“5G for Drone-based Vertical Applications”

D1.2 – Initial description of the 5G trial facilities

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Executive Summary

This Deliverable aims at extensively describing different partners' 5G facilities required to carry out trial experiments in the 5G!Drones project. The deliverable highlights the initial description of the 5G trial facilities. The 5G facilities of different partners contributing towards this project include, the 5GENESIS, Athens 5G site, the 5G-EVE, Sophia Antipolis 5G site, Aalto university X-network, and the University of Oulu 5G Test Network (5GTN). Each of the 5G facilities described in this deliverable focuses on the general configuration of the network, the capacity of the 5G facility in general terms and in terms of supporting the defined use case scenarios to be trialed in the 5G!Drones project. This deliverable further describes the initial list of key performance indicators (KPIs) set by the 5G!Drones project achievable within each facility, and the available interfaces to access these facilities The Deliverable finally highlights the mapping of each of the use case scenarios to their respective 5G facilities, outlining each use case scenario implementation on the 5G facility in terms of the objectives, 5G requirements, and targeted 5G KPIs.

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List of Abbreviations

4G	Fourth Generation Cellular Telecommunications Network
5G	Fifth Generation Cellular Telecommunications Network
5GC	5G Core
5GNR	5G New Radio
API	Application Program Interface
COTS	Commercial-of-the-shelf
DC	Data Center
EMBB	Enhanced Mobile Broadband
EMS	Element Management System
EPC	Evolved Packet Core
FFD	Frequency Division Duplex
FTTH	Fiber to The Home
KPI	Key Performance Indicator
LoS	Line of Sight
LTE	Long Term Evolution
MANO	Management and Network Orchestration
MEC	Multi-access Edge Computing
MMTC	Machine-to-Machine Type Communication
NBI	North Bound Interface
NFV	Network Function Virtualization
NFVI	Network Function Virtualization Infrastructure
NFVO	Network Function Virtualization Orchestrator
NMS	Network Management System
NR	New Radio
NSA	Non-Standalone
NSI	Network Slice Instance
NST	Network Slice Template
OAI	Open Air Interface
ODL	Open Day Light
OSM	Open Source MANO
PNF	Physical Network Functions

PoP	Point to Point
RAT	Radio Access Technology
RRU	Remote Radio Unit
SA	Standalone
SBI	South Bound Interface
SDN	Software Defined Network
TDD	Time Division Duplex
UAV	Unmanned Aerial Vehicle
UPF	User Plane Function
URLLC	Ultra-Reliable Low Latency Communication
VIM	Virtual Infrastructure Manager
VLAN	Virtual Local Area Network
VNF	Virtual Network Functions
WAN	Wireless Area Network
WIM	WAN Infrastructure Manager

1. INTRODUCTION

1.1. Objective of the document

The main objective herein will be to define the supported features and requisites of the 5G test sites to trial 5G!Drones. Thus, a definite analysis of the supported functionalities will be defined per each trial facility. This will incorporate 5G wireless features and interfaces for platform accessibility. In parallel, the project oversees and reports on the status and recommendations of the participating ICT-17 facilities and support sites in order to further scrutinize or incorporate respective new and innovative features.

The mapped vertical use case features, defined in WP1 task T1.2 of the project, will be applied to the respective facility components. In this line, each facility declares its capacity and capabilities regarding the respective technical features for each use case scenario, further mapping and reporting 5G specifics at an unmanned aerial vehicle (UAV) service component level.

The document reports the determined gaps and the overall diagnosis of the 5G facility components of the selected use cases per (test bed) facility. Consequently, the deliverable reflects on the findings (feedback) and reports them to the drone operators. In this perspective, an initial spherical and fine-tuned 5G facility description will be formed and utilized for the preparation and upcoming execution of trials.

The document will further describe how each of the proposed use case scenarios and sub-scenarios by different partners will be achieved within the available 5G facilities, taking into consideration the UAV requirements and specifically the 5G requirements.

1.2. Structure of the document

This Deliverable is structured in five chapters:

Chapter 1 highlights the general introduction of the Deliverable in-terms of its objectives, aims, and targeted audience.

Chapter 2 describes different partners' facilities in extensive details. Starting from the H2020 ICT-17 sites which include 5GENESIS[1] and 5G-EVE[2], and other supporting sites including the Aalto X-Network [3]and the Oulu 5GTN[4].

Chapter 3 discusses how different use case scenarios within the 5G!Drones project will be implemented / trialed in the available 5G facilities. This further extends highlighting different requirements of each use case scenario with respect to UAVs and 5G platforms/facilities, and their targeted KPIs.

The conclusion references and appendix are presented in Chapter 4.

1 https://5genesis.eu/
2 https://www.5g-eve.eu/
3 http://5gtnf.fi/sites/espoo
4 https://5gtn.fi/

1.3. Target Audience

This project consortium deliverable is mainly addressed to the general public for obtaining a better understanding of the framework and scope of the 5G!Drones project. It shows how different trial facility partners are aligned with the use case scenarios that were defined within the project. Furthermore, this deliverable is also targeting the two communities in scope of the project namely 5G (5G PPP and beyond) & UAV.

2. 5G TRIAL FACILITIES

2.1. 5GENESIS Athens 5G Site (NCSRD)

2.1.1 Site topology & 5G Architecture

The 5Genesis Athens platform is part of the 5Genesis 5G Facility. The 5Genesis project's objective is to design and establish a 5G experimentation blueprint that unifies diverse 5G components to support verticals and develop a 5G Facility that instantiates this experimentation blueprint in five interoperable end-to-end Platforms in order to qualitatively assess and quantitatively validate business, performance, and societal 5G PPP KPIs in representative 5G use cases.

The 5Genesis project builds on the following guiding principles for the envisaged experimentation facility:

- The 5GENESIS Facility is distributed and is comprised of various geographically dispersed platforms;
- The platforms are complementary in terms of features, nevertheless aligned to the proposed common reference architecture;
- The platforms are administratively independent, exposing open interfaces for inter-platform coordination and verticals experimentation;
- The platforms accommodate multiple experiments from various verticals with diverse requirements;
- The platforms are fully interoperable and can be interconnected in order to form a truly end-to-end Facility.

In this respect the Athens platform is autonomous, and thus the instantiation of the 5Genesis blueprint can offer experimentation services to verticals in an autonomous and isolated manner. This capability can be leveraged and extended in the 5G!Drones project to optimize the execution of the drones-related vertical use cases.

In brief, the 5Genesis reference architecture considers three main layers, as graphically depicted in Figure 1:

- The **Coordination** Layer, is the top layer of the blueprint that interacts with the experimenters in order to support all functions related to experiments life cycle (such as create, execute, repeat, report) management, and end-to-end configuration (infrastructure and user requirements, as well as requested service templates). It implements the open API that is envisaged by 5Genesis in order to interface with the vertical industries and offers a web portal to facilitate the over the web interactions.
- The **Management and Orchestration** Layer encapsulates all the management and orchestration capabilities that are necessary to deploy, realize and administer the required experiments on the supporting networks. The Slice manager, the MANO systems and the SDN as well as NMS components are typically part of this layer.
- The **Infrastructure** Layer contains all access, core and transport network components as well as Cloud and virtualized architecture to implement the relevant network services and handle the user traffic. All 5G NR, Core, UE components, as well as the Mobile Edge Computing and Data center facilities are considered part of this layer.

The platform is currently reaching the end of the second phase instantiation, and the full extent of capabilities shall be made available by the end of 2020 with the final third instantiation phase.

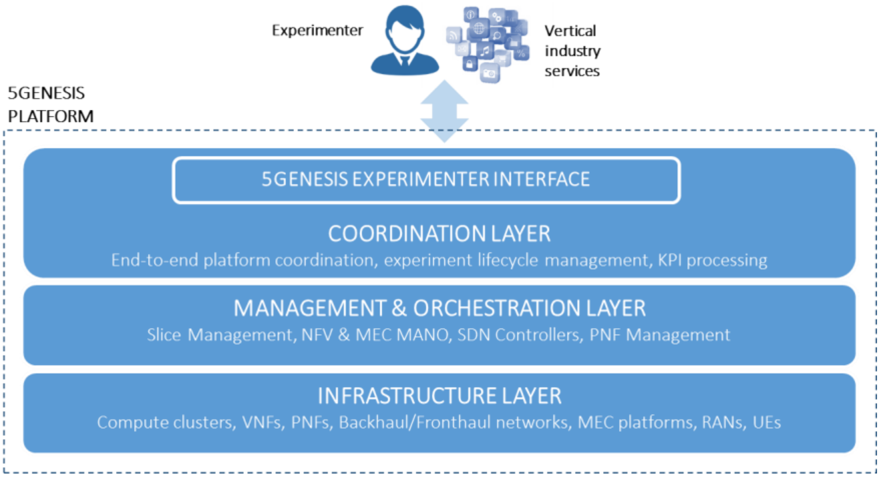


Figure 1: 5Genesis Athens Platform Experimentation Blue Print.

