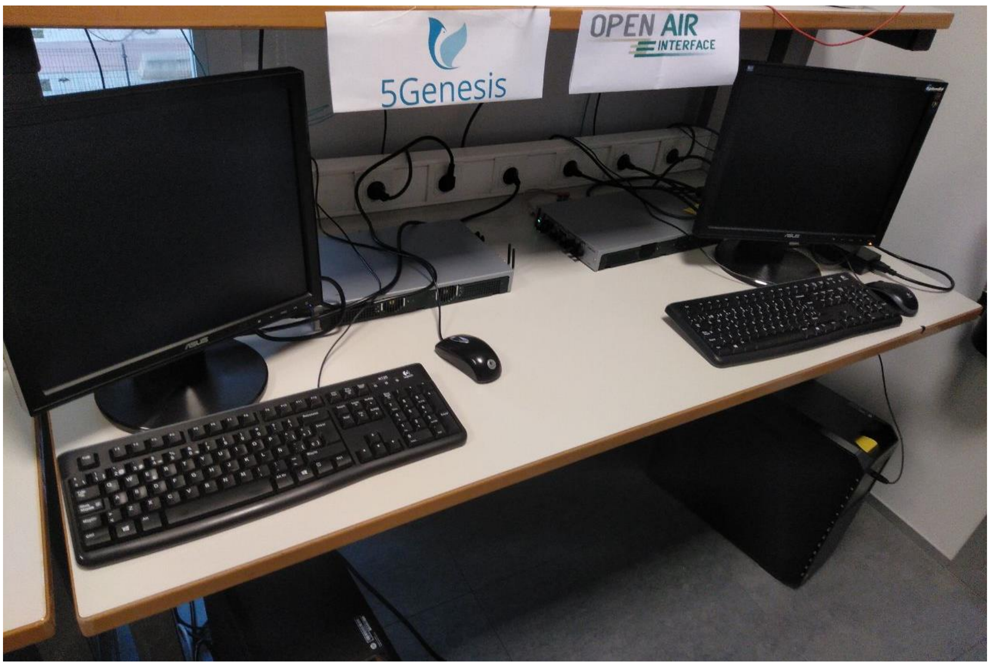

Figure 15: OpenAirInterface setup 3 at Málaga Platform

RunEL has also provided a 5G Infrastructure to the 5GENESIS Málaga Platform including 5G New Radio (PHY and MAC) already optimized for Ultra Reliable Low Latency Communication (URLLC), as can be seen in Figure **16**. The RunEL gNB includes advanced features such as: 2 frequency bands 3.5GHz and 28 GHz, Beam Forming, MIMO, flexible frames, 200MHz BW and more.

Figure 16: RunEL setup 4 at Málaga Platform

The RunEL equipment provides a 5G physical layer implementation. The setup includes the main two units which comprise the physical layer: the DRAN (Distributed RAN) unit and the RRH (Remote Radio Head) unit. To enable testing of this units, the setup includes also a UE emulator and software for a basic MAC layer and a video server. The RunEL setup is shown in the following Figure 17.

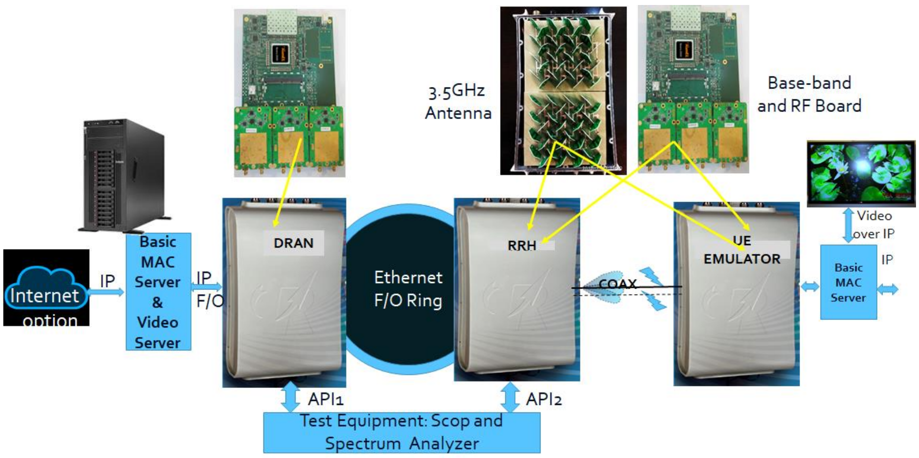

Figure 17: RunEL 5G setup architecture

More detail about both OAI and RunEL equipment and setups can be found in Appendix 1.

Outdoor LTE and 5G deployments

UMA and TID have designed the expected outdoor deployments for UMA campus and the city centre to be covered within the 5GENESIS budget, as was depicted in Figure 11 in the platform overview.

The technology integrated in the platform for the outdoor deployment is the Nokia AirScale Solution, which can be seen in Figure 18 and Figure 19. This solution includes the following components:

- Common equipment
  - Nokia AirScale System Module Indoor. BaseBand Unit, supporting a variety of technologies as GSM, WCDMA, TDD-LTE, FDD-LTE and 5G NR, and a capacity of up to 10 Gbps per system module with up to 96 LTE cells.
- 5G equipment
  - Nokia Micro RRH 5GC001274. RRH for 5G.
- LTE equipment
  - Nokia Micro RRH 474147A. RRH for LTE.

Technical details about the AirScale System integrated in the Málaga Platform are available in Appendix 1.

Figure 18: Nokia 5G and 4G micro RRH in Ada Byron building rooftop

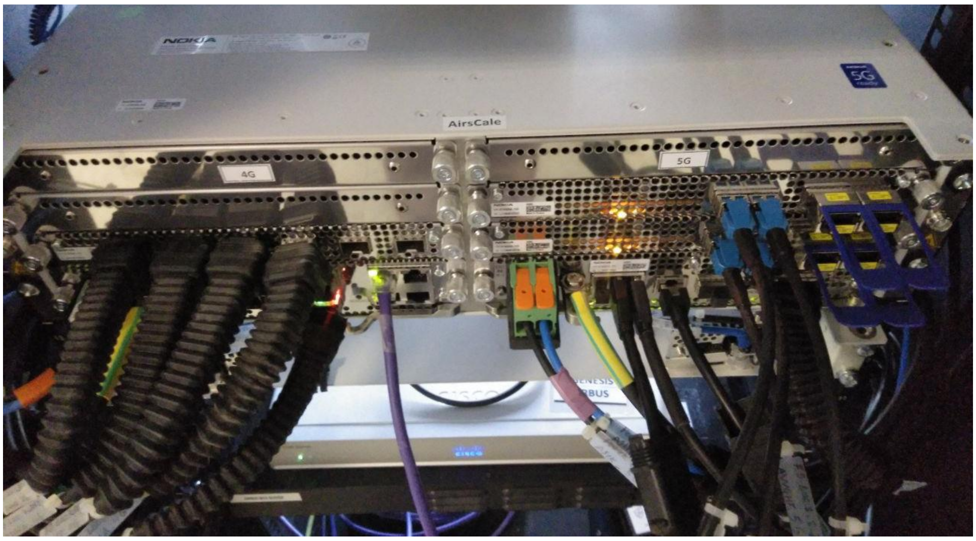

Figure 19: Nokia Airscale BBU at Ada Byron site

Mobile Core Network

Athonet's mobile core is based on a highly efficient and effective software-only implementation. The expensive, proprietary, hardware centric CAPEX of traditional mobile core solutions has been replaced with a wholly software-only product that runs on standard off the shelf servers or in a virtualized environment since its first release in 2010. The solution has a reduced footprint that can run on x86-based as well as on ARM-based platforms.

The platform is a full 5G-NSA mobile core that implements 3GPP Release 15 defined network functions, including 5G-NSA support for 3, 3a and 3x configurations, 5G extended bandwidth support for uplink/downlink bearers and dual registration.

While Athonet's solution is the mobile core for the Main data center, Polaris's LTE NetEPC is the chosen one for being used in the Edge. Polaris NetEPC, which includes MME, SGW, PDN-GW, HSS, PCRF, makes possible the use of the components individually to create a testbed with a mix of real and emulated EPC elements, as well as the use of all the Polaris elements together to have a complete LTE EPC. The components support all the 3GPP defined network interfaces and implement all the protocols required for an EPC to operate in an LTE network.

More detail about both Mobile Core solutions can be read in Appendix 1.

User equipments (UEs)

On top of the experimental UEs provided by ECM and RunEL, the platform is integrating several commercial UEs:

- MCS - Samsung S8 provided by Airbus, Sonim XP8 provided by Nemergent. Both of the UEs prepared for MCS have been provided with specific MCS applications by the corresponding partners.
- LTE - Samsung S9.
- 5G NSA – Samsung S10 5G, Xiaomi Mi Mix 3 5G. New 5G compatible UEs will join the Málaga Platform in the coming months.

2.2.2. Management and Orchestration Layer

As explained in deliverable D2.2, most of the 5GENESIS components in the management and orchestration layer are also common to the six platforms in the project, and they are described in the deliverables D3.X provided in WP3, as for example D3.1 for the MANO or D3.2 for the slice manager. However, there are some variants in the MANO and the NMS systems due to the hardware/software installed in each platform and also due to the previous existence of some MANO solutions.

For the Release B of the Málaga Platform, the Málaga team has installed and configured Open Source MANO release SIX (OSM6) as NFVO, upgrading from the FIVE version previously installed. Along with the NFVO upgrading, the core VIM has also been reinstalled and upgraded to the Openstack Rocky version. The Edge VIM remains untouched from Release A and keeps the Open Nebula 5.8.1. The first stable release of the Katana Slice Manager has been installed and integrated with the rest of the existing components and also the configuration of the NMS to support hardware coming from TRIANGLE and from radio vendors have been done.

The following table shows a brief description of all the components of the management and orchestration layer.

Table 5: Monitoring and Management Tools

Network/Element Management Systems	Description
4G/5G Legacy EMS	Most Mobile Network elements deployed in the platform provide proprietary solutions that allow operations like configuration and monitoring for the respective devices. These systems are exploited to perform configuration management and retrieve status information per case.
WIM	WIM is the WAN infrastructure Manager, a component that has the overview of the Wide Area Network (WAN), the physical network that is used to provide connectivity to any physical and virtual component of the platform. It keeps track of the way on which all networking devices (SDN switches, routers), NFV Infrastructures and physical devices of the platform are connected, in the form of a network graph.
OpenTAP	OpenTAP is an open-source test sequencer developed by Keysight Technologies which can be extended using custom plugins. Several TAP plugins have been developed within the 5GENESIS project for the automation of the different components of the platforms.
Monitoring Tools	**Description**
Prometheus	Prometheus servers deployed in hierarchical mode are collecting aggregated time series data from a larger number of subordinated

	servers and can be used to take measurements from any device on the platform by creating custom exporters that use the SNMP protocol.
Grafana	Used for the visualization and analytics of the Prometheus metrics. Additionally, Grafana supports a lot of presentation dashboards.
NFV MANO	**Description**
OSM	OSM[5] is an open source MANO aligned with the ETSI framework for NFV. OSM is an orchestration and management system which manages life-cycle and configuration aspects of the hosted virtual network functions (VNFs) that are deployed on the wide number of supported NFV Infrastructure (NFVI) platforms. These MANO capabilities are critical to implement the sophisticated services expected by the 5G communication systems and utilize the underline management systems and tools. For the purpose of the 5GENESIS Platform, the deployed OSM is of release 6 and is already integrated with the Element management systems and monitoring tools as well as the Virtualisation Infrastructure Managers (Openstack).
Slice Manager	**Description**
Katana	Release A implementation of the 5GENESIS reference architecture Slice Manager implementation (WP3 component).
Traffic Generators	**Description**
iPerf	iPerf is a cross-platform network performance measurement tool that can produce standardized measurements on any network. iPerf agents have been deployed for PC and Android devices, allowing the automation of the iPerf tool. More information about these agents can be seen in Deliverable D3.5.
Ping	Ping is a round trip time measurement tool available in most operating systems. Like in the case of iPerf, PC and Android agents have been deployed in the platform in order to automate the use of this tool. More information can be seen in Deliverable D3.5.
Exoplayer	Exoplayer is a library and media player for Android that provides support for DASH, SmoothStreaming or HLS adaptive playback. The source code of this application is available and designed to be easily customizable and extensible. The Exoplayer instances deployed in the Malaga Platform have been adapted for automation and result retrieval.

[5] OSM, https://osm.etsi.org/

2.2.2.1. NFV Management & Orchestration

The Málaga Platform NFVI will be managed by two different technologies distributed in two different domains: OpenStack for the Core NFVI and Open Nebula for the Edge infrastructure.

In the Main data center, located at the UMA campus, there are three dedicated servers to host and manage the network service instances using OpenStack (Rocky release): the controller, the compute and the storage nodes. As stated in the previous section, this component has been upgraded to a newer version for the Release B.

In the Edge NFVI, an Open Nebula (v5.8.1) portal and a controller are available.

On top of the infrastructure management, there is a single orchestrator handling the NFV deployments in both the Core and the Edge. In this case, the edge orchestrator will not be actually necessary as these functionalities are delegated to the Core NFVO, which has been implemented with OSM Release SIX in Release B. On top of that, we have developed and integrated a wrapper to perform the necessary actions over the NFVO and the VIM, bypassing the security introduced by the components themselves, simplifying the usage to adapt it to 5GENESIS and enhancing some features like the advanced descriptor validation

A simplified network diagram of the above deployment is shown in Figure 20.

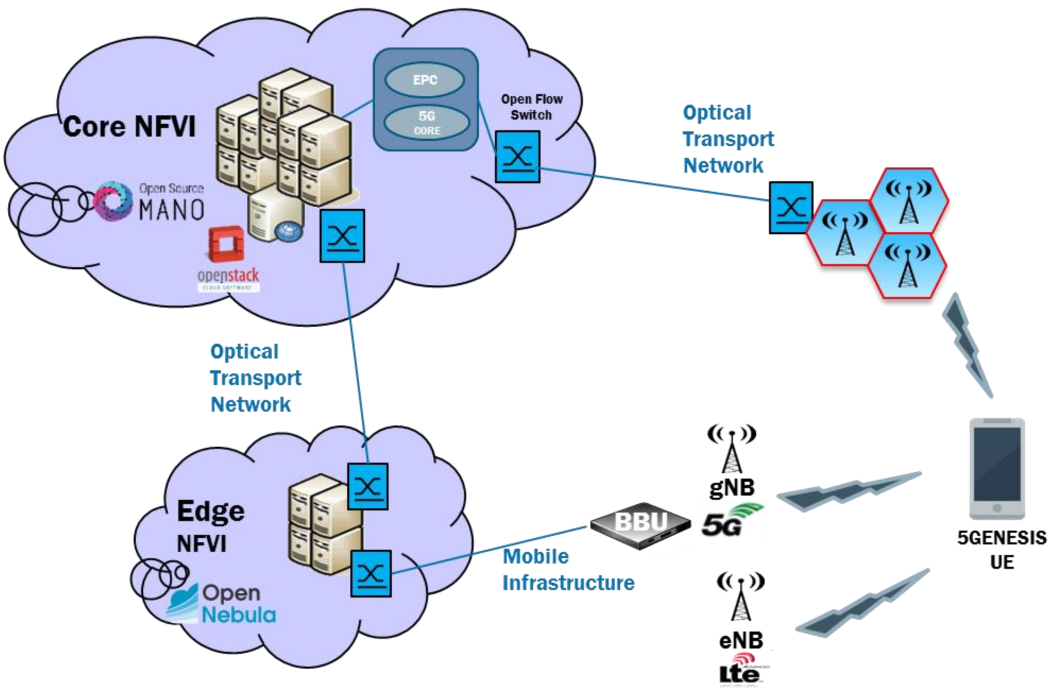

Figure 20: Core NFVI and Edge Composition

In order to properly communicate the infrastructure management (OpenStack) with the NFVO (OSM), we needed to set a specific configuration for OpenStack and the networks it manages in order to:

1. Guarantee that OpenStack API endpoints are reachable from OSM (particularly from RO container).
2. Create a management network, with DHCP enabled, reachable from OSM (particularly from VCA container).
3. Create a valid tenant/user with rights to create/delete flavors.