2.1.2 5G Platform Capabilities & Roadmap

The Athens platform consists of three different sites dispersed over Athens city, as illustrated in Figure 2:

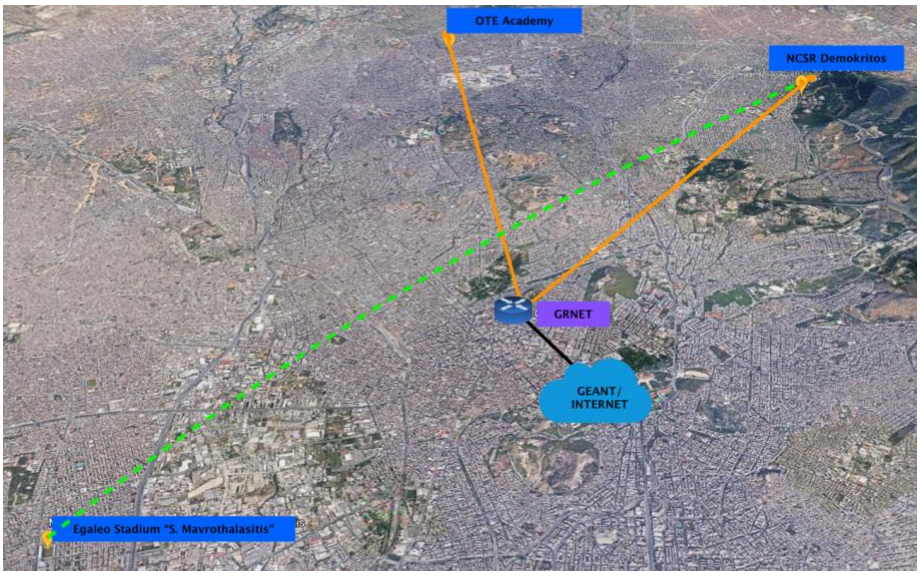


Figure 2: 5GENESIS Athens Platform Topology.

- The **campus of NCSR "Demokritos"**, in north-east Athens, is a 150-acre area, combining indoor and outdoor environments, dispersed around the campus and interconnected by an optical fiber backbone; NCSRD is directly connected to Greek Educational, Academic and Research Network (GRNET), which provides access to

Internet and GÉANT (pan-European data network for the research and education community). This site is responsible for hosting most of the infrastructure required for the management, orchestration and coordination of the Athens platform. In this context, it is an important site for the execution of all the Use Cases defined for the Athens platform.

- The **COSMOTE building (OTE Academy)**, in the north of the city, is a multi-functional complex, combining various indoor and outdoor usage scenarios; It is also directly connected to GRNET and this provides its access. Internet access is provided by OTE network. This site hosts infrastructure components, radio access and NFV infrastructure / MEC and functions of the coordination layer if necessary.
- The **stadium of Egaleo** (Stavros Mavrothalasitis), in west Athens, that is used to host demonstrations in a more “realistic” environment and suitable to investigate backhaul related issues (i.e. latency, throughput, etc.). The location’s connectivity is based on a wireless point-to-point link to NCSRD. Wired access via fiber connection (FTTH – Fiber To The Home) is anticipated. This site will host infrastructure components that will allow the experimentation and support of use cases related with the edge computing, and Control Plane – User Plane separation in a realistic environment. Therefore, edge computing equipment will be deployed along with the 5G radio access components and user plane functionalities (i.e. 5GC User Plane Function - UPF). This site, in coordination with the NCSRD site, will demonstrate the Connectivity Extension use case.

The overall deployment architecture of the Athens platform is graphically depicted in Figure 3. The platform is already formed, following the successful interconnection of all the testbeds in a star formation, exploiting NCSRD site as the central node. On the technical part of the interconnection, the link between NCSRD and OTE Academy sites is realized on top of GRNET optical fiber infrastructure at rates up to 1 Gbps, whereas the link between NCSRD and Egaleo stadium is realized via radio backhaul technology (i.e. UBUQUITI PRISM AC GEN2 at 5 GHz Wide Band). Infrastructure status is currently considered as 5G Ready, i.e. components and infrastructure elements are in-place at operational status, however new technologies that are 5G related are going to be integrated as soon as they become available. However, some early features are already available and are beyond 4G.

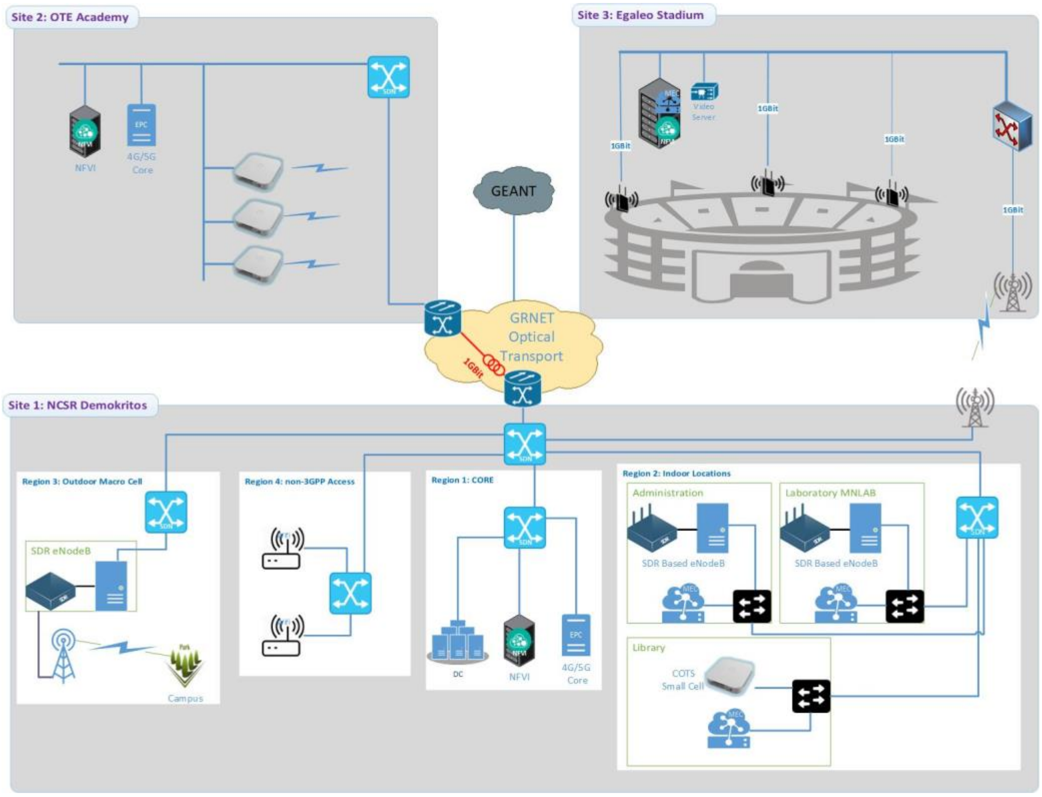


Figure 3: 5GENESIS Athens Platform Deployment.

2.1.1.1. Mobile Network Technologies

The Athens 5GENESIS platform has already an LTE infrastructure deployed in all three sites as part of other 5G-PPP Phase 1 and 2 projects (i.e. SONATA, SESAME, CHARISMA, ESSENSE). For example, in the case of NCSRD, the existing infrastructure encompasses mature solutions for SDR implementations of eNB, 4G LTE Core and relevant COTS components. For the first phase of 5G!Drones this equipment will be re-used and is considered the baseline towards further 5G evolutions and upgrades of the Athens Platform in view of demonstrating according to the objectives of the project. This procedure will be incremental as more and more new components are added in the infrastructure during each integration phase. It is envisaged that as part of the 5GENESIS platform a full 5G network will be deployed by the end of 2020. The core network is installed in the NCSRD data center, while the Egaleo stadium and OTE Academy host radio access components and MEC capabilities.

The supporting 5G technology and roadmap are depicted in below Table 1, and technical descriptions can be found in Appendix: 5Genesis Athens Platform Technical Details.

Table 1: 5GENESIS Athens Platform 5G Technology and roadmap

	Mobile Core	Radio Access	UE	3GPP Option
Phase 1 6/2019	Amarisoft 4G vEPC	Amarisoft 4	Commercial 4G	(option 1)
	OAI vEPC	OAI eNodeB	Commercial 4G	(option 1)

	Athonet EPC	OAI eNodeB	Commercial 4G	(option 1)
	Athonet EPC	NOKIA Small Cells	Commercial 4G	(option 1)
Phase 2 12/2019	Athonet 5G Core r. 15 CUPS	OAI/SDR ETTUS gNodeB RunEL gNodeB	OAI/SDR ETTUS	(option 3)
		NOKIA mRRH+BTS	Commercial 5G	(option 3)
Phase 3 12/2020	Athonet 5G SA/other solutions	5G New Releases	Commercial 5G	(option 2)

In respect to the 5G Spectrum 3.5 GHz trial licenses shall be used, until the auction for commercial licensing takes place, which is expected in 2020. The spectrum that will be allocated to COSMOTE, partner of the 5GENESIS platform, shall be used instead.

In respect to existing Phase1 Athens Radio Access Deployment the following are currently deployed (Table 2):

Table 2: 5G Athens Deployed Radio Access Components

Site	Deployed Radio Access Equipment's
NCSRD	• Four small cells that run the Amarisoft RAN software on i7 hosts connected to the Amarisoft core network component via the backhaul networkcover the administration building and NCSRD library. • Two Nokia Small cells connected to the Athonet Core Network through the backhaul network cover the Institute of Informatics and Telecommunications (IIT). • A Macro cell, located at a high mast for the coverage of the outdoor area of the NCSRD campus. The antenna used is Kathrein 80010682 and the carrier frequency is at 2.6 GHz.
COSMOTE	• 8 NOKIA "Flexi Zone Multiband Indoor Pico BTS" (FZ MBI) small cells
Egaleo Stadium	• Three small cells placed in cabins at positions in the stadium creating the coverage areas.