4. Modify the default security group or create a new one. By default, OpenStack apply the "default" security group that blocks any incoming traffic to the VM. However, *ssh* access might be needed. Therefore, we had to modify the default security group to allow TCP port 22 or create a new security group and configure RO to use it when a data center is added.

2.2.2.2. Slice Manager

The Katana Slice Manager was introduced as part of the Malaga Platform Release A, and it has been updated to a newer version for Release B. Its focus is to deal with the experiment slices, taking over the command of instantiation of network services in the NFVO. Katana is installed in a dedicated server with network access to the NFVO. As explained in D3.3 [5], the Slice Manager for Release B provides the following functionalities:

- VIM user and project management, creating a new user and project for each deployment to improve the isolation (operations supported for OpenStack and OpenNebula VIM types).
- NFVO VIM management, creating a new VIM in the NFVO to complement the above bullet point.
- NS service deployment as part of a new slice, making use of all the items created in the mentioned points.

To carry out the previous features, the Slice Manager needs to be preconfigured with information such as the available PoPs, the network services that are going to be deployedand where (PoP), the type of slice, etc.

2.2.2.3. Element Management Systems

The Element Management System (EMS) is the component in charge of the fault, configuration, accounting, performance, and security (FCAPS) operations of each Network Element. It provides self-configuration functionalities for the centralized SON (Self-organize Networks) (cSON), where functions are implemented in a central location, and operates over a powerful resources area, specially designed for optimized group of resources in terms of interferences, transmitting power, cell, etc. It also controls the distributed SON (dSON) features, usually considered in a closer location to the user, allowing specific configurations for better performance. A schematic diagram of the EMS inter-relations is presented in Figure 21.

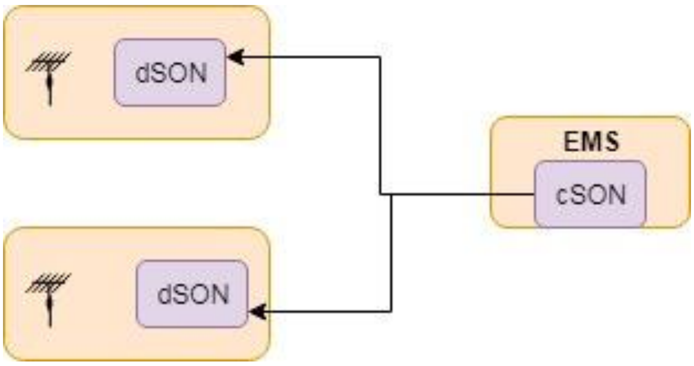

Figure 21: Functional Architecture of Self-functions

This capability of Self-functions allows an automatic operation and autonomous process to be executed, instead of the classical manual planning that implies more complexity and time. Among the functionalities that are provided, we can highlight:

- Self-planning: automation and configuration of the deployment nodes and extension of the deployed ones.
- Self-healing: automation of the fault management processes.
- Self-optimization: to maintain or improve the network performance of the operational network state.

The EMS is decomposed also as physical and as specific instance network elements, although it can be treated just as a single system component. The Physical Network Functions (PNF) EMS is responsible for managing PNFs and provides a consolidated view of all their components; it is decomposed into separate views that are organized as a hierarchy of managed objects in the physical network elements:

- Configuration Management (CM).
- Fault Management (FM).
- Performance Management (PM).

The EMS can manage objects that represent:

- The slice that a certain vertical owns, including the VNF and the services deployed.
- The neighbor cells where the NVF can be migrated.

2.2.2.4. Network Management Systems

The NMS is being implemented using the TAP framework [15][16] already used in TRIANGLE project to support full automation of all the hardware and software components. In order to accomplish this level of automation, we are developing TAP plugins for controlling the different components of the platform. Each TAP plugin will communicate with the component using the most appropriate interface available, for example, several instruments expose an SCPI interface for control, while others can be controlled by sending commands through *ssh*.

TAP includes a generic SCPI Instrument that can be used out of the box, but we have developed a new generic TAP Instrument that is able to send commands and transfer files through *ssh*. These Instruments can be extended, which will allow us to create specific instruments for a particular component of the platform. This, in turn, will help to create more fine-tuned steps for controlling the different actions that an instrument can perform. Details about the implementation of this TAP plugin can be seen in section 4.3 of deliverable D3.15.

In a similar way, we can develop generic plugins for communicating with components that can be only controlled using a different interface. For instance, we can create a generic REST instrument using the libraries already available for C# and possibly extend it to better support a specific component of the platform if necessary.

For the Release B of the Málaga Platform, multiple TAP plugins have been integrated for automation of different equipment.

2.2.3. Coordination layer

As detailed in deliverable D2.2, devoted to the architecture, the 5GENESIS coordination layer is common to all six platforms in the project; their components have been described in the deliverables D2.2 and D2.3. The implementation of these components will be described in the deliverables D3.X provided in Work Package 3 (WP3). Each platform shall instantiate a number of these components depending on the features supported per platform. In the case of Málaga Platform, the plan is to integrate all the components, including interconnection with the 5GENESIS Athens Platform through the Dispatcher component, which has been developed to serve as the entry point to the platform, abstracting the features of the subjacent components via the Open APIs.

Release A of the components provided by Work Package 3 have already been deployed in the Release B of the Málaga Platform. Components that are part of the coordination layer of the Málaga Platform are summarized in the following table:

Table 6: Coordination Tools

Experiments Coordination	Description
5GENESIS Portal	WP3 Release A implementation. The 5GENESIS Portal is a custom web application developed in Python + Flask that provides an easy to use point of entry for external users, allowing them to run experiments in the different platforms. More information about the 5GENESIS Portal can be seen in Section 4 of Deliverable D3.7.
Experiment Life Cycle Manager	WP3 Release A implementation. The ELCM is a custom application developed in Python that oversees the execution of concurrent experiment in the 5GENESIS platforms, communicating with the layers below so that the actions required by an experiment are correctly coordinated and executed. More information about the ELCM can be seen in Deliverable D3.15.
Results Repository	InfluxDB is the open-source storage engine provided within the InfluxData framework, and handles in particular time series data and is used to store all monitoring events and metrics that are necessary for the generation of the end-reports and KPIs validation.
Analytics	Custom Python scripts are developed to support the statistical analysis requirements for results presentation and KPI validation. The scripts are utilizing the native Influx DB capabilities to support Python. More information can be seen in Deliverable D3.5.

2.2.3.1. Monitoring & Measurements

The monitoring and analytics framework at the coordination layer is common for all platforms; however, the actual probes to get measurements are platform-dependent because they are coupled with the current infrastructure. Málaga Platform will integrate probes in all the relevant points in the E2E path: UE, BBU, transport network, Edge, EPC/5GCore, NFVI, MANO, and, in general, in all the components of the 5GENESIS architecture where radio or IP level information can be retrieved. Some interesting locations to include the probes are the OpenFlow switches and the BBUs, provided that the vendors offer these features. The platform will also integrate the tools identified in the 5GPPP TMV WG, including MONROE nodes and TRIANGLE tools where applicable. All the probes will be automated via TAP so that they can be integrated in the NMS system.

For commercial Android UEs, UMA has developed and integrated a set of Android applications and TAP plugins for control and measurement retrieval for the Release B of the platform. These applications provide information about the usage of resources in the devices, as well as generating iPerf traffic and measuring round trip time using ping.

3. Evolution of the MALAGA Platform

3.1. Phase 2 Instantiation of the 5GENESIS architecture

5GENESIS works towards establishing a 5G Experimentation Facility, spanning over a set of fully interoperable platforms with diverse capabilities, through the proposition of an experimentation reference architecture common among all the member platforms.

Figure 22 below depicts the reference architecture to be implemented in each of the 5GENESIS facilities. Colours in the figure show the Málaga instantiation plan among the three integration cycles of the project.

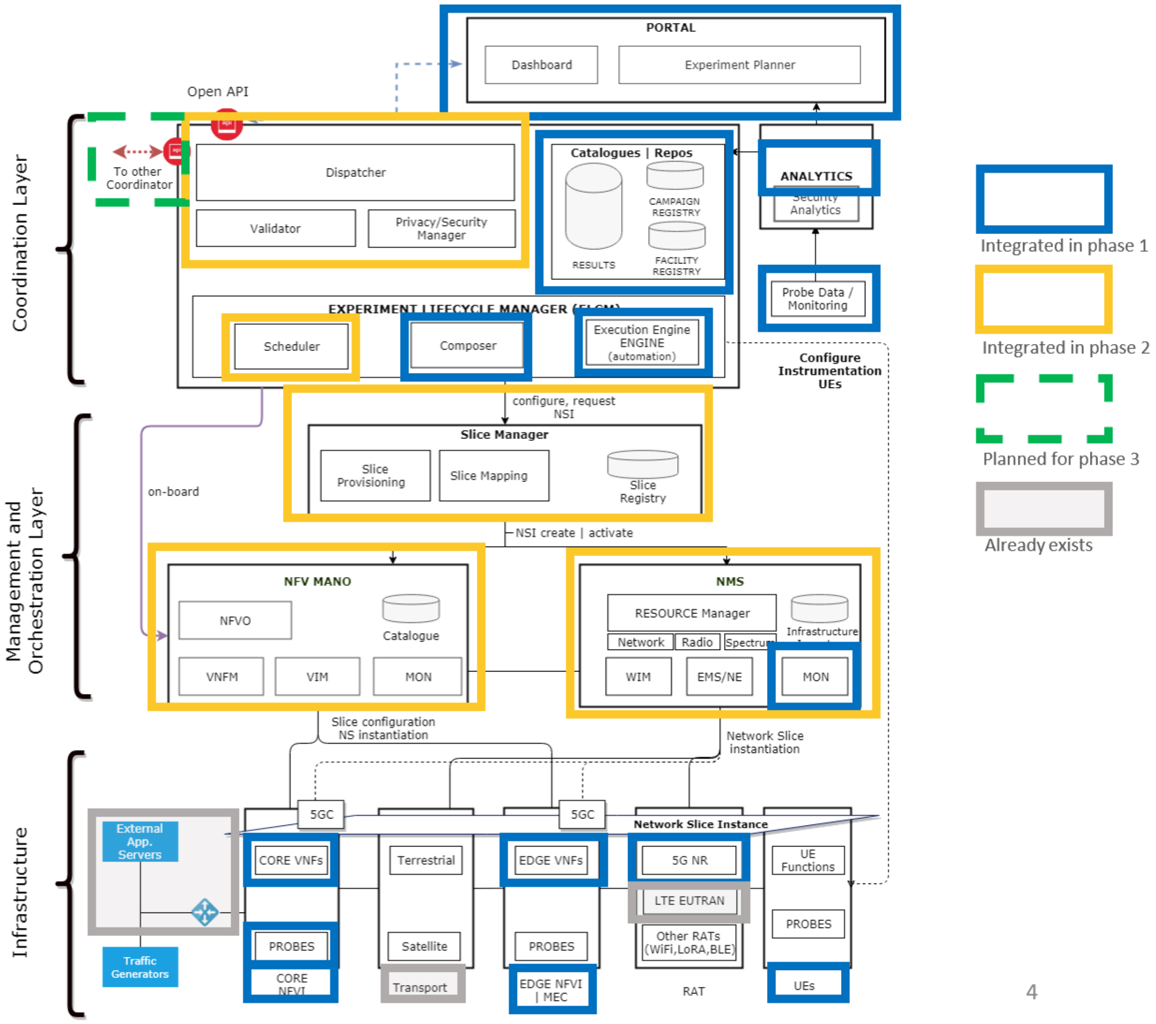

Figure 22: The Málaga Platform Evolution based on 5GENESIS Reference Architecture

Release A of the platform is represented in Figure 22 with blue boxes. It targeted to support the fundamental functionality in the coordination layer (i.e., the required functionality to run experiments with the infrastructure already in place). Thus, this release included an initial development of the portal and the experiment lifecycle management capable of defining experiments and automating their execution, plus a basic capability to monitor the results and present values of KPIs to the experimenter. In terms of infrastructure, release A included an expansion of the available testbeds in UMA with the addition of servers, edge nodes and 5G NR equipment.

The current Release B (yellow boxes) integrates most of the expected components in the final E2E platform. It includes full support for slicing with 5G NR and 5G core thanks to the slice manager integration, full support for automation and KPI computation through the NMS, Management & Orchestration with MANO NFV, as well as previously missing parts of the coordination layer. The following Table 7 and Table 8 detail the setups currently deployed or in the process of being deployed in the Málaga Platform, most of them as result of Release B integrations.

Table 7: Deployed LTE setups detail

Deployment Parameters	LTE Products/Technologies Options		
ID	1.TRIANGLE	2.Indoor LTE	7. Indoor LTE VIM
Description	Legacy TRIANGLE testbed	Indoor E2E 4G setup	Indor E2E 4G setup in VIM
Core Cloud	No	No	Yes - OpenNebula
Edge Cloud	No	No	Yes - OpenNebula
# Edge Locations	1	1	1
Slice Manager	NA	Yes - Katana	Yes - Katana
MANO	NA	OSM v6	OSM v6
NMS	NA	TAP	TAP
Monitoring	NA	Prometheus	Prometheus
3GPP Technology	4G LTE+	4G LTE+	4G LTE+
3GPP Option	NA	NA	NA
Non-3GPP Technology	NA	NA	NA
Core Network	Polaris EPC	ATHONET Rel. 15 vEPC	Polaris EPC
RAN	OAI eNB	Nokia Flexizone picoBTS	Nokia Flexizone Small Cell
UE	COTS UE	COTS UE	COTS UE
Relevant Use Cases	TBD	Use Case 2	Use Case 3

Table 8: Deployed 5G setups detail

Deployment Parameters	5G Products/Technologies Options		
ID	3.Indoor 5G ECM	4.Indoor 5G REL	8. Full E2E 5G
Description	5G setup with ECM OAI solution	5G setup with RunEL solution	Indoor & outdoor E2E 5G (in progress)
Core Cloud	No	No	Yes - OpenStack
Edge Cloud	No	No	Yes - OpenNebula
# Edge Locations	NA	NA	1
Slice Manager	NA	NA	Yes - Katana
MANO	NA	NA	OSM v6
NMS	TAP	TAP	TAP
Monitoring	NA	NA	Prometheus
3GPP Technology	5G	5G	4G LTE+, 5G NSA
3GPP Option	NoS1	NoS1	NA
Non-3GPP Technology	NA	NA	NA
Core Network	No Core	No Core	ATHONET Rel. 15 vEPC
RAN	OAI eNB	RunEL eNB	Nokia Airscale System (indoor and outdoor)
UE	OAI UE	RunEL UE Emulator	COTS UE
Relevant Use Cases	TBD	TBD	Use Cases 1, 2, 3

Release C (green box) will add interconnection with 5GENESIS Athens Platform to run distributed experiments and will also integrate improvements required based on the feedback obtained from experimenters since the second experimentation cycle.