2.1.1.2. Data Centre and Edge Computing Technologies

The Main Data Centre of the 5Genesis Athens facility is located at NCSRD, and is comprised of a 3-node Openstack[5] virtualisation infrastructure standing as Network Function Virtualization Infrastructure Point of Presence (NFVI-PoP). A second NFV Infrastructure exists as a

[5] https://www.openstack.org/

Kubernetes Cluster, with one master and one worker node, enabling container-based deployment of VNFs.

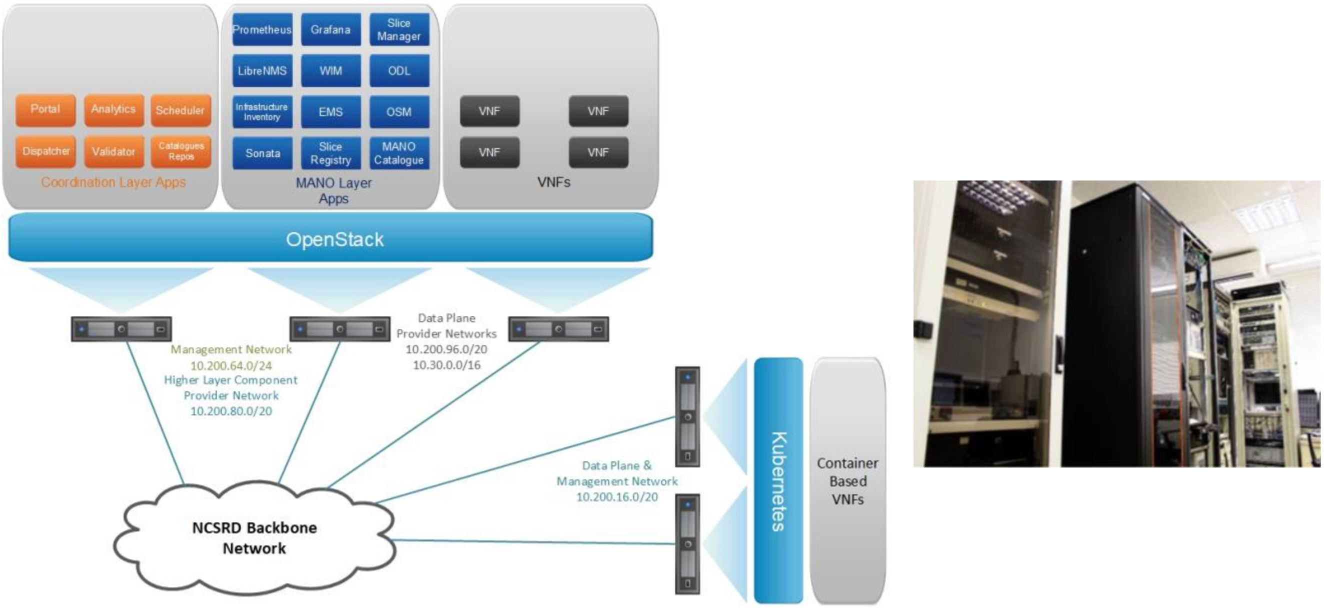


Figure 4: Main Data Centre at NCSRD.

At the COSMOTE Site, an Openstack infrastructure for 5-GENESIS is deployed, comprised of a 2-node Openstack NVFI-PoP co-hosted with radio access components to extend the NFV capabilities of the Athens platform and support edge capabilities at OTE Academy building as needed.

At the Egaleo stadium, three cabinets are available to host the gNB components as well as necessary application components to support the 5G-Drones use case demonstration. A graphical representation can be seen in Figure 5.

Figure 5: Egaleo Edge Site Cabins.

2.1.1.3. Orchestration and Management Technologies

For the purpose of Monitoring and performance benchmarking of the platform components, a number of tools are part of the Athens platform. The overview is provided in the following table (Table 3):

Table 3: 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 platform specific 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 on the way that all networking devices (SDN switches, routers), NFV Infrastructures and physical devices on the platform are connected, in the form of a network graph.
Monitoring Tools	**Description**
Netdata	Used to measure health, performance and available resources on cloud physical components (Servers). [4].
LibreNMS	Used to measure state, health, configuration (Ports, VLANs, Neighbours, STP, Inventory and Logs) and performance (throughput, traffic, latency, loss) on networking devices (Switches, Routers, etc.). [5].
Ceilometer	Used to measure resources (memory, cpu, vcpu, disk, networking, etc.) on cloud instances. [6].
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 and supports a lot of presentation dashboards.
NFV MANO	**Description**
OSM	OSM[6] 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

[6] https://osm.etsi.org/

	and tools. For the purpose of the 5Genesis platform the deployed OSM is of release 5 and is already integrated with the Element management systems and monitoring tools as well as the Virtualisation Infrastructure Managers (Openstack).
Traffic Generators	**Description**
uPerf	Network Performance tool supporting modeling and replay of network traffic [7]
Moongen (HW generator)	A fully scriptable high-speed packet generator built on DPDK and LuaJIT. [8]
OWAMP	One-way ping tool for measuring latency and loss [9].
PerfSonar	A network measurement toolkit designed to provide federated coverage of paths and help to establish end-to-end usage expectations [10].
TRex	An open source, low cost, stateful and stateless traffic generator fueled by DPDK. It generates L4-7 traffic based on pre-processing and smart replay of real traffic templates. TRex amplifies both client and server-side traffic and can scale up to 200Gb/sec with one UCS [11].

2.1.1.3.1. Slice Management Capabilities

A key orchestration capability, built on top of the management systems as part of 5Genesis, is the Slice Manager component that assures the creation of end-to-end logical networks, namely “network slices”. The key function of a Slice manager is to satisfy requests for the provisioning of slices matching specific 5G services by utilizing the underlay infrastructure components to allocate tailored resources utilizing the MANO and management systems deployed. A key characteristic of the Slice Management system is to communicate with the layers coordinating the User requirements in a concise manner, and this is a target focus of the 5Genesis facility architecture.

2.1.1.4. Experimentation and Coordination Capabilities

The capabilities at the network, infrastructure and management level including the orchestration provided by the Slice manager are the building blocks for the dynamic provisioning of resources envisaged in the 5G era. On top of this, the 5Genesis Athens platform addresses the capability to interact efficiently with the “verticals” - the clients of these services, through user-oriented coordination components that collect the end experimenter requirements and translate them to artefacts that can be effectively implemented through the Slice Manager through the underlying management systems on the available infrastructure components.
The fundamental components of the coordination capability of the Athens platform are summarized in Table 4:

Table 4: Fundamental components of the Athens platform

Experiments Coordination	Description
GENESIS Portal	A proprietary web-interface exposed to experimenters to offer a user-friendly interaction. This is the entry-point for experimenters wishing to interact with the platform in order to define new experiments, examine

	the results and logs of previous executions or manage deployed VNFs among other features. Furthermore, experimenters can view information about their latest performed actions and access to system notices. Note that 5Genesis perceives also an alternate, non-graphical, way for experimenters to interact with the platform through the open API implementation.
Experiment Life Cycle Management	Keysight's TAP commercial-off-the-self testing automation tool is used to implement the experiment life cycle management activities that are triggered by the vertical's requests through the portal or the open API.
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.

2.1.3 Existing interfaces to access the facility

The Platform Coordination layer (see Figure 7) of the 5GENESIS reference architecture is the layer through which the experimenter interfaces with the Facility.

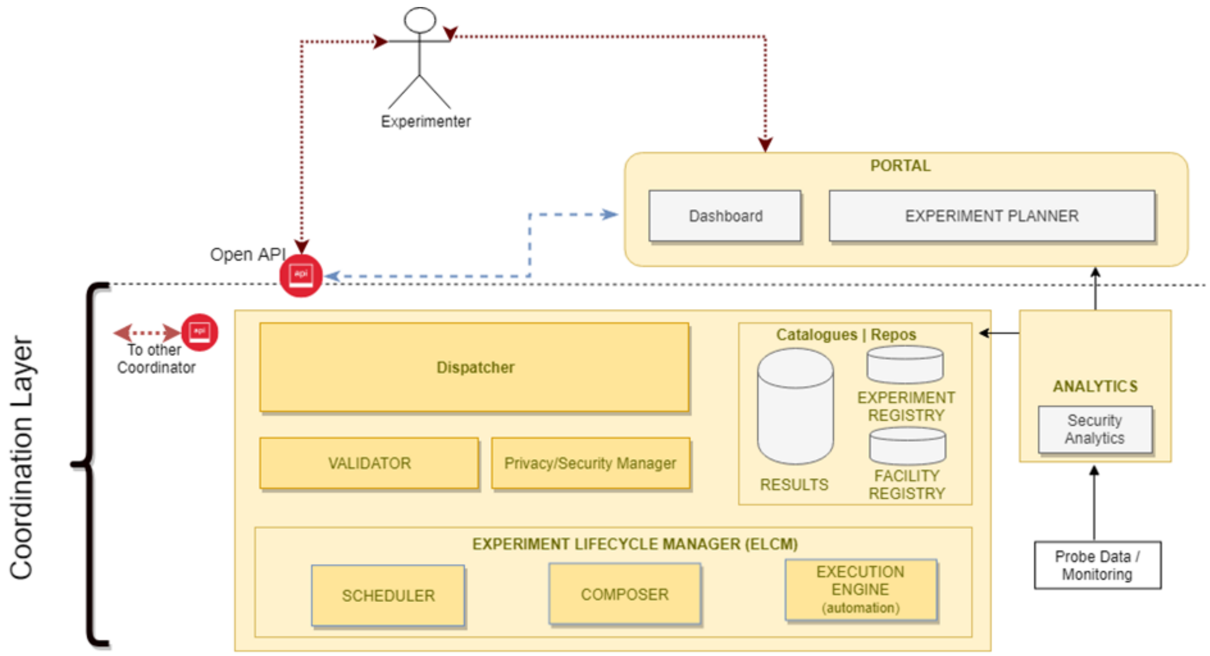


Figure 6: 5GENESIS Coordination Platform.

- **The Portal:**

  The Portal primarily provides the Web UI that exploits the Open API exposed by the Coordinator and secondly allows the experimenter to execute a number of preparatory actions related to the experiment and monitoring of their status as well as visualize the outcome of certain experiments, following the approach adopted in [23]. In detail, the Portal allows (1) on-boarding of service package (i.e. network service, slice and VNF descriptors, VNF images, configuration scripts); (2) on-boarding of testing descriptor (i.e. test scenario definition, scripts); (3) planning of testing cases (i.e. plan execution time, resource reservation, configuration) and (4) access and visualization of the results of the experiments. The information and data model that the project will adopt for the descriptors included in the service package, shall be in-line with the currently accepted and defined ETSI NFV format (i.e. OSM compatible [24]. Moreover, the project will specify and implement a Network Slice descriptor scheme in order to support the Network Slice creation on top of each platform physical infrastructure. Eventually, the project may extent the descriptor scheme in order to cover specific requirements of the platform that are beyond current MANO jurisdiction.

The Portal includes two main components: i) the Dashboard that essentially provides the UI and methods for presentation and visualization of the results and ii) the Experiment Planner that acts as means for enabling intuitive experiment configuration and planning operations to the experimenter.

The Portal will use the 5GENESIS Open API to communicate with the coordination block component.

- The Open API:

  The 5GENESIS Open API is the interface offered by the Coordination layer for the definition and execution of the experiments. The 5GENESIS Open APIs are designed to be used as an extension point of the features offered by the 5GENESIS platform towards verticals in ICT-19 projects.

  The anticipated procedures to be exposed through 5GENESIS Open API are the following:

  1. Store and delete descriptors,
  2. Consult descriptors available in the database,
  3. Validate descriptors,
  4. Define experiments,
  5. Monitor status of the facility and the experiment,
  6. Schedule the execution of a testing experiments,
  7. Retrieve measurements and testing reports,
  8. Notifications,
  9. Access control and authorization

2.2. 5GEVE Sophia Antipolis 5G Site (EURECOM)

The 5G!Drones project aims to try several UAV use cases that cover eMBB, uRLLC and mMTC 5G services, and validate 5G KPIs which apply to support such challenging use cases, and to enhance them with powerful features. In this regard, EURECOM will build on top of the

5G facilities provided by the ICT-17 projects as seen in Figure 7, while identifying and developing the missing components to trial UAV use cases.

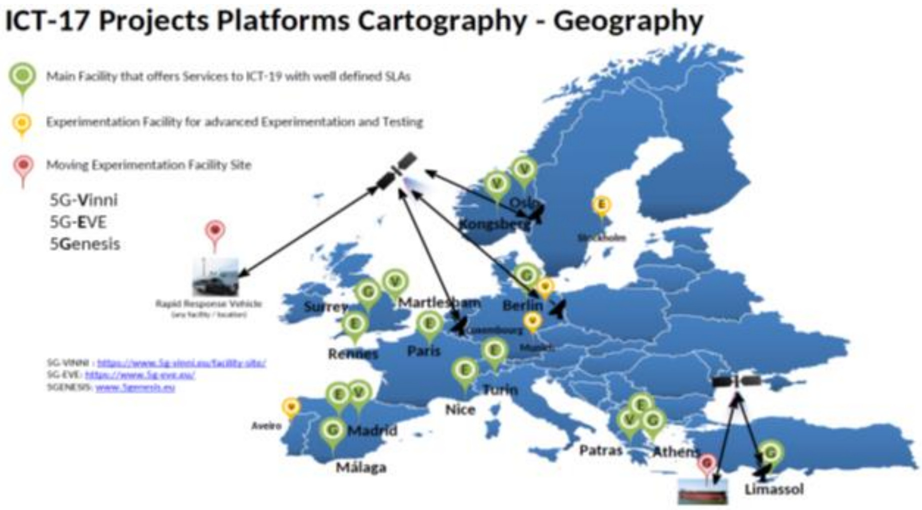


Figure 7: H2020 ICT-17/19 experimental landscape in Europe.

2.2.1 Site topology & 5G Architecture

The trial facility at the EURECOM site (in Sophia Antipolis, France) is part of the French site of the 5GEVE ICT-17 project (see Figure 8).

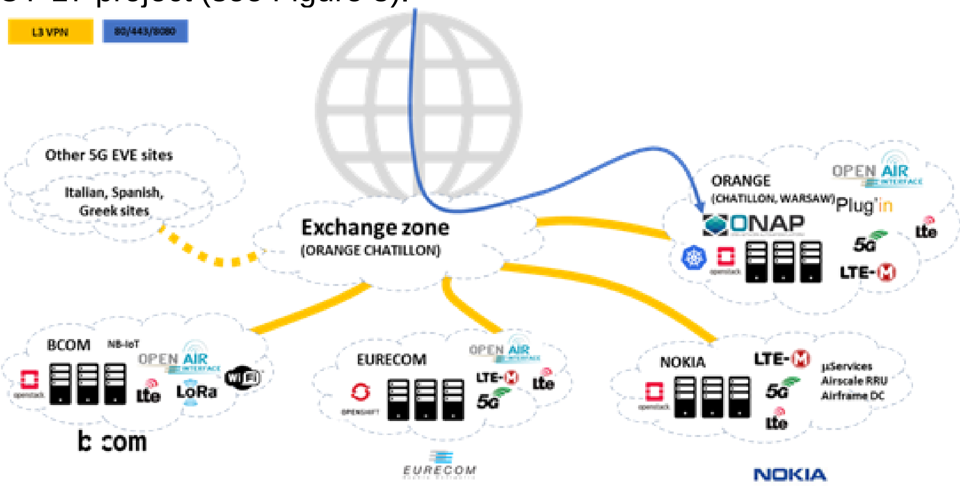


Figure 8: 5G EVE architecture.

The EURECOM site includes 26-36-core servers for 5G NR procedures (precoding, L1, MAC-RLC), LTE/LTE-M/NB-IoT network components, and to host vEPC and 5G Core software. The site is fully OpenAirInterface-powered, and the OAI components (core and RAN) are available for virtualised deployment using Openshift. Both COTS (4G) and OAI-based UEs are supported.

Regarding the transport network infrastructure, 2 distribution switches with 20Gbps optical interconnections driving up to 10 Remote Radio Units (RRUs), each with a 1GBase-T copper link, to a 1Tbs switch are installed.

The EURECOM facility is interconnected with GEANT via the French academic network (RENATER). The introduction of 5G NR/core features depends on their development progress and availability in the OAI community. The first upgrades to 5G NR are expected by the end of 2019, will mainly enable 5G connectivity in a Non-standalone mode, via the installation of OAI-based gNB.

Currently, there is an existing indoor LTE RRU deployment in Band 38 (TDD, 2.6 GHz) with up to 30 MHz of usable spectrum, which covers two floors of the EURECOM building. The outdoor deployment includes open-source RRUs (including all the necessary RF, baseband processing, high-speed interconnection, and other components in a waterproof enclosure) as parts of OAI 5G RAN nodes. Licenses for LTE band 38 (2580-2610 MHz, TDD) and NR band 28 (708-718/763-773) and 78 (3600-3680 MHz, TDD) are already granted to the EURECOM facility, while applications have been filed for operation in LTE band 68 (698–703/753–758 MHz, FDD) and LTE Band 14 (733–736/788–791 MHz, FDD).

As soon as the licenses for bands 68 and 14 are available, OpenCellular devices will be installed for NB-IoT and LTE-M coverage. The facility plans to have up to 64 radiating antenna elements with fully centralised and synchronised L1 processing.

Experimental Licenses

EURECOM has received the following 4G and 5G experimental licenses from the French regulatory body (ARCEP) for both indoor and outdoor experiments:

- LTE Band 38 2585-2605 MHz (TDD), 47 dBm (50 W) EIRP
- NR Band 78 3600-3680 MHz (TDD), 61 dBm (> 1 kW) EIRP

EURECOM has also requested two frequency allocations in the 700 MHz band for experimentation with cellular IoT (internet-of-things), in particular LTE-M and NB-IoT. This band will be used to cover a larger zone around the campus in comparison to the 4G/5G elements. The exact bands are

- LTE band 68 (698 – 703/753 – 758 MHz FDD)
- LTE band 28 (733 – 736/788 – 791 MHz FDD)

The request is for 57 dBm EIRP which corresponds to 20 W transmit power. Note that this is substantially lower than conventional UHF transmitters (on the order of 10 times). It is important to note the fact that EURECOM is officially labelled by the ARCEP as a 5G trial site and has an obligation to report on its experiments to the ARCEP and to the 5G-EVE consortium.

Outdoor Deployment Details

The outdoor network includes 2 antenna sites on EURECOM's main roof interconnected with the main server room via high-speed optical Ethernet. We will work with the University of Nice Sophia-Antipolis and INRIA in order to deploy similar equipment on other buildings on the SophiaTech Campus at a later date. An aerial view showing the approximate coverage area of the where 4G/5G outdoor experimentation will take place is shown in Figure 9 and Figure 10. In a first phase, a single sector will be deployed for all services. The red zone corresponds to coverage of dual-connectivity 2.6 (4G+ LTE) and 3.6 GHz (5G NR) high data-rate services. The white zone corresponds to cellular IoT and legacy LTE services. Commercial IoT terminals will be deployed in the forested areas, around the campus and potentially in the area around Carrefour Antibes. Figure 11 shows the specific areas where antennas are deployed on EURECOM's main roof (above level 0). The antennas will be placed on masts 3m above the surface of the roof.