All the three releases will also integrate appropriated extensions to support the three use cases defined with the collaboration of Málaga Police Department and described in deliverables D2.1

and D2.2 to drive the validation of KPIs in the platform. These three use cases are: 1) wireless cameras and video support in UEs for surveillance, 2) Mission Critical Services in the core network, and 3) Mission Critical Services deployed at the edge.

3.2. Phase 1 Accomplishments

The first integration cycle, as of March 2019, was focused on the initial deployment and configuration of the infrastructure that would support and host successive Releases of the platform. Nonetheless, some end-to-end services were already integrated to the platform, and their basic functionality tested against the rest of the components.

Accomplishments in the first integration cycle:

At the coordination layer:

1. First version of the portal.
2. First version of the experiment life cycle manager (ELCM).

At the management and orchestration layer:

3. First implementation of the NVFI with Open Stack.

At the infrastructure layer:

4. New servers and communication equipment to support the main data center.
5. New equipment to create the indoor 5G NR set up with both UE and gNB.
6. Integration of the Athonet core network with the indoor UMA Nokia small cells.
7. Deployment of the Edge Computing infrastructure by TID.
8. Integration of Nemergent adapted UEs to test MCS with LTE.

At the use cases level

9. Deployment of the first version of video for Police, with cameras and video receiving application integrated into the testbed.
10. Deployment of Nemergent MCS service.

The integration process of the first integration cycle was in line with the internal plan detailed in [17] and summarized in Figure 22. Moreover, Release A of the platform already included some of the progress initially planned for release B, namely the creation of the initial NFVI with OpenStack and OSM. However, the finalization of the outdoor deployment at University of Málaga (UMA) and the old city centre, initially foreseen for the first cycle, was decided to be postponed to the second cycle, since such deployment implied a number of risks, including: i) the need to formalize an agreement with an MNO to access the spectrum that should be approved by the national regulator, ii) the availability of 5G spectrum already assigned in Spain to the operators, iii) the availability of commercial equipment, and iv) the publication and evaluation of the public procurement. However, the project organized a number of meetings with the national regulator, Telefonica and major vendors, and there was a clear progress towards the final deployment.

As detailed in the Risk Management section of the DoA [18], the following actions were taken to mitigate this delay:

- The creation of a set up including both 5G UE and 5G gNB with OAI framework (the project only considered the UE, and UMA will use internal budget to expand to the gNB).
- The expansion of the proposed outdoor deployment to integrate also commercial users in the area in order to make additional testing of the 5GENESIS platforms, experimenting also with spectrum slicing with different tenants.
- The addition of a new mmWave oriented radio access network to be purchased by UMA with funding from the Spanish government to reinforce the activities in the Phase 3 of the project.

3.3. Phase 2 Accomplishments

The second integration cycle, as of December 2019, has integrated almost all the necessary components to have an E2E platform. All the expected components in the Coordination and Management & Orchestration layers have been implemented, although they will be upgraded and adapted in the final Release, Release C, attending to the needs of the platform. New integrations have also been made in the infrastructure layer, adding new 5G components and improving functionalities of the already existent elements.

Current accomplishments for Release B are explained in following subsections. A summary of them, as well as the concrete sections of this document where the related components are mentioned, can be seen in Table 9 below.

Table 9: Summary of Málaga Platform Release B accomplishments

Feature	Architecture layer	Description	Section in the document	Status
Radio access – RunEL	Infrastructure layer	RunEL 5G setup installation at Malaga	2.2.1.3.	Completed
Radio access – OAI	Infrastructure layer	OAI 5G noS1 mode development	2.2.1.3.	Completed
Radio access – OAI	Infrastructure layer	OAI 5G UL development	2.2.1.3.	In progress
Radio access – BTS outdoor	Infrastructure layer	5G outdoor deployment with Nokia AirScale	2.2.1.3.	Completed
Core network	Infrastructure layer	Rel. 15 Athonet EPC upgrade	2.2.1.3.	Completed
User equipment	Infrastructure layer	Integration of new UEs for 5G NSA	2.2.1.3.	Completed
Police video Use case	Infrastructure layer	Fiber connection between city centre (police) and UMA	2.1.4	In progress, only backhaul available

Slice Manager	Management & Orchestration	Katana Slice Manager deployment	2.2.2.2.	Completed
MANO and NFV	Management & Orchestration	MANO updated to OSM version 6, NFV at Main Data Center updated to OpenStack Rocky release	2.2.2.1.	Completed
NMS – Android UE	Management & Orchestration	Integration of Android UE probes	2.2.3.1.	Completed
NMS – OAI	Management & Orchestration	TAP plugin for OAI setup 3 automation	2.2.2.4.	Completed
NMS – RunEL	Management & Orchestration	TAP plugin for RunEL setup 4 automation	2.2.2.4.	Completed
NMS – BTS indoor	Management & Orchestration	TAP plugin for Nokia BTS automation	2.2.2.4.	Completed
Experimenter Portal	Coordination	Release A final version integration	2.2.3	Completed
ELCM	Coordination	Release A final version integration	2.2.3	Completed
Portal – Dispatcher – ELCM communication	Coordination	Development of the Dispatcher module for future integration with the Experimenter Portal and ELCM (Release B)	2.2.3	In progress

3.3.1. Infrastructure layer Accomplishment

1. RunEL 5G setup installation at UMA Lab.

   The installation of setup 4, with RunEL 5G equipment, will allow the Málaga Platform to perform tests indoor with a controlled set of hardware. This setup will offer measurements and information that would not be available with commercial equipment. New parameters and measurements will be made available as the setups evolves during the rest of the 5GENESIS project duration.

2. Development of OAI 5G noS1 mode for setup 3.

   In the current release of the platform, OAI has introduced a new mode (noS1) to perform tests with IP traffic over 5GNR physical layer. As the interoperability with the

RunEl gNB is in progress, this mode is currently used for native testing only between the OAI components (gNB and nrUE). In this mode, there is no real connection of the gNB to any core network over the S1 interface and the exchanges, that would normally take place between those two entities during the UE attachment to the network, are bypassed/emulated. Moreover, the noS1 mode uses some of the functionality of the LTE RAN stack (as can be seen in Figure 23) to allow the traffic flow to/from the *NR-PHY layer*. Finally, by performing static pre-configuration for the data plane (i.e., data radio bearer, IP address configuration etc.), IP traffic can be transferred between the gNB and UE entities. This mode has been validated so far with Downlink traffic.

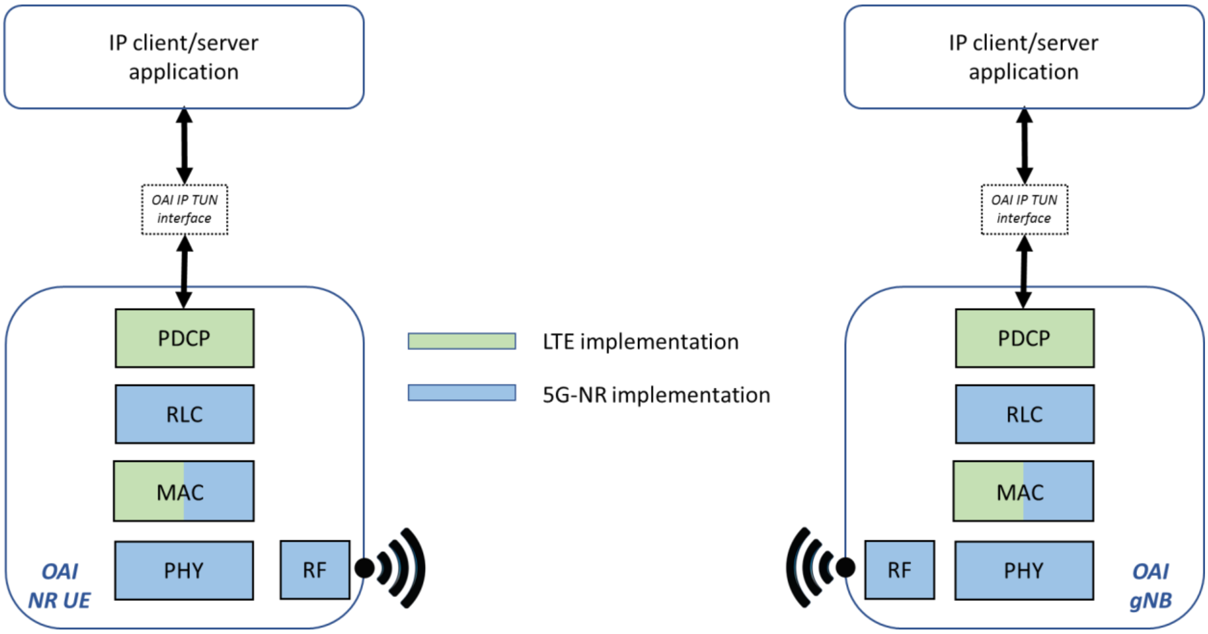

Figure 23: OAI noS1 mode architecture supporting IP traffic flow

3. OAI 5G UL development

   The development of the Uplink procedures (i.e., implementation of NR-PHY uplink channels and procedures, NR-MAC layer extensions and interfacing with NR-PHY) that allows to enable noS1 mode for uplink traffic as well is also complete at the time being. Nevertheless, the UL for the noS1 mode is not fully ready, and some more work is still needed to achieve a proper performance of the link. In its current status for Release B it allows to test connectivity and to make a limited set of experiments. Once this gets enhanced and fully validated, testing with Uplink IP traffic will also be feasible without the current limitations.

4. 5G outdoor deployment with Nokia AirScale System.
5. Rel. 15 Athonet EPC upgrade.
6. Acquisition and integration of 5G NSA compatible UEs.

   The previous achievements 4, 5 and 6, are a huge step forward in the platform development. The integration of a commercial 5G RAN, a 5G NSA compatible EPC and 5G NSA COTS UEs allows us to experiment with a 5G network that is as real as a commercial deployment. Additionally, the outdoor deployment will serve to make very diverse and interesting experiments and demonstrations in the future, as for example 5G drones experimentation.

7. Fiber connection between city centre (police) and UMA Lab.

   This last infrastructure achievement is very important too, because it adds the UMA lab connectivity with the city centre and some police facilities, which is a must to execute some showcases related with the MCS uses cases planned for the Málaga Platform.

3.3.2. Management and Orchestration layer Accomplishment

1. Deployment of Katana Slice Manager.

   The Katana Slice Manager developed by NCSRD has been correctly integrated within the Málaga Platform, and it has been used during the first experimentation phase as part of the Facility and for the obtention of the Slice Creation Time KPI.

2. Update of MANO to OSM version 6 and NFV to OpenStack to Rocky release.

   The new OSM version 6 to which MANO has been updated enhances its features, with, for example, a lighter orchestrator with Network Services and Slicing capabilities, performance/fault/policy management features, or an enhanced GUI with a service composer. It also improves its support for different kinds of VIMs, adding support for OpenNebula among others.

   Regarding the new OpenStack release installed, it also contains new features like high availability, edge/IoT, high-performance computing or serverless, and it improves most of its projects enhancing their capabilities.

3. Integration of Android UE probes in NMS.
4. Development and integration of OAI TAP plugin for setup 3 automation in NMS.
5. Development and integration of RunEL TAP plugin for setup 4 automation in NMS.
6. Development and integration of Nokia BTS TAP plugin for setup 2 and 7 automation in NMS.

   The UE probes and the set of TAP plugins developed will allow the full integration of the different setups in the platform through its automation for experiment execution and measurement reporting. This will make possible for an experimenter to use these setups through the experimenter portal once the setups are connected to the coordination layer.

3.3.3. Coordination layer Accomplishment

1. Integration of Release A final version of Experimenter Portal.
2. Integration of Release A final version of ELCM.

3. Development of Dispatcher module for integration of it with the Experimenter Portal and ELCM in the immediate future.

   The fulfillment of these accomplishments establishes a stable release for the coordination layer components that were missing in the previous platform release. This will make available most of the coordination features this layer is meant to provide.

3.4. Next milestones

The integration plan depicted in Figure 22 shows that the only element left for integration in Release C is the interconnection with other coordinators, meaning in our case the interconnection with the Athens Platform. Nevertheless, the 5G infrastructure of the Málaga Platform will continue evolving and adding functionalities in order to integrate the pending 5G setups outlined in Table 3.

Next milestones for Release C:

- Interconnection with Athens Platform.
- Integration and testing of Uplink support for the RAN developed by RunEL.
- Interoperability testing between RunEL and Eurecom solutions.
- Integration of setups 6,7:
    - Setup 6: 5G NSA lab setup with ECM UE + ECM gNB + ATH EPC Rel 15 NSA
    - Setup 7: Full 5G lab setup with ECM UE + REL gNB + ATH 5G CORE
- Finish integration of setup 8:
    - Setup 8: Full 5G SA setup with indoor and outdoor deployment
- OAI and REL setups complete integration with the platform Coordination and Management and Orchestration layers, allowing the execution of experiments from Portal and expose experiments results.

4. MALAGA USE CASE-SPECIFIC EXTENSIONS

Each 5GENESIS platform focuses on the validation of a subset of 5G KPIs. In particular, as introduced in deliverables D2.1[1], D2.2[2] and D2.3[3], Málaga Platform will focus on measurements on latency, capacity, speed, availability, service creation time and network management CAPEX/OPEX. The setups described in the previous sections are oriented to analyze these KPIs in controlled environments. The three uses cases defined in the Málaga Platform will conduct the validation of relevant 5G KPIs in realistic scenarios, which will involve both the Málaga Police Department and final users.

4.1. Use Cases Target Deployment

4.1.1. Use case 1 – Wireless Video in Large Scale Event

4.1.1.1. Use Case 1 Components and Technology

This use case intends to enhance the functionality of the video security service that Málaga Police Department operates in the city centre. These video cameras are connected to a main control room, providing additional security to the area. 5GENESIS will work on two scenarios to enhance this service.

The first one consists in the deployment of portable cameras with 4G and 5G modems, which will allow to extend and improve the coverage easily for specific events. The second scenario included in this use case consists in the access of the policemen to the real-time video of the cameras while they are on the street and not in the control room. For this matter, the cameras must be able to broadcast the high-quality video in the area, and policemen must have UEs (such as tablets or smartphones) with 4G and 5G connectivity to watch the video of a specific camera.