Figure 9: Approximate Area for 4G/5G Outdoor Coverage.

Figure 10: Approximate Area for 4G/5G Outdoor Coverage.

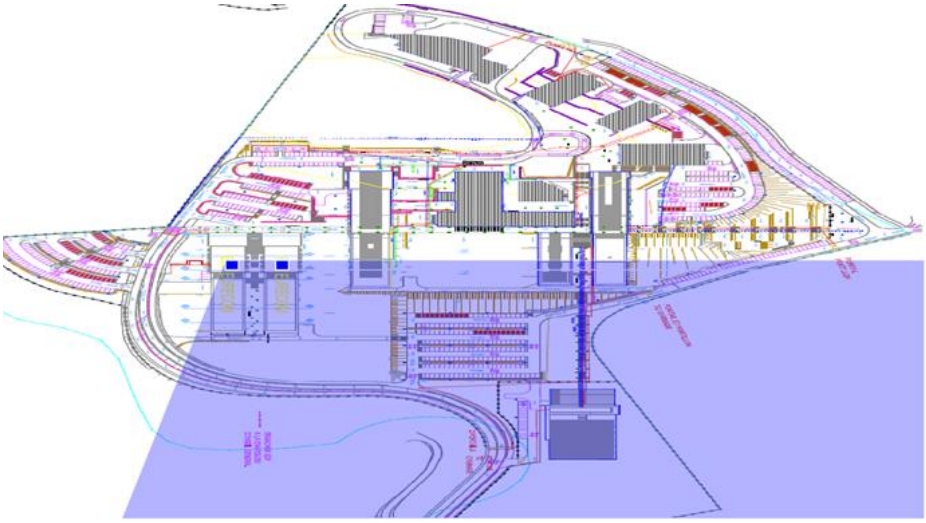


Figure 11: Initial single-sector coverage area on campus map.

The following equipment are or are in the course of being deployed:

- 2 8-antenna 5G RRU (32 W, band 78)
- 2 eCPRI 4G RRU (20W, band 38) [end 2019]
- 2 IoT RRU (20 W, bands 68 and 28)
- 1 mast with 8 active 5G antennas and 2 active 4G/IoT antennas (bands 68 and 28) and 4 active 4G (TD-LTE, band 38)
- Cabling
    1. Fiber 22 x 10 G SR OM3
    2. Fiber 2 x 1 G SR OM3
    3. 220 V (2 kW peak per cabinet)

    An overview of the 5G RRUs (per 4-port panel) is shown in Figure 12.

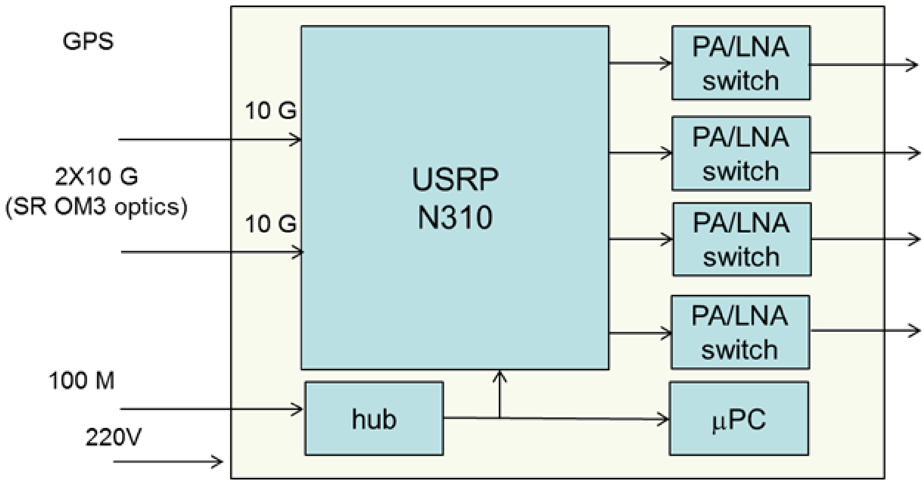


Figure 12: 5G NR RRU (4 antenna port).

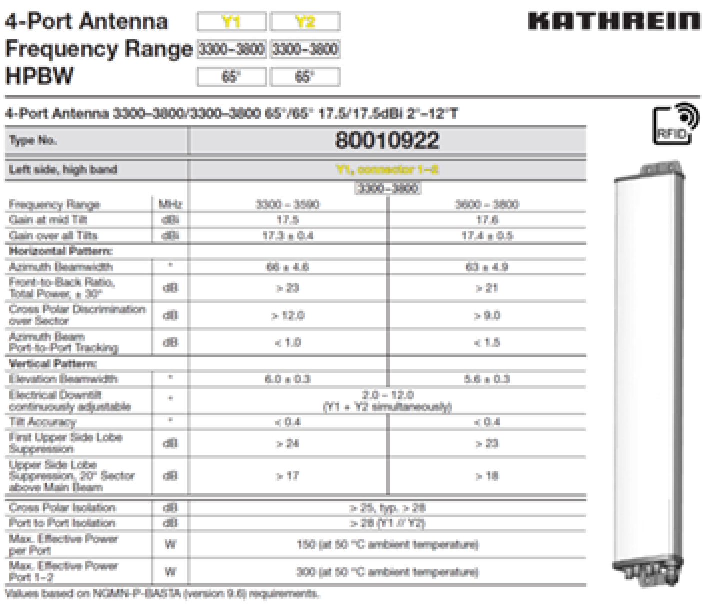
Two of the above RRU units will be placed on the main roof of the EURECOM building. The main interconnections will be achieved using SR optics (OM3) over a 300m interconnection

between RRU and data center in the EURECOM's server room. The antennas will be mounted on a *non-permanent basis* for the duration of the 5G trials.
The physical constraints of the above units are summarized as:

- **USRP N310**
  - Power consumption 50-80W / N310 => 160 W (12V power supply, 220 V input)
  - 3.13 kg / N310 => 6.26 kg
  - 1U frame for rack mounting (~1 kg)
- **PA/LNA modules (2W radiated power per module)**
  - Power consumption: 60 W/module: 480W (28V power supply, 220 V input)
  - ~4 kg
- **Power supplie (12,28V)**
  - 3 kg
- **Totals per 5G RRU (8 antenna elements)**
  - 640W, 15 kg

The chosen Antennas for 5G NR are summarized as (see Figure 13)

- Kathrein 4-port panel (80010922), 3300-3800 MHz, remote-controllable option \(electronic tilt) as seen in Figure 13
- Antenna gain 17.5 dBi
- +- 65 degrees azimuth beamwidth
- 2-12 degree downtilt
- 6 degree elevation beamwidth



4-Port Antenna | Y1 | Y2
Frequency Range | 3300–3800 | 3300–3800
HPBW | 65° | 65°

KATHREIN

4-Port Antenna 3300–3800/3300–3800 65°/65° 17.5/17.5dBi 2°–12°T

Type No.		80010922	
Left side, high band		Y1, connector 1–2	
		3300–3800	
Frequency Range	MHz	3300 – 3590	3600 – 3800
Gain at mid Tilt	dBi	17.5	17.6
Gain over all Tilts	dBi	17.3 ± 0.4	17.4 ± 0.5
Horizontal Pattern:			
Azimuth Beamwidth	°	66 ± 4.6	63 ± 4.9
Front-to-Back Ratio, Total Power, ± 30°	dB	> 23	> 21
Cross Polar Discrimination over Sector	dB	> 12.0	> 9.0
Azimuth Beam Port-to-Port Tracking	dB	< 1.0	< 1.5
Vertical Pattern:			
Elevation Beamwidth	°	6.0 ± 0.3	5.6 ± 0.3
Electrical Downtilt continuously adjustable	°	2.0 – 12.0 (Y1 + Y2 simultaneously)	
Tilt Accuracy	°	< 0.4	< 0.4
First Upper Side Lobe Suppression	dB	> 24	> 23
Upper Side Lobe Suppression, 20° Sector above Main Beam	dB	> 17	> 18
Cross Polar Isolation	dB	> 25, typ. > 28	
Port to Port Isolation	dB	> 28 (Y1 // Y2)	
Max. Effective Power per Port	W	150 (at 50 °C ambient temperature)	
Max. Effective Power Port 1–2	W	300 (at 50 °C ambient temperature)	

Values based on NGMN-P-BASTA (version 9.6) requirements.

Figure 13: UHF Antenna characteristics (3300-3800 MHz).

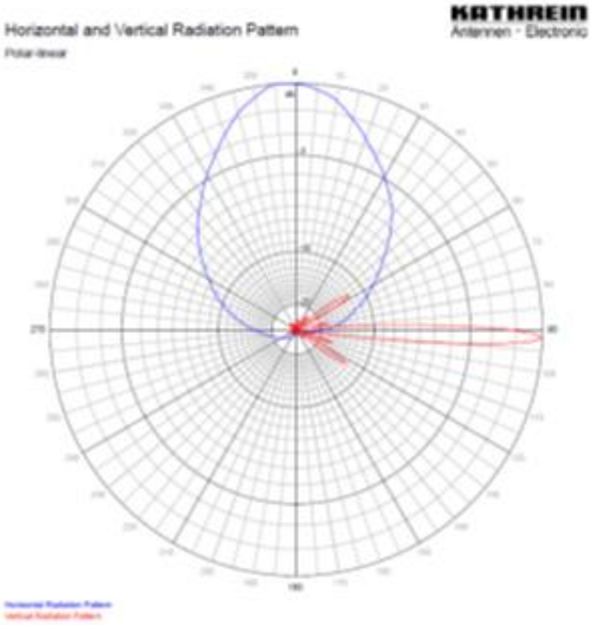


Figure 14: Horizontal and Vertical Antenna Patterns for UHF Antennas.

These are classical cellular panel antennas (Figure 14 and Figure 16). They provide excellent gain in the main lobe of azimuth beam. The local power in the immediate vicinity of the antenna (i.e. sidelobe) is significantly lower since the vertical beam width is narrow so as to provide strong signal farther from the antenna. The vertical tilt will be chosen to provide coverage on the portion of campus in the main azimuth lobe while minimizing the energy at very short range. Moreover, the transmit power chosen is 10 times lower than the authorization from ARCEP and of current pre-commercial 5G trials by Orange, SFR and Bouygues Telecom in urban areas.

The UHF-frequency components are summarized as (see Figure 15):

- **Kathrein 2m panels 698-894 MHz**
- **Remote Radio Unit**
  - 2x20W Power Amplifier
  - 2 low-noise Amplifiers
  - Band14 and/or Band 68 duplexer (700-800 MHz)
  - 220V, 400W power consumption
  - N connectors for 2-port panel antenna
- **Additions for IoT baseband processing**
  - One USRP B210
  - One pico-ITX PC with USB3 + 1GbE

The overall 5G + IoT radio sub-system to be deployed alongside the antennas is shown in Figure 17 and Figure 18). The waterproof housing for the electronic components for the 5G component will be similar to the one shown in Figure 18 and has yet to be designed. It will be in the form of an 8U cabinet with waterproof optical networking and power interconnections.

2-Port Antenna | R1
Frequency Range | 698–894
HPBW | 65°
Integrated replaceable Remote Control Unit | iRCU

KATHREIN

2-Port Antenna iRCU 698–894 65° 17dBi 0.5°–9.5°T

Type No.	80010736v01	
A) Antenna specifications	R1	
	698–894	
Frequency range	698 – 806 MHz	824 – 894 MHz
Polarization	+45°, –45°	+45°, –45°
Gain	14.25 dBd / 16.4 dBi	14.85 dBd / 17 dBi
Horizontal Pattern:		
Half-power beam width	67°	68°
Front-to-back ratio	Copolar: > 30 dB Average: 35 dB	Copolar: > 30 dB Average: 35 dB
Cross polar ratio Maindirection 0° Sector ±60°	Typically: > 25 dB > 11 dB, Avg. 15 dB	Typically: > 20 dB > 11 dB, Avg. 15 dB
Vertical Pattern:		
Half-power beam width	9.5°	8.6°
Electrical tilt	0.5°–9.5°, continuously adjustable	
Min. sidelobe suppression for first sidelobe above main beam: Average:	0.5° ... 5° ... 9.5° T 16 ... 16 ... 16 dB 18 ... 18 ... 17 dB	0.5° ... 5° ... 9.5° T 18 ... 18 ... 17 dB 20 ... 20 ... 20 dB
Impedance	50 Ω	
VSWR	< 1.5	
Isolation, between ports	> 30 dB	
Intermodulation IM3	< –150 dBc (2 x 43 dBm carrier)	
Max. power per input	500 W (at 50 °C ambient temperature)	
Input	2 x 7-16 female iRCU in: 1 x 8pin male iRCU out: 1 x 8pin female	
Connector position	Bottom	
Wind load	Frontal: 1160 N (at 150 km/h) 2900 N (at 150 mph) Lateral: 390 N (at 150 km/h) 970 N (at 150 mph) Rearside: 1380 N (at 150 km/h) 3450 N (at 150 mph)	
Max. wind velocity	241 km/h (150 mph)	
Height/width/depth	2438 / 303 / 99 mm (96 / 11.9 / 3.9 inches)	
Category of mounting hardware	H (Heavy)	
Weight	17 kg (37.5 lb) / 19 kg (41.9 lb) (clamps incl.)	
Packing size	2600 x 315 x 115 mm (102.4 x 12.4 x 4.5 inches)	
Scope of supply	Panel and 2 units of clamps 42 – 115 mm diameter	

iRCU specifications (86010149) see page 228

Figure 15: UHF Antenna characteristics (698-894 MHz).

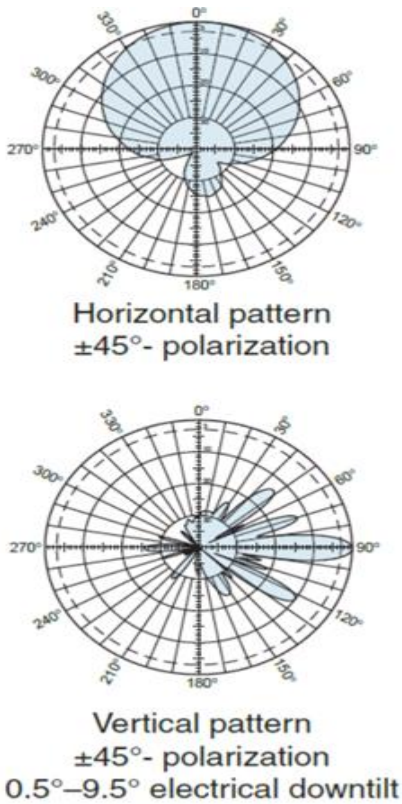


Figure 16: Azimuth and Vertical Antenna Patterns for UHF Antennas.

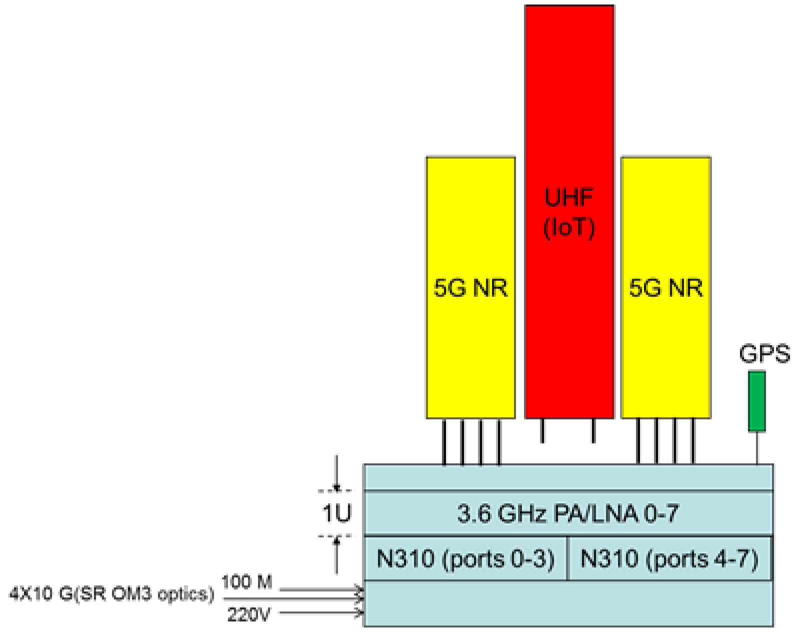


Figure 17: 5G + IoT Radio Subsystem (5G component on roof).

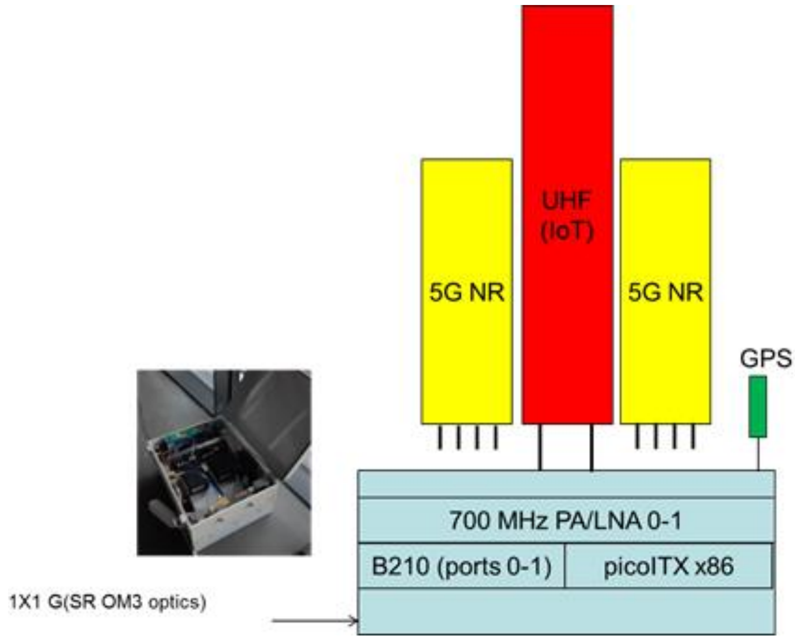


Figure 18: 5G + IoT Radio Subsystem (5G component on roof).

Indoor Deployment

The deployment consists of an indoor network on levels -3 and -4 of the EURECOM building and one outdoor transmitter already connected to amplifiers in the CS-department RF lab. The radio transmitters and receivers use Band 38 (2.5 GHz) time-division duplex (TDD). The aggregation switches are located in the control rooms next to the Shannon and Fourier meeting rooms and are used to distribute 20 GBit’s optical fronthaul connected to the server room to radio equipment deployed next to the WIFI access points in the ceiling on levels -3 and -4. Along with the switches, there are two 10 MHz frequency distribution units to provide synchronization to the radio units. The indoor radio units (20 antennas in total deployed on levels -3 and -4 in the CS-department and SI wing) consist of the following components:

- Pico-ITX or smaller motherboard (Commell LP-173E, Congatec CONGA-PA3 or up-board)
- Baseband-to-RF radio units (e.g. USRP B200-mini, LimeSDR, or EPIQ Sidekiq)
- EURECOM-designed Band 38 RF front-end circuits (15 dBm EIRP / antenna)
- Wiring for 1Gbit/s Ethernet with Power-over-Ethernet modules (PoE) to provide power to the radio units. An additional 10 MHz frequency synchronization cable is also distributed to each RRU.