This use case allows to measure KPIs such as availability, capacity and service creation time through the deployment of new cameras and the broadcasting of real-time video thanks to 5GENESIS technology.

With Release B, this use case will start including interaction with the city centre. Aside from the scenarios developed in the indoor deployment at Ada Byron building, which will be shown and detailed in next subsection, the general topology of the final use case with city centre deployment is being integrated in the platform.

A number of components have been added to the Málaga Platform in order to support this use case:

- **IDIS video cameras.** Fixed IP video cameras for outdoor operation, which include capabilities such as video resolution up to 4k UHD or H.265/H.264/JPEG compression. These cameras are part of the existing Police surveillance system in the city centre, and will be connected to 5GENESIS Málaga Platform. Apart from the city cameras, Málaga Platform indoor deployment includes an IP video camera for operation and measurements in different scenarios.

Figure 24: IDIS video camera

- **IDIS video streaming server**. Specific IDIS equipment is included as the anchor point for the different video cameras in the network. This server will allow to control and configure the IP cameras and serve the corresponding video flow to the clients requesting it, both real-time and recorded, since IDIS software includes recording capabilities. The video server will take part in the management of the portable cameras´ deployment too through IDIS Center software.

Figure 25: IDIS Center management software

- **Portable cameras.** This equipment is mandatory for the development of the first described scenario. In order to be easily deployable on the field, portable cameras must include 4G/5G capabilities to connect to the mobile network. The most straightforward approach is to use 4G/5G smartphones with an app that transmits the video recorded in real-time to the platform.
- **eMBMS service**. To allow broadcast and multicast of the video flow to different clients, the eMBMS must be configured and activated at the EPC. An experiment for the police video use case will include eMBMS to broadcast the video, while other experiment will just provide an individual video flow to every client that requests it, allowing to analyze the difference of using eMBMS.

4.1.1.2. Use Case 1 Topology and Architecture

The target final deployment of Use case 1 is presented in Figure 26. It represents both scenarios previously explained in section 4.1.1.1. , including the deployment of portable cameras and the streaming of the video to UEs, along with the commercial users that will use the network at the same time (but managed by their MNO). Figure 27 shows more detail about the architecture in the UMA Lab for this use case.

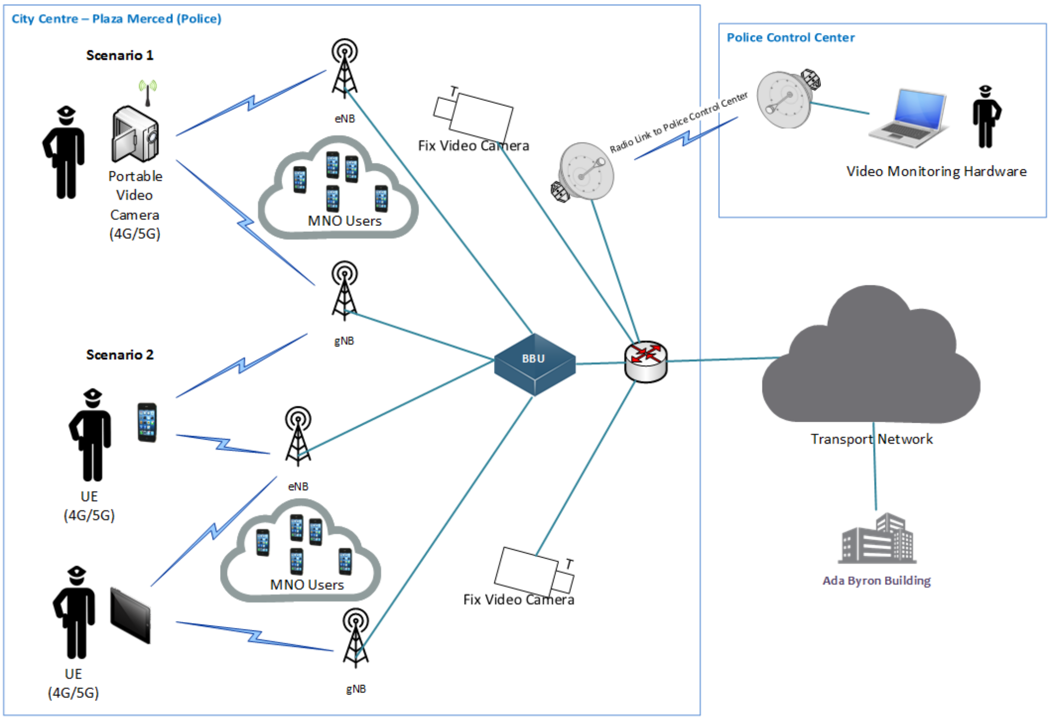

Figure 26: Use case 1 Final Deployment

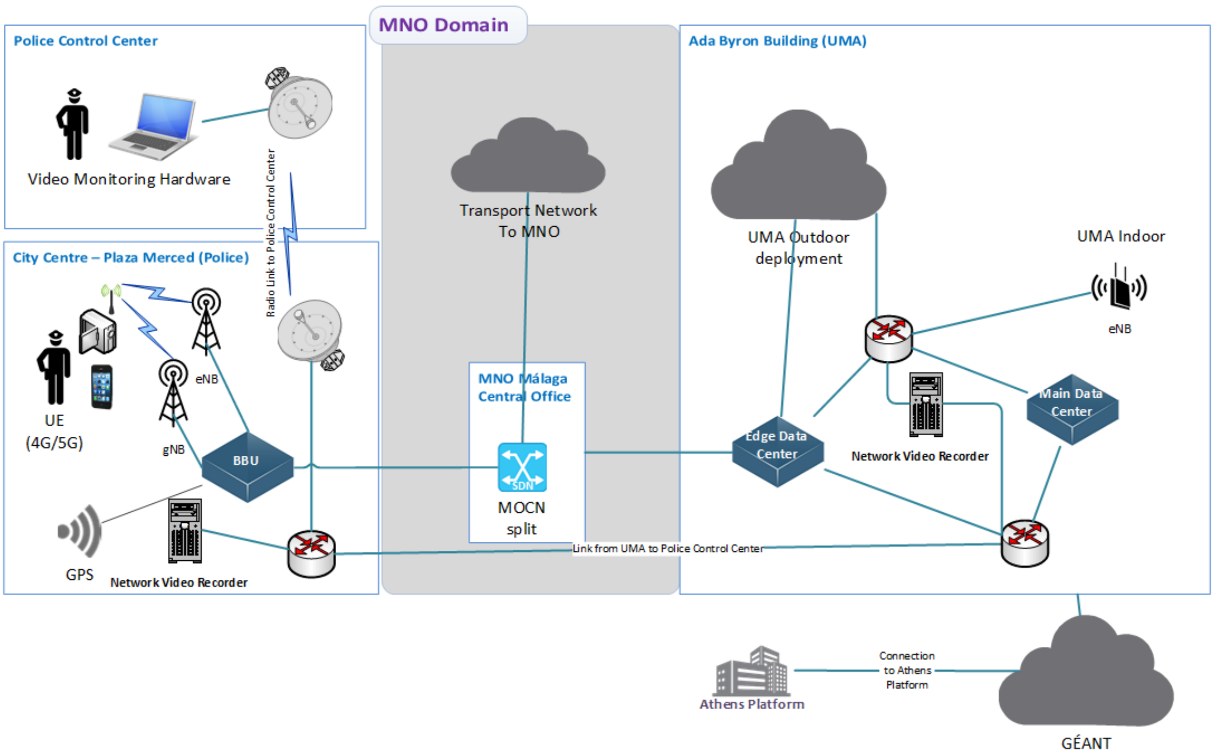

Figure 27: Use Case 1 outdoor experiment setup

The use case will make use of the different setups deployed in the Málaga Platform for testing and measurements. The tests will be performed gradually as the platform setups are ready. This way, for the Release B, the use case will be tested with RunEL setup and also with the outdoor 5G setup. In the final release of the platform, the use case will be executed with the full setup, namely setup 8.

4.1.2. Use Case 2 – Multimedia Mission Critical Services

4.1.2.1. Use Case 2 Components and Technology

This subsection describes the components and technologies to support the MCS for Use Case 2 which, using voice services, instant messaging, video communication and emergency calls, will provide the means to validate some of the Málaga Platform targeted 5G KPIs.

The g components deployed or that will be added in the next cycle to the Málaga Platform to support this use case are described in the following section.

4.1.2.2. Infrastructure components

- **MCS Server:** the MCS Server provides the control and management of voice, video and data communications for both private and group calls. This functionality is divided into Controlling Server(s) and Participating Server(s):
  - The MCS Controlling Server is responsible for:
    - Communication control (e.g. policy enforcement for participation in the MCS group communications) towards all the MCS users of the communication group (i.e. a group of users capable to communicate with the rest of users at once), as well as private communication;
    - Managing floor control entity for a group communication and private communication;
    - Managing media handling entity.
  - The MCS Participating Server is responsible for:
    - Communication control (e.g. authorization for participation in the MCS communications) to its MCS users for group communication and private communication;
    - Relaying the communication control and floor control messages between the MCS client and the MCS server performing the controlling role;
    - Media handling for its MCS users for unicast media;
    - Management of the quality of service (QoS) by interfacing with the network using the 3GPP Rx interface with a Policy and Charging Rules Function (PCRF) or using the 5G equivalent.
- **Identity Management Server (IdMS):** this server is provisioned with the user's MC ID, MCPTT ID and password. The user is also provisioned with its MC ID and credentials. The IdMS authenticates an MCS user by verifying its credentials.
- **Key Management Server (KMS):** this server stores and distributes the security information such as encryption keys for private and group calls to the key management client on the UE, to the group management server and to the MCS servers. It enables integrity and confidentiality of the signaling and media flows. The encryption keys are generated by a separate tool and imported to the KMS.
- **Group Management Server (GMS):** this server is used to perform the management of communication groups. It manages the group call policy information and media policy information to be used by a given UE.
- **Configuration Management Server (CMS):** this server is used to configure the MCS application with non-group management related information and configure data on the

configuration management client. The configuration management server manages MCS configurations (e.g. user profile, UE configuration, functional aliases and service configuration).

- **SIP Core:** it is the entity responsible for registration, service selection and routing in the SIP signaling control plane.
- **HTTP Proxy:** acts as the proxy for all hypertext transactions between the HTTP clients (on the mobile device) and HTTP servers. The HTTP proxy terminates the TLS session with the HTTP client of the MCPTT UE in order to allow the HTTP client to establish a single TLS session for hypertext transactions with multiple HTTP servers.
- **MCS Configuration Server:** it is used by the MCS system administrators for the management of tactical and technical configuration information.
- **IP Networking Services:**
  - STUN Server: it enables MCS clients to discover the IP addresses and ports that must be used for MCS services in case of NAT traversal.
  - DNS Server: it is used by MCS servers to resolve IP addresses of hosts.
  - DHCP Server: it is used to provide IP addresses to the MCS servers.
  - NTP Server: it is used for time synchronization of MCS servers.

4.1.2.3. Client components

- **MCS Client application:** it runs on the mobile device and implements the MCS protocols, the MCS client entities which are communicating with the servers mentioned above, and the graphical user interface.
- **Mobile Devices:**
  - Samsung Galaxy S8 running the MCS Client application.

Figure 28: Samsung Galaxy S8 running the MCS Client Application

  - 5G UEs, as the previously mentioned Xiaomi Mi Mix 3 5G and Samsung S10 5G, will be tested with the MCS Client application.

- The Airbus Tactilon Dabat is a rugged smartphone which supports both broadband and TETRA networks. In the scope of this project, only the broadband functionality will be used. The Airbus Tactilon Dabat runs the Android operating system and mobile applications, such as the MCS client application.

Figure 29: The Airbus Tactilon Dabat Device running the MCS Client Application

4.1.2.4. Use Case 2 Topology and Architecture

The Use case 2 deployment architecture for release B is shown in Figure 30. The figure shows where the components, which are described in Section 4.1.2.1. , are installed. As a first Network Functions Virtualization (NFV) step, the MCS infrastructure components are installed as virtual machines on a hardware server. A virtualization server and a centralized management application are provided in order to run and manage these virtual machines.

In this release, the MCS services will run over both 4G and 5G in order to perform KPIs measurements and comparison between 4G and 5G.

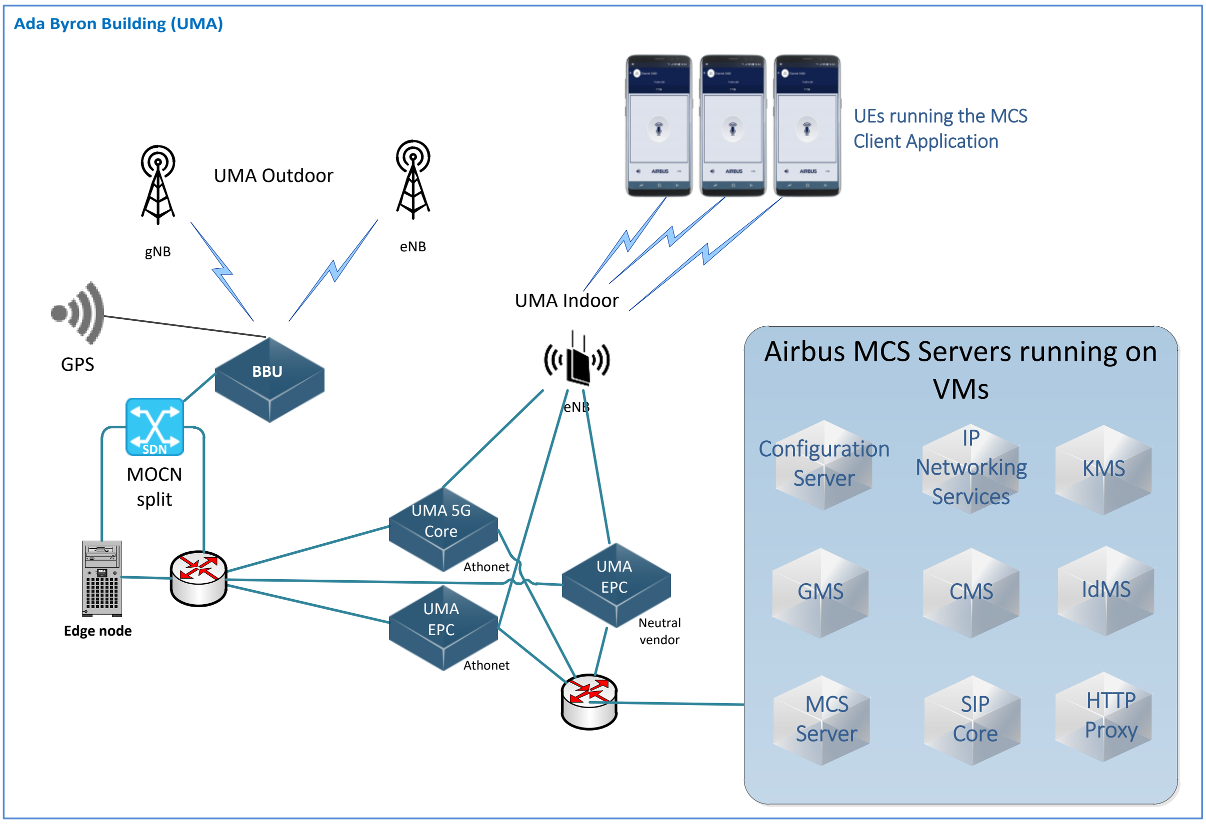

Figure 30: Use Case 2 Deployment for release B

In future Release C of the platform, the Airbus components will be updated to support further experimentations and KPIs validation. In the final Release C, it is planned that the Airbus devices will be deployed also on the UMA outdoor and Málaga city centre networks. Figure 31 shows the expected final deployment.