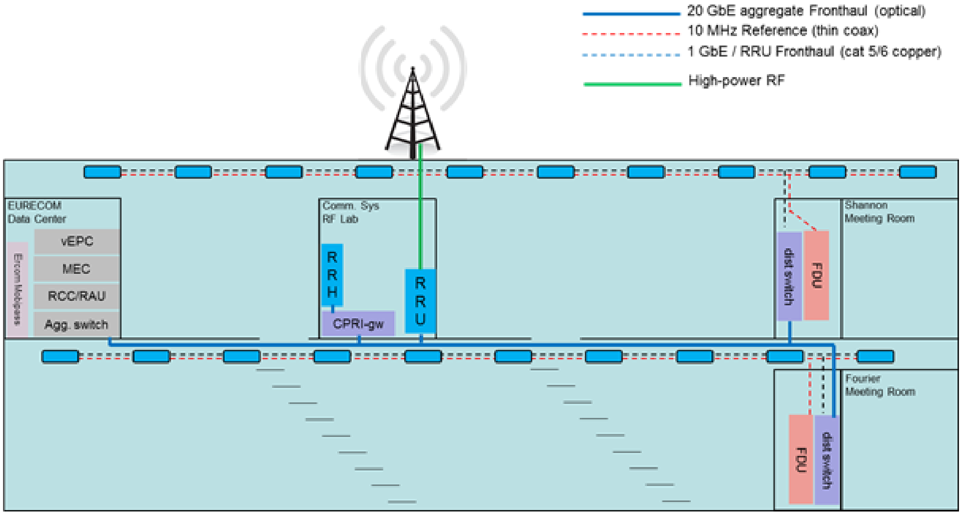


Figure 19: Indoor Physical Deployment Sketch.

Figure 19 represents the indoor physical deployment sketch. In size, the indoor RRU are slightly smaller than the Cisco WIFI access-points currently deployed and require two copper interconnections with the control room (Cat 5/6 Ethernet and a thin 10 MHz coaxial cable). The maximum transmit power of the indoor radio units is limited to 15 dBm EIRP (31.6 mW), which represents one-third of the power of the lowest 4G base station power class (100 mW) of a so-called HeNB (home base station)[7]. All RRUs will receive continuously but may not all transmit concurrently with the same power-level. The transmit power is tailored to the user traffic dynamically and the entire network will act as a centralized multi-antenna system. LED activity indicators will indicate the transmitter operation of each RRU. Both these indicators and global power indicators of the RRU will be made visible for people in the vicinity of the radio network. Note that the WIFI access points currently deployed also use 100 mW per channel and that each unit currently uses two or more 20 MHz channels (2.4 GHz and 5 GHz). Note also that a HeNB usually also has a WIFI transceiver (and hence double the radiated power). This 100mW/channel limit is seen as an acceptable level of radiation from a sanitary perspective in most parts of the world when it comes to short-range exposure. Please see the dedicated section below for more information. Under the assumption that the current EURECOM WIFI access-points use a single channel at both 2.4 GHz and 5 GHz, the CloudRAN radio units will be operating at approximately 6.2 times less radiated power than the current WIFI deployment. This is also one of the objectives of the experimental activity, namely to show that CloudRAN type (or ultra-dense) deployments are significantly more power-efficient and moreover also

[7] Please see Section 6.2, Table 6.2.1, of 3GPP Specifications 36.104 (Base station Radio Transmission and Reception)

reduce the power emission levels of the user-equipment (cell phones) because of an increased number of receivers per square-meter. Even if we were to add a second channel in Band 42/43 (3.5 GHz) in the future, the CloudRAN deployment will still radiate half the power of EURECOM's current WIFI system when in close proximity to a radio-unit and thus should not be a concern from a sanitary perspective. The outdoor unit will also operate in Band 38 (2.5 GHz) with a transmit power not exceeding 10 Watts EIRP and comprise both EURECOM and Nokia RF (standard-compliant) equipment.

2.2.2 5G Platform capabilities & Roadmap

Services Capabilities
The 5GEVE site managed by EURECOM on the SophiaTech campus aims to provide experimental 5G services including so-called Enhanced Mobile Broadband (eMBB) and massive machine-type communications (mMTC), while uRLLC features (new numerology, and short TTI) are expected to be supported end of 2020.
The experimental facility has also been proposed for use in international verticals such as the capability to be used for the communication of Drones. This initiative will likely make use of EURECOM's infrastructure remotely in order to test open-source contributions from major industry and showcase them integrated with OAI on EURECOM's 5G infrastructure.

Radio Access Networks
The test network architecture is highly heterogeneous including in addition to LTE and 5G PoC technologies wireless technologies such as IEEE 802.11, Bluetooth Low energy, LoRa, NB-IoT, UWB and LTE evolutions like LTE-M and LTE-U.

MEC and Orchestration Capabilities
EURECOM also contributes its ETSI compliant MEC platform and orchestration components, including a minimal-footprint Edge VIM developed by EURECOM on top of lxc/lxd, offering a REST NBI for onboarding, instantiation and lifecycle management operations of edge application instances. The Mobile Edge Orchestrator is implementing the ETSI MEC 010-2 specification for the interface towards the OSS/BSS (Mm1 reference point). It can operate on top of the above VIM (Mm4 reference point) but also OpenStack. It supports traffic redirection/offloading services (Mp1 and Mp2 reference points), and a Radio Network Information Service (Mp1 and Mp2 reference points), using RESTful and publish subscribe APIs. Finally, a network slice orchestrator has been implemented, supporting full (programmable RAN, virtualized core and transport) end-to-end slices.

2.2.3 Existing interfaces to access the facility

The initial interface's model to access the 5GEVE platform has been defined as follows:

- Interface for the Multi-Site catalogue, where it is stored all the information related to Networks Service Descriptors (NSDs) and VNF Descriptors (VNFDs) that can be used by the 5G EVE portal for the provisioning of single-site and multi-site vertical experiments.
- Interface for the Multi-Site Inventory, which is the component in charge of maintaining the status of the Network Services instantiated in any of the 5G EVE sites. The Multi-site Inventory is fully managed by the Multi-site Network Service Orchestrator, who is in charge of notifying of all the changes that have to do with service provisioning.

- Interface for the data collection manager, which is the component responsible for the collection and persistence of all the network and vertical performance metrics that are required to be gathered during the execution of experiments, with two objectives: monitor the experiment and validate the targeted KPIs.
- Interface for the runtime configurator, which is the component intended to apply tailored runtime configurations to the provisioned end-to-end VNFs and PNFs for supporting the Vertical use case experiments, acting as Day-2 configurator.

More details of these interfaces has been defined in a 5GEVE deliverable [RAM18]. As its name indicate, it is just a first model, which will be refined and more detailed in the future. The final description of the interfaces is expected by the beginning of 2020.
5G-EVE will support different 5GDrone UC: UC1-scenario1related to the UTM command and control application, UC2-scenario1 and UC2-scenario2 related to the safety.

2.3. 5GTN infrastructure (UO)

In addition to ICT-17 facilities, 5G!Drones will make use of additional trial sites to evaluate UAV use cases and validate the underlying KPIs.

5GTN represents 5G test network developed and deployed in Oulu, Finland, together with different partners that are closely involved in the development and specification of the 5G technology. The test network targets to serve various application developers by providing extensive test facilities in a carrier-grade state-of-the-art network. 5GTN includes the University of Oulu campus, VTT and the technology village together with several distant locations around Oulu, for example, Oulu University Hospital Test Lab and Nokia factory.
Additionally, outside Oulu Region, Ylivieska test network with approximately 15 base stations was connected to 5GTN at the end of 2017. Another two distant locations are Ii Micropolis and Sodankylä airport, where 5GTN is utilised for testing vehicles in winter conditions and in general, for future self-driving technology. The locations 5GTN covers can be seen in Figure 21. Overall, 5GTN has close to 50 on-air base stations around northern Finland in an area with 450km distance between the two farthest remote locations.

2.3.1 Site topology & 5G Architecture

The network architecture depicted in Figure 20 includes the currently existing assets (green and white) as well as during 2018 upcoming assets (orange). The current 5GTN uses technologies including 3GPP specified evolved packet core elements and LTE radio access technology, with a special emphasis on small cell-based solutions. The first 5G proof-of-concept (5G-PoC) devices are also an integral part of the network.

The network is controlled by operator grade EPC (Evolved Packet Core) and which makes the University of Oulu in practice a network operator. The network within the campus is being complemented by a wireless sensor network (IoT, internet of things) extension with estimated 1000 small form factor IoT platforms with different kinds of sensors and wireless connectivity. Furthermore, big data computing servers for network data analytics purposes complement the network. Some of these servers are distributed within the network thus allowing mobile edge computing as well as caching services.

The Nokia EPC runs in a virtualized environment connected to application creation environment with open application programming interfaces, which make it possible to integrate new services to e.g. network management and IoT applications, which thus can be integrated as a part of the whole network offering the experimental environment for research also in data acquisition, cloudification, and analytics.