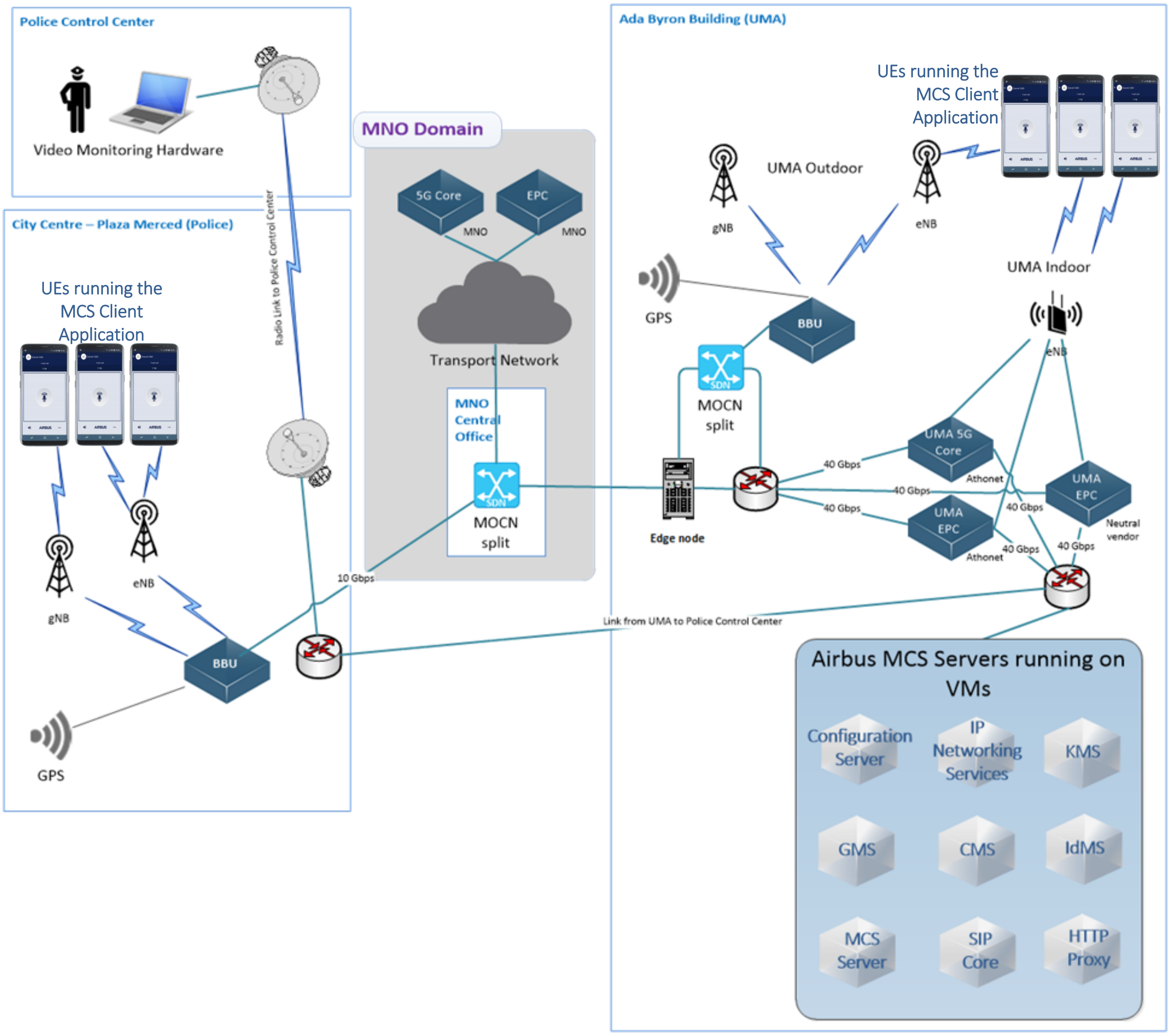

Figure 31: Target Use Case 2 Deployment for the Final Release

4.1.3. Use case 3 – Edge-based Mission critical services

4.1.3.1. Use Case 3 Components and Technology

In the Use case 3, Nemergent provides its technology to run standardized mission critical services, both behind the core network or having an Edge infrastructure in place. The provided and integrated products can be divided in two main sides: the server-side and the client-side.

4.1.3.2. Server-side

The Nemergent MCS server-side provides the application-level components required to deploy the full 3GPP Rel13 Mission Critical Push-To-Talk (MCPTT) service, together with a selection of the main features in the 3GPP Rel14 Mission Critical Video (MCVideo) and Mission Critical Data (MCData) services. The main standardized mission critical architecture and components were first described in 3GPP Rel13 MCPTT definition and later inherited in following releases. This architecture comprises MCPTT/MCS application servers (ASs) –both controlling and participating - and MCPTT/MCS UEs deployed over a MCPTT-compliant SIP Core (e.g. IMS core) and a professional LTE access network that supports QoS-enabled unicast connectivity with PCC and native multicast support with eMBMS.

To cope with these requirements, the Nemergent solution mainly focuses on the IMS/SIP signaling plane and the user data plane between the MCS AS, and in the anchors from the MCPTT/MCS AS to the underlying networks through the Rx and MB2-C/MB2-U interfaces. Other basic nodes and interfaces, such as MCPTT/MCS configuration and management servers, are also included in the solution, namely the Identity, Group and Configuration management servers. Even though the Nemergent solutions could work as a simple E2E OTT solution (without network coupling interfaces), the Málaga Platform would support Public Safety requirements such as QoS, multicast, etc.

The server-side of Nemergent's mission critical solution also includes mechanisms more related to administration and management and all the underlying procedures to support this management appropriately. Being more precise, the solution also includes the 3GPP Rel13 and Rel14 MCS specifications for user registration, authorization, affiliation, location configuration provisioning and location reporting.

These features enable that authorized MCS users (e.g., system administrator, dispatcher…) can manage the system configuration. To this end, the solution also includes an OAM interface intended to provide easy OAM and configuration/troubleshooting operations and being capable of managing MCS users and groups creation, deletion, modification and configuration (implements the CSC interfaces according to 3GPP Rel13 and Rel14, and private OAM interfaces for provision the IMS system).

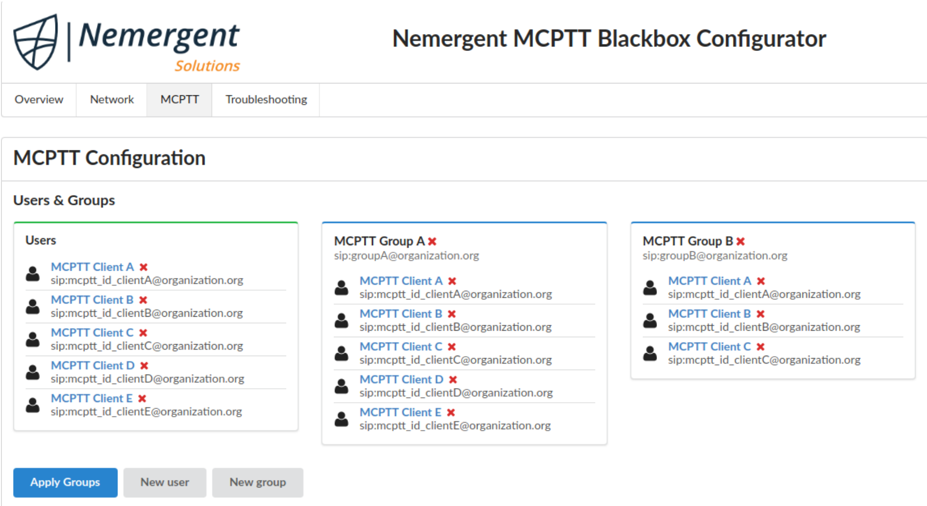

Figure 32: Simplified Users and Groups Management OAM GUI

The Nemergent MCS system is deployed as a series of server components, each of them fulfilling a different functional role. All the server components may be deployed as standalone services in the host system, as an all-in-one Virtual Machine or a VNF (desired setup in Málaga Platform).

The following figure contains the explained components and the target interfaces to be integrated with the LTE or 5G (the final way to interconnect still needs to be standardized) side to be considered standardized mission critical services, highlighting in orange the modules provided by Nemergent in this Use case 3.

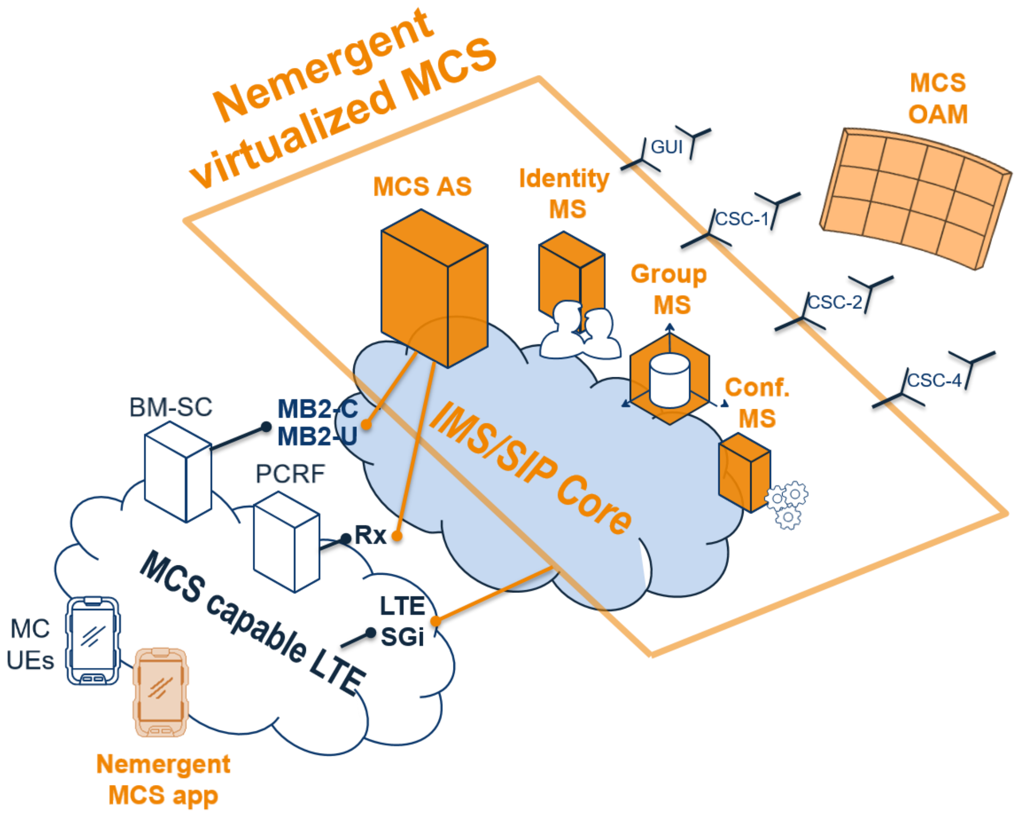

Figure 33: MCPTT/MCS Basic Components and Integration Interface

4.1.3.3. Client-side

The Nemergent MCS client-side is divided by two main components: the selected UE (HW) and the MCS client App running on it (SW).

Taking into account the specific needs of Use case 3 in Málaga Platform, Sonim XP8 [6] devices were provided in release A. This UE version is tough and endurable in its form and fully supports the required frequency bands, QCIs and eMBMS in order to be 3GPP compliant. Release B has been responsible for adding new 5G NSA/SA UEs where the same MCS client will be run, so that 4G and 5G UEs communicate with each other using the same Nemergent MCS client SW.

As for the MCS client, Nemergent introduces all the functionalities with 4 different components. Thus, a whole MCS Client System consists of a GUI, an SDK and two service plugins.

- MCS SDK: Main component of the client-side that carries the majority of the workload and abstracts the logic for the upper and below components through its northbound and southbound interfaces.
- MCS GUI: It is the GUI whereby the user could use the preselected client and all the functionalities offered by the App (enabled by the supporting SDK and plugin layers).

[6] https://sonimtech.com/xp8/

- **Provisioning Tool App**: It allows the user to select one of the pre-loaded client's profiles. Moreover, the user is able to edit the proxy of the IMS core address and port so as to reach the MCPTT/MCS Servers.
- **eMBMS middleware:** It makes possible the communication and synchronization between the eMBMS API of the UE and the MCS SDK.

In order to better understand the relation between the abovementioned components, the following figure represents the relation between them and the existing communication interfaces.

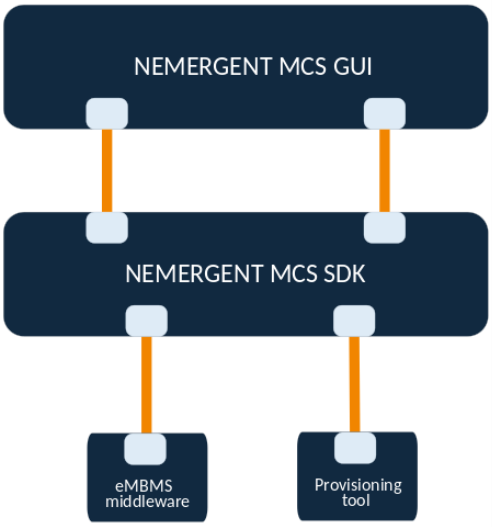

Figure 34: MCS Client Building Blocks

Due to the full support of 3GPP standardized QCIs and eMBMS in all HW and SW components, the MCS system can both: a) Establish the DIAMETER connection (Rx interface) to the PCRF to handle QoS in default and dedicated bearers; b) Establish the DIAMETER connection to the BMSC. If the eMBMS´s request is properly handled by the LTE network, the eMBMS LTE bearer will be created for the media plane of each new MCPTT group call received.

4.1.3.4. Use case 3 Topology and Architecture

The Use case 3 topology and architecture has evolved throughout the different releases. While the last objective is the full 5G integration and orchestration of the services outdoor in real-world scenarios where the first responders most require the involvement of new public safety technology, the release A focused on the integration of Nemergent's MCS server-side, the Athonet's EPC, the Nokia's small cell and the Nemergent's MCS client-side indoor in the Ada Byron building. Release B is responsible for introducing new 5G components and evolving the NSA mode of the platform while the Use Case 3 functionalities are tested and validated.

The following figure represents the portion of the indoor deployment in release A for Use case 3.

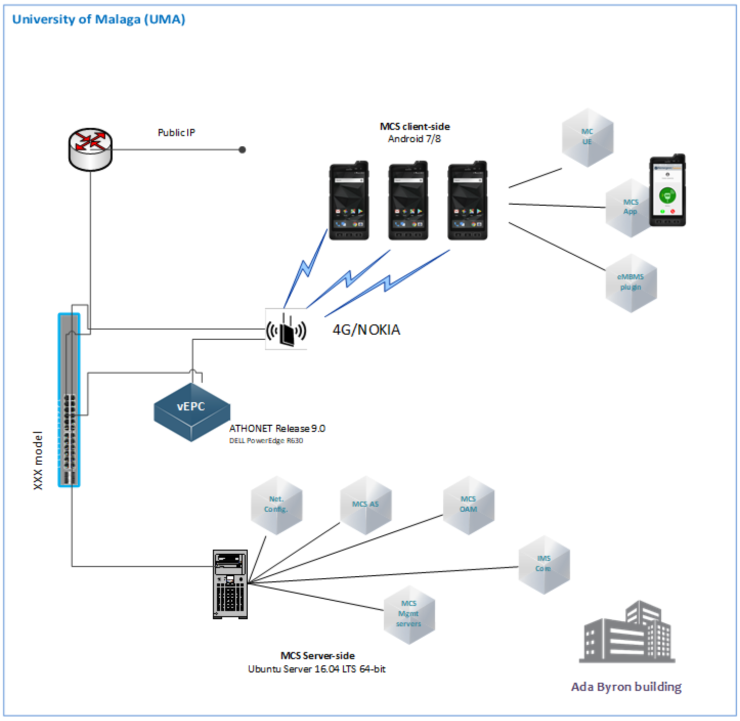

Figure 35: Release A - Use Case 3 Indoor Deployment

The idea of the Use Case is to evolve to outdoor deployment little by little by integrating with the available 5G equipment. Besides, the MCS service will be deployed behind the Edge server in order to ensure high bandwidth to MCS with high demand such as MCVideo. The final Use Case 3 setup is expected to look as the following integrated figure:

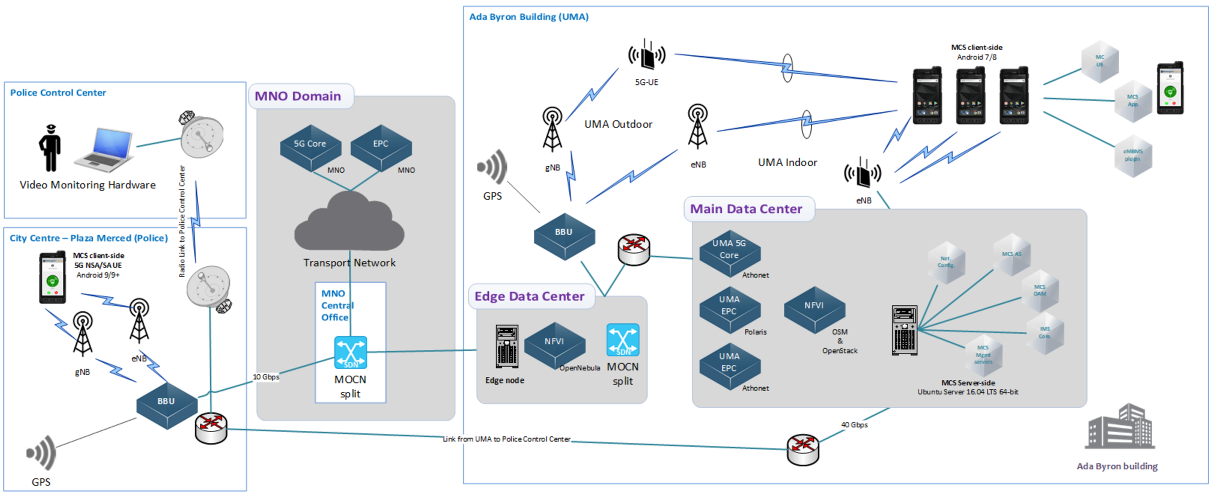

Figure 36: Advanced Use Case 3 Deployment

4.2. Use Cases Phase 1 Accomplishments

During the platform first integration cycle some achievements regarding use case preparation were accomplished. The installation of most part of the necessary equipment at the UMA laboratory was performed during phase 1, as well as initial configuration and testing to check proper configuration of all the equipment and services installed. Some experiments and measurements were also carried out after the first integration cycle.

Phase 1 achievements include:

- Use Case 1. Installation and setup of IDIS video camera and control software at UMA lab.
- Use Case 1. Installation and setup of IDIS mobile apps to receive video from fix camera and stream video from smartphone.
- Use Case 1. First experiments and measurements for Use Case 1, as described in D6.1.
- Use Case 2. Initial trials for ADS MCS service setup and configuration.
- Use Case 3. Setup of mini PC with NEM MCS server at UMA lab and initial configuration.
- Use Case 3. Setup and configuration of NEM MCS apps at UEs for NEM MCS service testing.
- Use Case 3. Initial testing to correct and confirm NEM MCS service configuration and networking.
- Use Case 3. Integration of NEM MCS server as VNF in Main Data Center, in substitution of mini PC.
- Use Case 3. First experiments and measurements for Use Case 3, as described in D6.1.

4.3. Use Cases Phase 2 Accomplishments

In the current status of the platform, new milestones have been reached regarding the different use cases. The work performed during the second integration cycle has been related to the installation and final configuration of equipment that presented some problems in phase 1, and also to the perfection and update of the different setups to set them closer to the final status outlined for each use case.

The new achievements accomplished during phase 2 include:

- Use Case 1. Installation and setup of IDIS NVR to mirror police's city centre setup accordingly.
- Use Case 2. Installation and setup of ADS MCS server and MCS router at UMA lab (Main Data Center).
- Use Case 2. Setup and configuration of ADS MCS apps at UEs for ADS MCS service testing.
- Use Case 2. New trials and testing to correct and confirm ADS MCS service configuration and networking.
- Use Case 3. NEM MCS server as VNF deployed at Edge Data Center in substitution of VNF at Main Data Center.

4.4. Use Cases Next Milestones

The Málaga Platform use cases require some necessary steps in the next integration cycle in order to complete their development and integration, which affect to integration and upgrade of the specific extension hardware and software previously detailed, as well as to the test of the use cases themselves.

The next milestones that will be fulfilled during phase 3 are:

- Use Case 1. Complete setup and connection between UMA lab and Málaga Police Emergency Centre.
- Use Case 1. Addition of portable cameras to setup.
- Use Cases 2 & 3. Adaptation and testing of MCS solutions to 5G UEs.
- Use Cases 2 & 3. Development and testing of interoperability among both ADS and NEM MCS solutions.
- Use Cases 1, 2 & 3. TAP plugin for automation of all use cases specific components.
- Use Cases 1, 2 & 3. Launch of use cases experiments using full platform from experimentation portal.
- Use Cases 1, 2 & 3. Test use cases with outdoor 4G/5G deployment at city centre as part of MCS showcases to demonstrate the platform potential for MCS.

5. CONCLUSIONS

This document presented the second release and the work done towards the final installment of the 5GENESIS Málaga Platform. During this second integration cycle, there was a lot of effort in the development and integration of the Coordination and Management and Orchestration layers. The work performed in that regard included the integration of the NFV MANO, NMS, Slice manager, and, at the Coordination layer, the Dispatcher or ELCM Scheduler, among other elements. In addition, the platform has enhanced its infrastructure layer upgrading already installed components and integrating new ones to complete the set of equipment needed according to the full architecture pictured initially. An example of the latter is the installation of the outdoor deployment both in the Ada Byron building and in the city centre, which includes 5G radio; examples of upgraded components includes the upgrade to Rel. 15 for Athonet EPC and developments in the OAI and RunEL 5G solutions.

In a similar way as in the first cycle, the following months will be dedicated to test the new integrations extensively, in order to check the proper configuration and performance of the platform in its current status. The next cycle, which is the last one, will target the pending developments and integrations needed for the platform to be fully complete. Those pending integrations include mainly the new 5G NSA and SA setups to finally obtain KPIs over an E2E 5G network, and the interconnection of the Málaga Platform with the Athens Platform.

This release of the platform will be used for the second round of experiments until March 2020, and the report on the KPIs will be available in deliverable D6.2 in March 2020. This document will be followed by the Deliverable describing the Release C of the platform in September 2020.

REFERENCES

[1] 5GENESIS Consortium, “Deliverable D2.1 Requirements of the Facility”, 2018. [Online]. Available: https://5genesis.eu/wp-content/uploads/2018/11/5GENESIS_D2.1_v1.0.pdf.

[2] 5GENESIS Consortium, “Deliverable D2.2 Overall Facility Design and Specifications”, 2018. [Online]. Available: https://5genesis.eu/wp-content/uploads/2018/12/5GENESIS_D2.2_v1.0.pdf.

[3] 5GENESIS Consortium, “Deliverable D2.3 Initial planning of tests and experimentation”, 2018. [Online]. Available: https://5genesis.eu/wp-content/uploads/2018/12/5GENESIS_D2.2_v1.0.pdf.

[4] 5GENESIS Consortium, "D3.1 Management and orchestration (Release A)," [Online]. Available: https://5genesis.eu/wp-content/uploads/2019/10/5GENESIS_D3.1_v1.0.pdf.

[5] 5GENESIS Consortium, "D3.3 Slice management WP3 (Release A)," [Online]. Available: https://5genesis.eu/wp-content/uploads/2019/10/5GENESIS_D3.3_v1.0.pdf.

[6] 5GENESIS Consortium, "D3.5 Monitoring and WP3 analytics (Release A)," [Online]. Available: https://5genesis.eu/wp-content/uploads/2019/10/5GENESIS_D3.5_v1.0.pdf.

[7] 5GENESIS Consortium, "D3.9 5G Core Network WP3 Functions (Release A)," [Online]. Available: https://5genesis.eu/wp-content/uploads/2019/10/5GENESIS_D3.9_v1.0.pdf.

[8] 5GENESIS Consortium, "D3.11 Access Components and User Equipment," [Online]. Available: https://5genesis.eu/wp-content/uploads/2019/10/5GENESIS_D3.11_v1.0.pdf.

[9] 5GENESIS Consortium, “Deliverable D4.4 The Málaga Platform (Release A)”, 2019 [Private]

[10] 5GENESIS Consortium, “Deliverable D5.1 System-level tests and verification (Release A)”, 2018 [Private]

[11] 5GENESIS Consortium, “Deliverable D6.1 Trials and experimentation – cycle 1”, 2019. [Online]. Available: http://5genesis.eu/wp-content/uploads/2019/12/5GENESIS_D6.1_v2.00.pdf

[12] 3GPP, “TS 36.101 Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) radio transmission and reception”

[13] 3GPP, “TS 36.104 Evolved Universal Terrestrial Radio Access (E-UTRA); Base Station (BS) radio transmission and reception”

[14] Florian Kaltenberger, Guy de Souza, Raymond Knopp, Hongzhi Wang, “The OpenAirInterface 5G New Radio Implementation: Current Status and Roadmap”, [Online] http://www.eurecom.fr/publication/5822

[15] Triangle Consortium “Deliverable D3.5 Implementation Report on the testing framework final release"

[16] A. Díaz, B. garcía, P. Merino, “An End-to-End Automation Framework for Mobile Networks Testbeds”, Mobile Information Systems

[17] 5GENESIS Consortium, “Description of action, Table 11: Initial Plan for 5GENESIS integration cycles”, pp. 43-44

[18] 5GENESIS Consortium, “Description of action, Table 21: Technological Risk Assessment”, pp.74-75

6. Appendix 1: MALAGA Platform Components and Architecture Details

6.1. Main Data Center

Table 10: Main Data Center servers

Name	CPU	RAM	Networking	Disk	Usage
Master	Single socket 6 physical cores	8 GB	1x10 Gbps (plus 1Gbps for administration, or IPMI)	512 Gb SSD 4 Tb (RAID0)	NFVO (OSM)
Controller	Dual socket 24 physical cores each	64 GB	2x 1 Gbps 2x 10 Gbps (plus 1 Gbps or IPMI)	500 Gb SSD 4 Tb (RAID0)	OpenStack controller
Compute	Dual socket 24 physical cores each	64 GB	2x 1 Gbps 2x 10 Gbps (plus 1 Gbps or IPMI)	500Gb SSD (RAID0)	OpenStack compute
Storage	Single socket 6 physical cores	32 GB	2 x 10 Gbps (plus 1 Gbps or IPMI)	500 Gb SSD (OS, RAID0) 24 Tb (6x4Tb, Ceph replication)	Openstack Storage

The Main Data Center infrastructure, by design, must be reachable by the core network and the radio elements, as well as by the end-users to support low-latency services on the edge of the operator's domain. The following diagram shows the networks that will be used in the NFV deployment and their relation to the other elements of the platform:

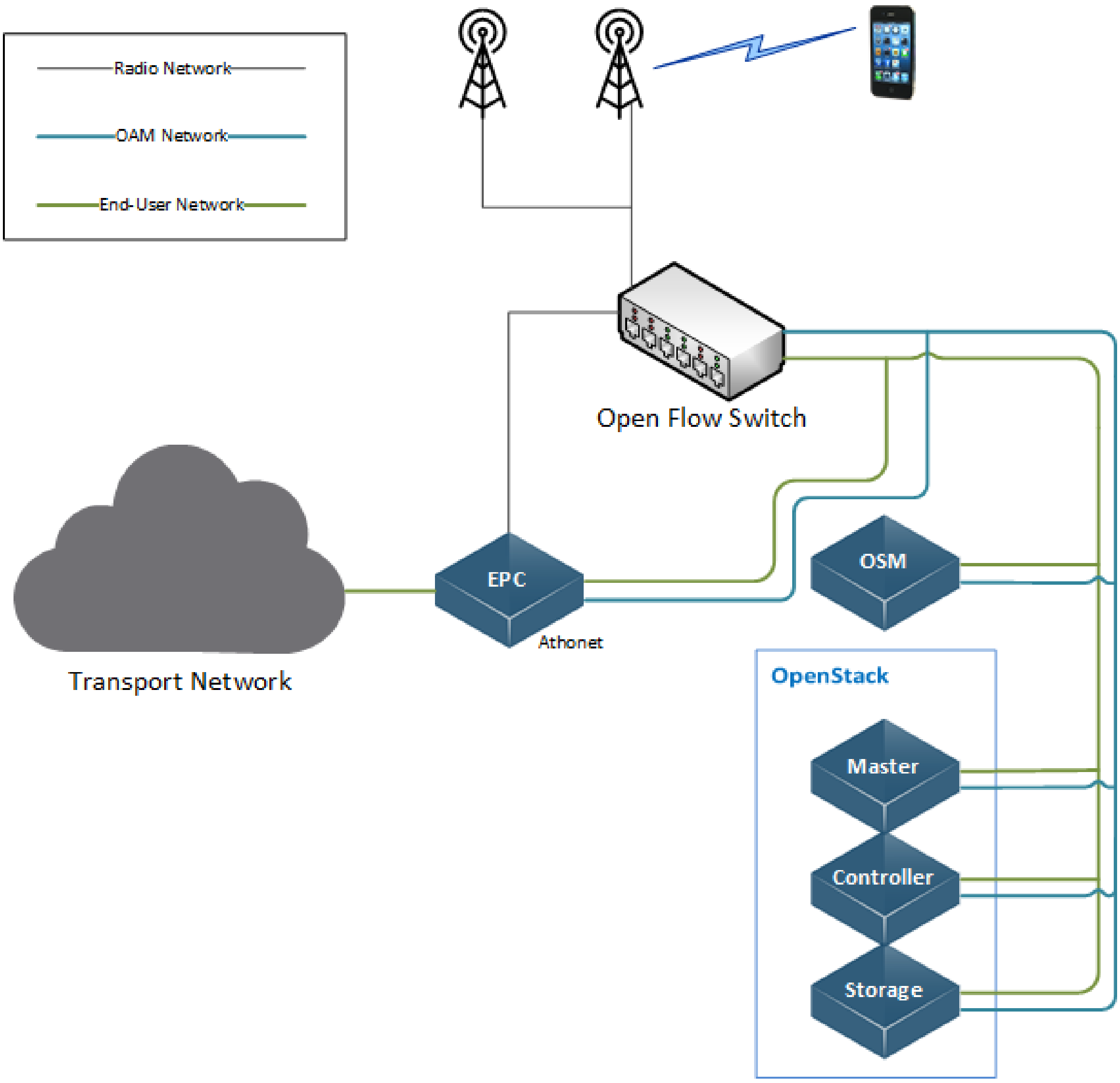

Figure 37: NFVI Deployment

6.2. Edge Data Center

Edge Data center includes the following components:

- **Computation Layer**: It comprises the following elements: 2x OCP server nodes with 2x Intel 6126 CPUs (12 Cores, 24 threads), Memory 128GB RAM, 500GB NMVe SSD and 2x 40Gb Mellanox NICs, 1x 1Gb management NIC, 1x console port.

- **Switching Layer:** This layer switches are based on the Broadcom BCM56870 Trident 3 chipset with 3.2 Tbps capacity and 48 QSFP + ports of 40Gbps each. There are 2 types of switches:
    - Leaf 1: D2060 Redstone XP, 48x10GbE ports, 6x40GbE ports.
    - Leaf 2, Spine: D4040 Smallstone XP, 32x40GbE ports.

  The switching fabric is comprised of 2 leaf and 1 spine switches.

- **GPON Optical Access Layer**: The unbundled OLT Ruby S1010 vOLT is used with 48 GPON ports of 2.5 Gbps and 6 QSFP ports of 40 Gbps. It uses the SoC (System-on-a-Chip) PAS5211 of MicroSemi. As such, it implements GPON media access control functions, OMCI GPON protocol management, IEEE 802.1ad VLANs, access control to the Ethernet medium.
- **Management switch**: Pebble D1050 switch will be used for management, it contains 48x1GbE ports and 4x10GbE ports.

Edge node has two physical networks cabled. The “Management Network” is a private IPv4 flat network that connects all elements through a management switch. This network carries only management traffic for OAM of the infrastructure. The following picture shows how all physical elements are connected:

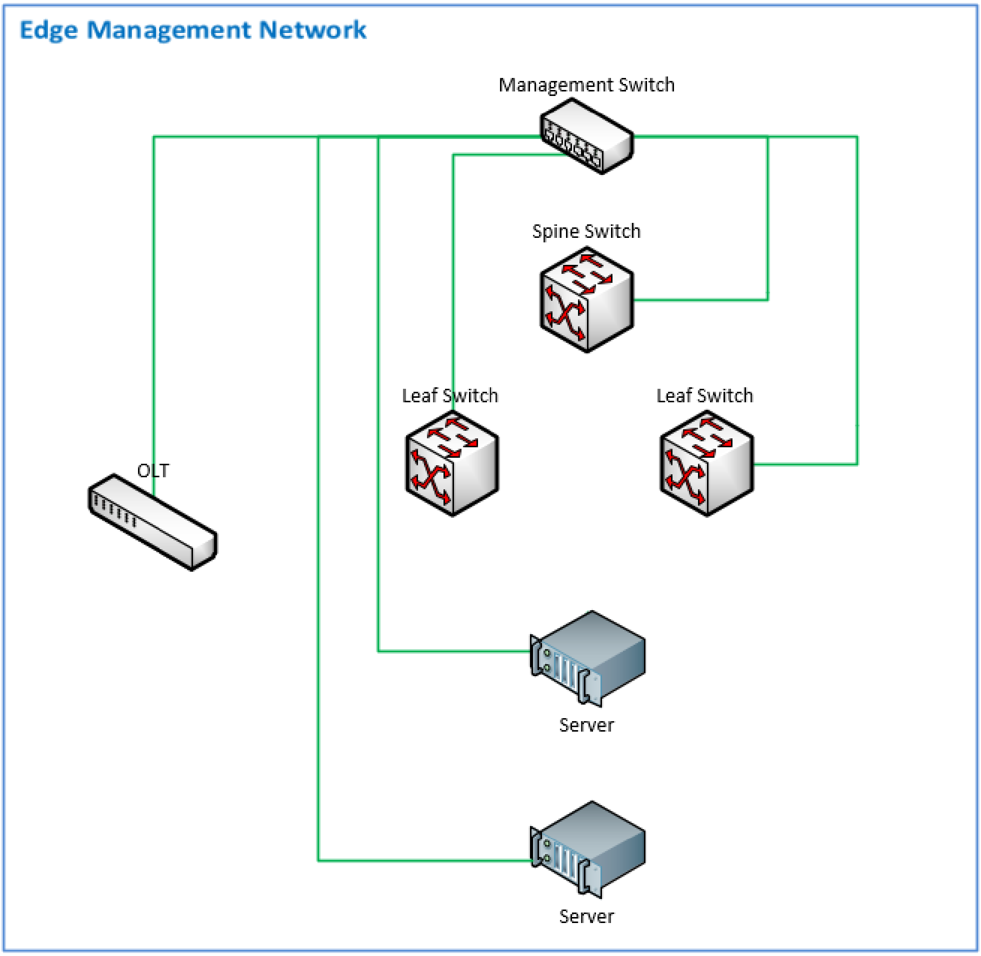

Figure 38: Edge Management Network

The second network is the called “Service Network”. This network supports both IPv4 and IPv6 traffic and carries out both the Control plane (Signaling) and Data Plane (user´s traffic). The service network is controlled by an SDN Controller, and it is connected as displayed in the following picture:

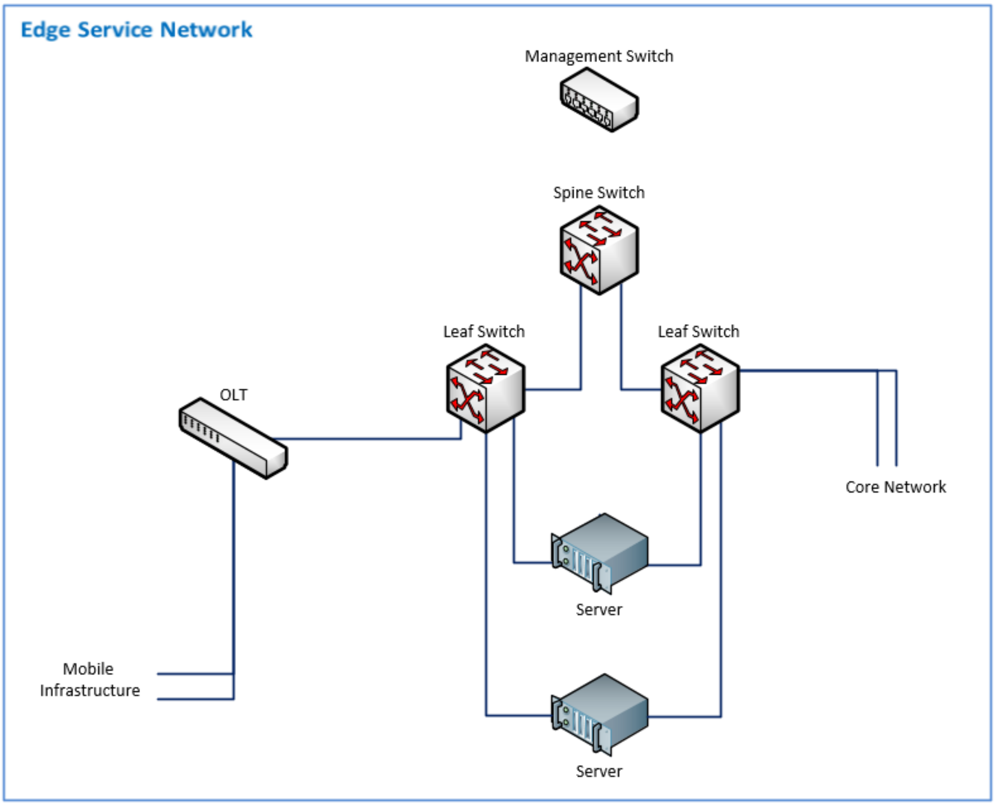

Figure 39: Edge Service Network

The distribution of the new components at the physical level is shown in the following picture:

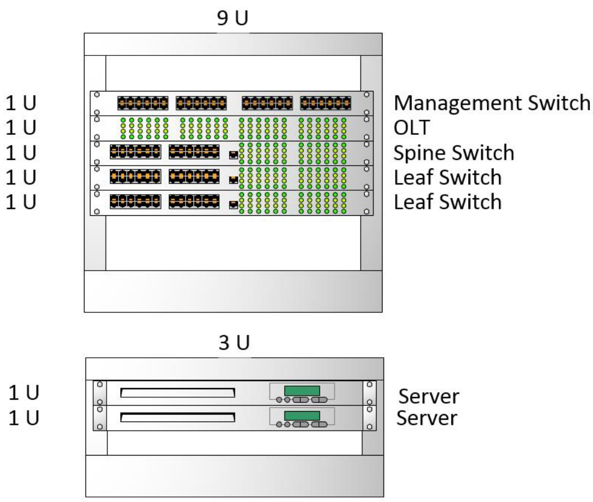

Figure 40: Edge Infrastructure Physical Layout

6.3. Mobile Core Network

6.3.1. Athonet Mobile Core

Being a commercial solution, Athonet's EPC can be connected to commercial OSS/BSS systems, which enforces regulatory obligations and billing by means of standard interfaces, i.e., X1, X2 and X3 for lawful intercept and Bx and Gy for charging.

In addition, Athonet mobile core is compliant with the 3GPP Release 13 MCPTT core network, as it includes the eMBMS system and supports QCI values for public safety MCPTT, i.e. 65, 66, 69 and 70.

Athonet has implemented a web-based Element Management System (EMS) that caters for performance, configuration and fault management. The EMS includes the following main features:

- System configuration for networking and 3GPP elements.
- User subscriber management and QoS profile assignment/management.
- Automated installation and insertion of license key.
- System configuration backup.
- Detailed user activity.
- Individual users monitoring and global system usage; historical data and statistics are also provided, based on different time granularity (daily/weekly/monthly/yearly).
- Secure access to the GUI via dual-authentication method based on TLS 1.2.
- Access and activity logging.

The following integration points are available for controlling the EPC using 3rd party management systems through the following integration items:

- SNMP for KPI and performance monitoring.
- SNMP traps for alarm indication.
- RESTful API is used for user provisioning and profile assignment in the HSS and other functions such as user enablement, examining users' CDRs (UL and DL traffic), enabling users for a certain traffic or time quota; the API is continuously evolving following customer requests and new functionalities are expected to be introduced.

6.3.2. Polaris LTE NetEPC

The solution deployed at the Edge as Mobile Core, Polaris NetEPC, provides some interesting features, including:

- Both control plane and user plane capabilities required to build an LTE network.
- Distributed scalable and cost effective architecture to meet requirements of different LTE networks.
- 3GPP Release 15 specifications alignment and clearly defined road map for later 3GPP releases.
- Availability on various carrier-grade platforms.

- Voice over LTE using IMS.

6.4. Indoor Radio Access Network

6.4.1. OpenAirInterface 5G

The OAI software is freely distributed by the OpenAirInterface Software Aliance (OSA) and it can be deployed using standard Linux-based computing equipment (Intel x86 PC architecture) and standard RF equipment (e.g., National Instruments/Ettus USRP). In this context, OAI offers a flexible framework for experimentation with prototype 4G/5G implementations of the UE and base station components.

The hardware platform, provided by EURECOM, is going to use the ETTUS N300 boards together with a powerful Laptop with a Core i7-7900 8 core processor. We will use a special adaptor to be able to connect the Thunderbolt 3 interface of the laptop with the 2x10Gbit Ethernet interface of the USRP. An additional RF frontend and antenna will provide enough output power and amplification to operate in an outdoor environment. A picture of this UE platform is given in Figure 41.

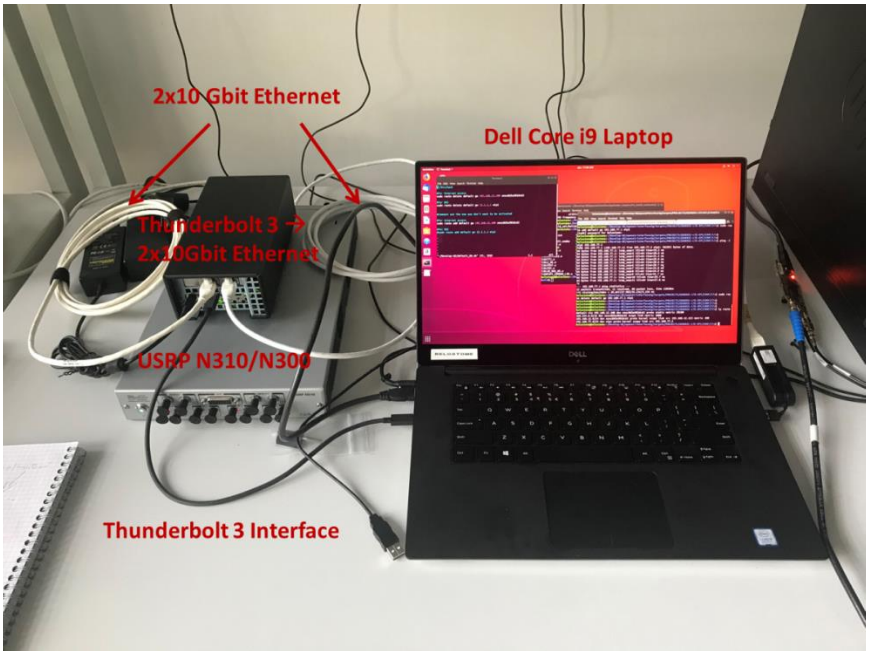

Figure 41: 5G-NR UE Platform running OpenAirInterface

Given the fact that the UE is a simple software program, it can easily be launched and accessed remotely through a *ssh* interface (provided that the laptop is connected to the Internet through an additional connection). In addition, performance measurements with tools like *iperf* or *ping* can be easily carried out locally or remotely.

Since neither commercial gNB nor UE were available for 5G NR at the beginning of the current release, in addition to the equipment provided by Eurecom, two USRP N310 are being used as part of the platform to test new developments and for integration purposes, running the most recent 5G branch of OAI software. OAI also recommends this SDR equipment for 5G NR, and thus it aligns perfectly with the Málaga Platform initially considered scenarios.

Figure 42: USRP N310

This SDR equipment needs an associated computer in order to take care of computation and, additionally, execute the corresponding OAI software for 5G NR initial deployment. This computer needs a capable enough CPU and high-speed network connections at 10 Gbps to exchange data with the USRPs.

The OAI 5G part of the deployment in this phase (setup 3) is composed by SDR cards running OAI software from Eurecom to provide a programmable 5G environment, which will also be used for the rest of the project in its evolved form. The SDR cards initially used are USRP N310, which are based on Xilinx Zynq-7100 System on Chip, and support bandwidth up to 100 MHz, frequency range from 10 MHz to 6 GHz, and 2x2 MIMO. Málaga Platform includes initially 2 USRP N310, one as 5G UE and other as gNB, to deploy its indoor 5G setup. This setup also includes two (one for each USRPs) HP Z6G4 Workstations, configured with Intel Xeon 6154, 3 GHz with 18 cores, and a dual port 10 Gbps Ethernet card for networking. Both USRP N310 are connected to the corresponding PCs with Cat6a Ethernet cable (and needed SFP+ to RJ-45 adaptors, since USRP N310 has SFP+ ports for data communication to the PC) for a proper 10 Gbps connection. Additionally, ECM provided an OAI platform based on USRP N300 SDR and a laptop, as previously described. The specific components for this UE platform are listed in Table 11.

Table 11: Part Items of 5G-NR UE Platform

Part Item	Vendor
USRP N300	National Instruments
Laptop with Intel Core i7-9700K or Core i9-9900K (8 cores) and Thunderbolt 3	Schenker, Dell, etc
Tunderbolt3 (2x) 10Gbit Ethernet convertor	Sonnettech Twin 10G or Solo 10G
3.5GHz RF frontend (PA/LNA/Switch)	Eurecom
3.5GHz Antenna	Lanbowan ANT3500D20W

An example setup, shown below in Figure 43, includes a fixed video camera and a streaming server as additional components to the previously mentioned setup 3 (indoor OAI components without EPC). Those components will allow to do initial testing with video traffic.

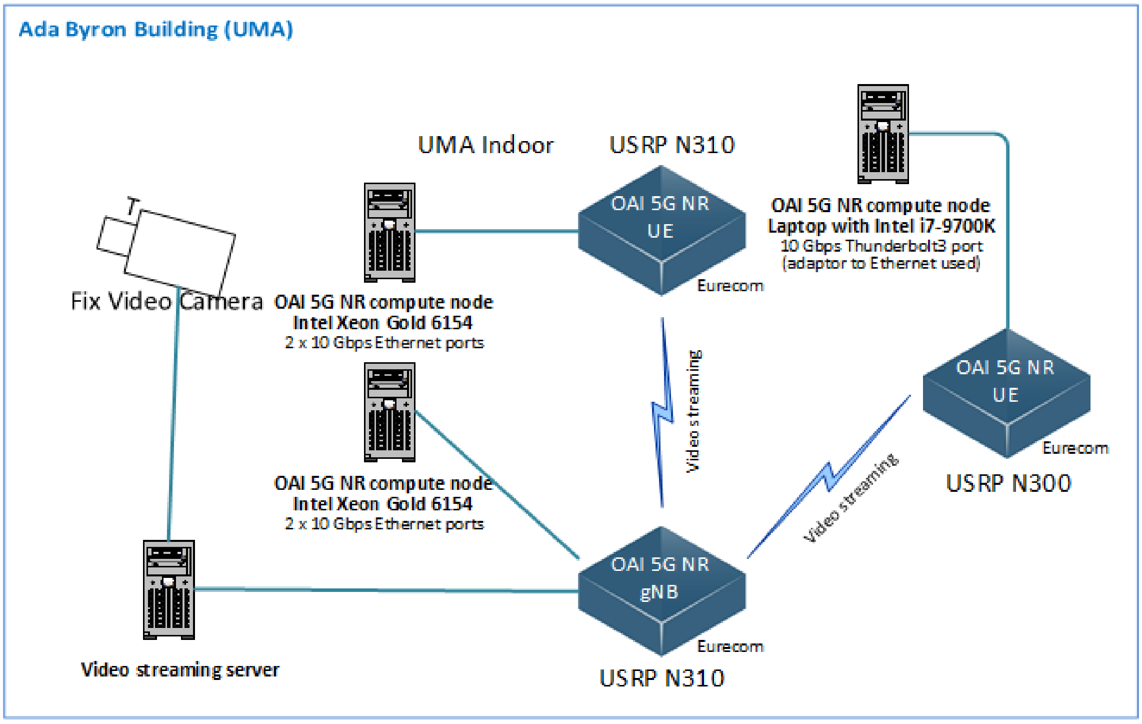

Figure 43: UMA Indoor OAI 5G Deployment

6.4.2. RunEL 5G

RunEL 5G setup includes the different interconnections between the elements that compose it, which are the following: the PC with the basic MAC layer and the video server that connects with the DRAN using IP over a F/O Ethernet link. The DRAN connects with the RRH by a F/O Ethernet ring. The RRH connects with the UE emulator by RF, using either antennas or RF cable. If the latter is used, there is no need to use the internal LNA module of the RRH or UE emulator.

This setup has been demonstrated delivering video and UDP packets from a PC acting as video server to a destination PC in which both the video and the UDP packets were received correctly. The transmitter PC was connected to the DRAN and RRH, while the destination PC was connected to the 5G UE emulator. The radio link between RRH and UE emulator used 3.5 GHz band (3.3 to 4.2 GHz), bandwidth of up to 100MHz, and the throughput achieved for video was of up to 100Mbps.

The software developed allows to optionally add CRC to the packets´ payload, which limits the maximum throughput up to 10 Mbps. The UE emulator includes the functionality to collect some data with performance measurements, e.g. SNR and packet loss.

Configuration of the hardware can be done either using a serial connection through USB or connecting the hardware to a local network through Ethernet to allow the connection to them using ssh. Available configuration for the three hardware components of the setup includes internal IP configuration and some RF parameters, as for example attenuation and gain for reception and transmission or start and stop of LNA module. Firmware update can also be done using either the serial or ssh connection.

6.5. UMA outdoor Radio Access Network

In collaboration with a commercial MNO, the University of Málaga has deployed several outdoor 4G and 5G Nokia base stations to perform mobility tests in real-world scenarios (i.e. outside the laboratory). These cells are connected to the same Athonet core network and Edge to further demonstrate the readiness of the entire setup as it expands its area of operation.

The public procurement to purchase this equipment contains the following main requirements:

- Support of LTE and 5G NR in order to implement the NSA mode.
- Distributed configurations with BBU plus remoted heads (RRH) to move towards a C-RAN deployment.
- Support of several PLMNs with MOCN technologies to implement a first level of slicing at the radio.
- Deployment of 6 cells at UMA campus and more than 10 cells at city centre.
- Provisioning of commercial LTE spectrum for LTE (2600 MHz FDD) and 5G (3500 MHz TDD).
- Sharing the cells at the city centre with the MNO providing the spectrum in order to include 5GENESIS UEs as MNO users to test 5GENESIS services with two different profiles (MNO and private 5GENESIS network).

The technical specifications of the AirScale system as the outdoor radio system deployed are the following:

- Nokia AirScale System Module Indoor. BaseBand Unit, composed by:
    - AirScale Subrack AMIA 5GC000623 (subrack).
    - AirScale Capacity ABIL 5GC000276 (Capacity Unit).
    - AirScale Common ASIK 5GC000275 (Common Unit).
- Nokia Micro RRH 474147A:
    - Band 7. UL 2500-2570 MHz, DL 2620-2690 MHz.
    - Up to 4x5W per TX.
    - Up to 4 bearers, with 5, 10, 15 and 20 MHz possible bandwidth.
    - MIMO 4x4.
    - 2x CPRI fronthaul CPRI ports (2x 9,8 Gbps).
    - 256 QAM modulation.
- Nokia Micro RRH 5GC001274:
    - Subset of band 78 (LTE band 43). UL 3400-3600 MHz, DL 3600-3800 MHz.
    - Up to 4x10W per TX.
    - Support for bearers with 40, 60, 80 and 100 MHz bandwidth. Upgrade to support 50 MHz bandwidth planned for 2020.
    - 4x4 MIMO.
    - 3x CPRI fronthaul (3x 9,8 Gbps).
    - 256 QAM modulation for DL, 64 QAM for UL.

- Support for 5G NSA mode, and future upgrade to support SA mode.

A brief diagram of the outdoor deployment at the Ada Byron site can be seen in Figure 44.

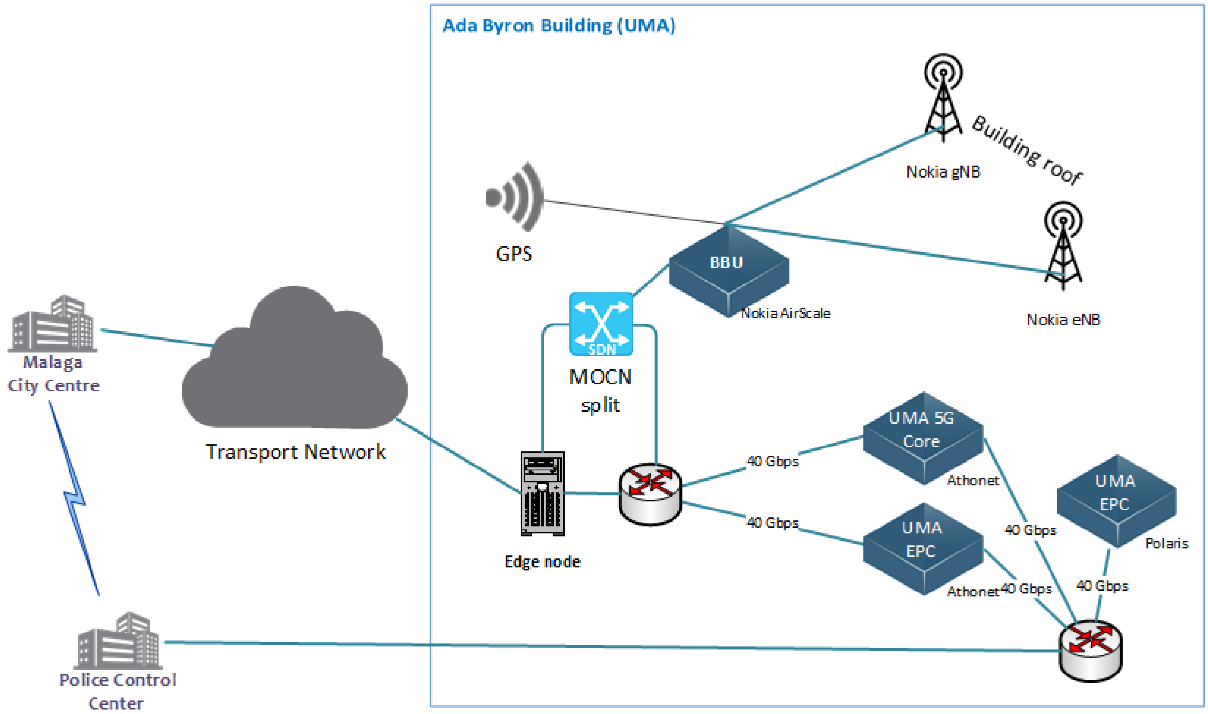

Figure 44: University of Málaga Outdoor Deployment Infrastructure

6.6. MoM outdoor Radio Access Network

Currently, the Police Department of Málaga has several security cameras and 4G base stations deployed in different locations of the city. During the project, those base stations are being upgraded to 5G technology and used in a hybrid approach. With the help of Telefonica and their Edge service, both commercial and experimentation users will be connected to the same cells, discriminating each users traffic to be processed by the core network of the MNO or the 5GENESIS one. The transport network of the platform will be used to forward the data plane of the end users during the experimentation phase to the Emergency Control Center by using a fixed radio link connected to one of the premises of the Police in the city. A diagram with some details about the city centre deployment can be seen in Figure 45.

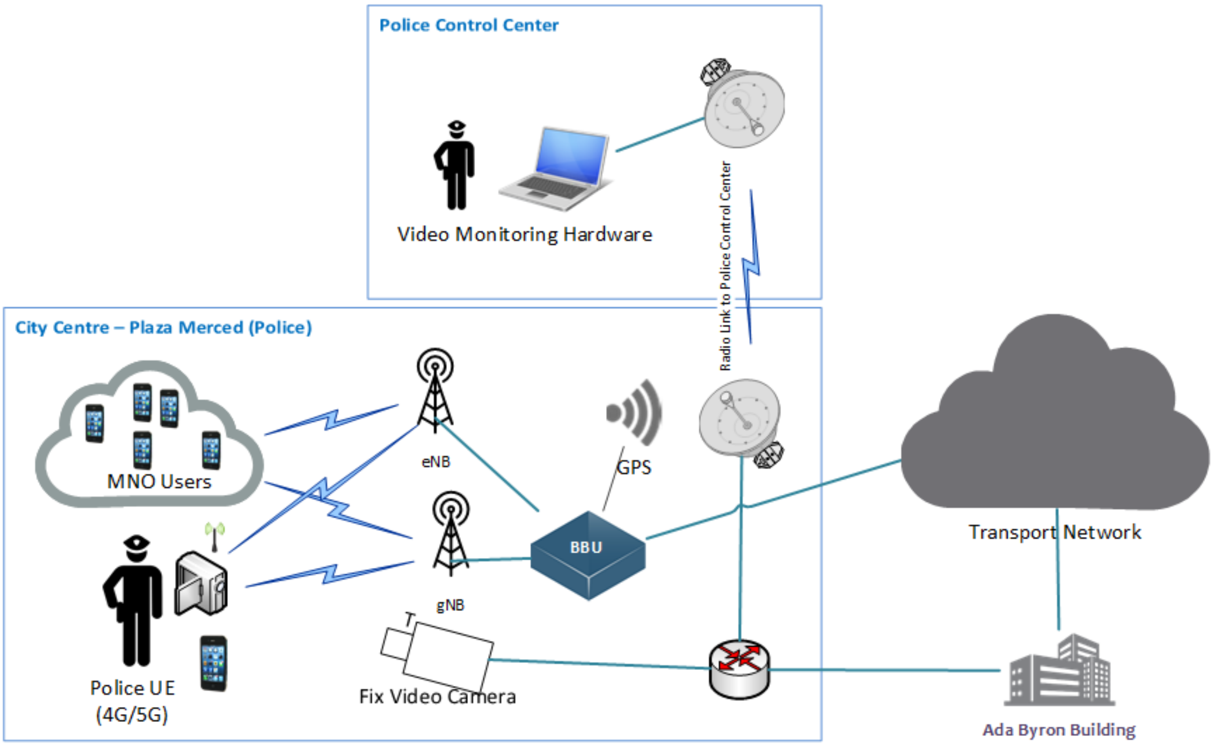

Figure 45: Police of Málaga Outdoor Deployment Infrastructure