The test network architecture is highly heterogeneous including in addition to LTE and 5G PoC technologies wireless technologies such as IEEE 802.11, Bluetooth Low energy, LoRa, NB-IoT, UWB and LTE evolutions like LTE-M and LTE-U.

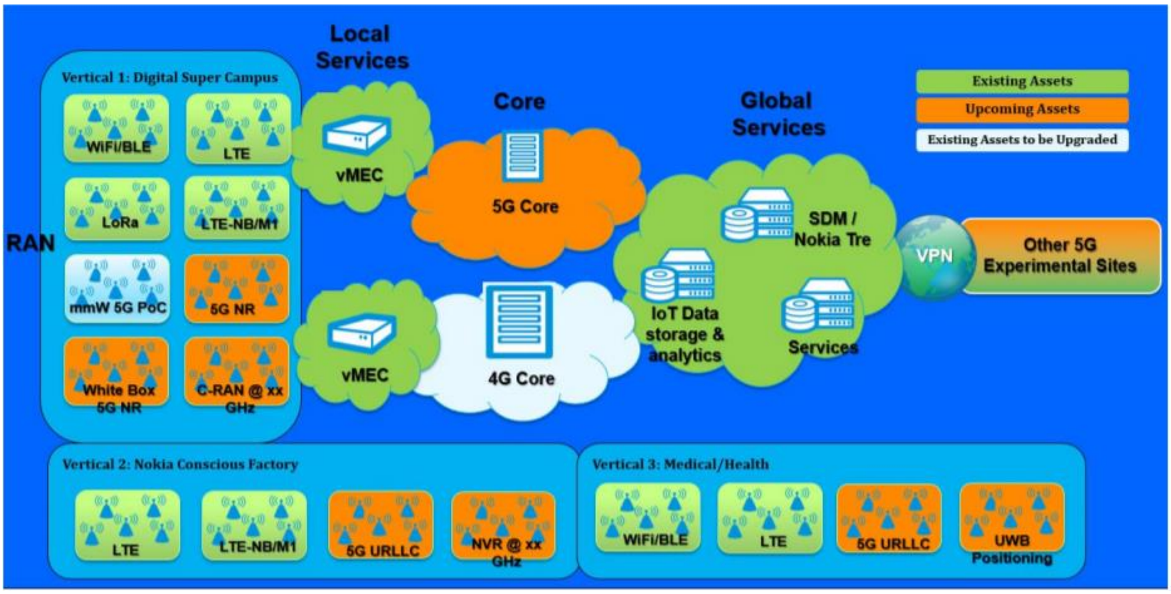


Figure 20: 5GTN architecture including existing and upcoming assets.

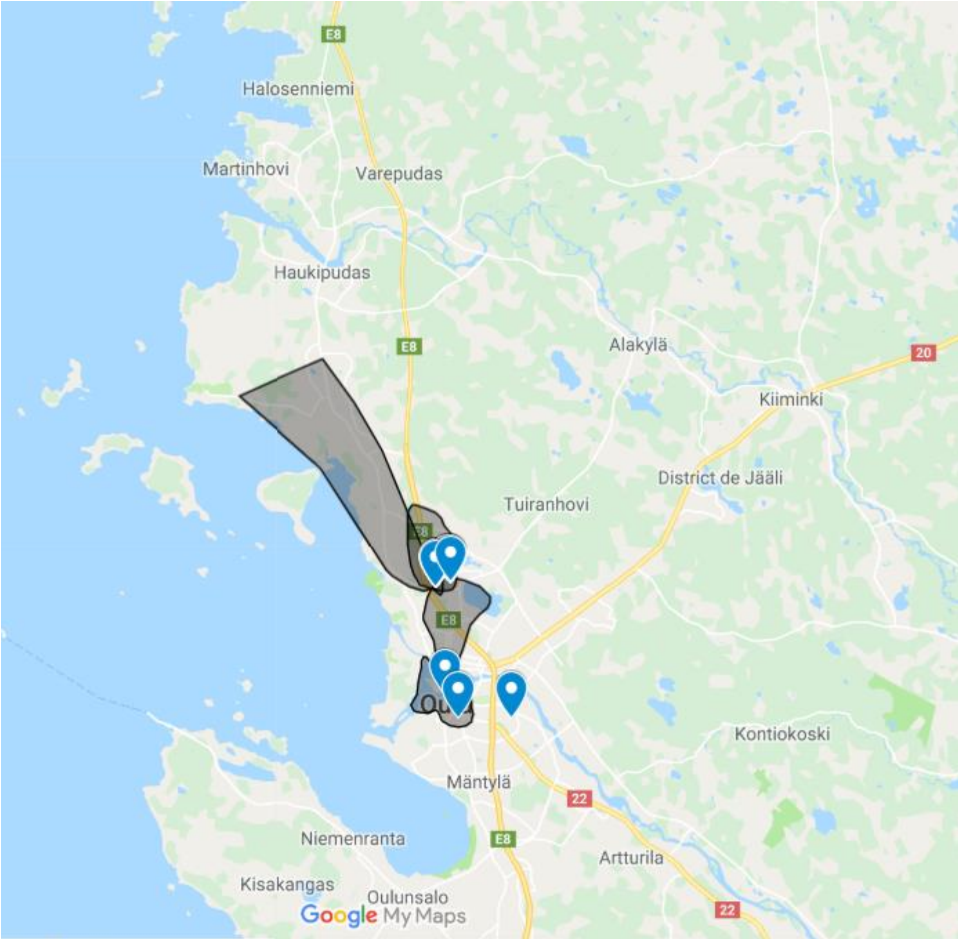


Figure 21: 5GTN coverage.

Virtual Multi-access Edge Computing (MEC) deployed in the test network enables service creation environment for low latency services complemented with location and privacy awareness. It also provides mobility and streaming data analytics with real time applications. Edge computing supports heterogeneity. Furthermore, the EPC core of 5GTN controls a licensed shared access (LSA) environment (CORNET network) included in the environment.

2.3.2 5G Platform capabilities & Roadmap

Radio Access Networks

Both test sites of the 5GTN currently deploy one macrocell and six small cell eNodeBs (eNB). The macrocells are installed outdoors, while the small cells are indoor installed. The eNBs operate in an LTE band 7 (2.6 GHz) and are based on the Frequency Division Duplexing (FDD) scheme. The near future plans are to deploy 3.5 GHz equipment and bring first proof of concept 5G radio equipment to the network.

Interoperability with WLAN networks was specified to 3GPP standards already in Release 8. Integrating WLAN networks both as trusted and un-trusted access into the 5G test network according to the 3GPP specifications are in near future plans. However, the transmission resources of WLAN networks can already be exploited in the test network through Layer-3 mobility protocols, such as Mobile IP (MIP), and multi-path protocols, like Multi-Path TCP (MPTCP).

Currently, the test network implements a pre-commercial 2 LTE-M capability (Category-0). Some LTE-M features are already standardized, while some other are still work in progress. However, the overall aim of LTE-M is to connect constrained IoT devices by exploiting the existing LTE infrastructure. Lower resource consumption of LTE-M compared with regular communications is obtained through a narrower bandwidth (1.4 MHz/200 kHz) and advanced power save modes. LTEM provides also enhanced coverage, reduced hardware costs, and simplified signaling.

Cloud Core

The core network entities run on an OpenStack cloud environment. In the first phase of the test network development, System Architecture Evolution Gateway (SAE-GW) and Mobility Management Entity (MME) are installed. The rest of the core network functionality runs from a remote core network, located at Nokia's premises in Tampere, Finland. The remote core network is connected over a Virtual Private Network (VPN) tunnel. However, as SAE-GW and MME run locally in the test network, all data traffic and most of the control traffic stays within the local network, in both VTT's and CWC's test sites separately.

MEC capabilities

The MEC functionality in the test network will be based on Nokia's MEC solution. The MEC concept is one of the key services in 5G. It allows third-party service providers to bring their services and service-specific functions close to users through standardized interfaces and an open architecture. As the services can be brought to RANs, MEC can result in lower delays and more efficient exploitation of network capacity. Being based on the cloud concept, MEC capabilities can be made dynamic and scalable.

MEC enables a lot more possibilities for application developers in mobile networks. When a service or, for example, a service-specific feedback system is very close to the users, control of service quality can be made efficient. Also, transmission resources for the end users' wireless links that typically act as bottlenecks in terms of capacity can be controlled better on application requirement basis. One example could be over the-top video content providers with CDNs. Instead of using CDN edge servers physically located in a remote cloud system, edge servers could be deployed in a MEC system with a cache containing the most used content in the area covered by base stations driven by the MEC system.

IoT Integration

The testbed provides also access points to Machine Type of Communication (MTC) systems and support the testing of different IoT scenarios and concepts. One of the key components in the integration of IoT systems to 5GTN is an IoT Gateway (IoT-GW) solution, shown in Figure 20. It enables utilizing different radio technologies used in different IoT systems, unifying the very heterogeneous IoT device set. The gateway software provides a plug-and-play style of integration for the southbound information collection interfaces (toward IoT devices) as well for the northbound interfaces for distributing the information to other entities and cloud systems.

Both IPv4 and IPv6 routing are supported in the gateway together with various data transfer protocols such as HTTP and Constrained Application Protocol (CoAP). The gateway supports a number of different radio technologies including Bluetooth, IEEE 802.15.4 ZigBee, LTE and LTE-M, IEEE 802.11 WLAN, and also the 868 MHz radio used, for example, by Enocean sensors. The proof of concept implementation and scenario realization of IoT-GW have also been done with VTT's Tiny Node sensors. IoT-GW acts as a point-of-attachment between the 4G/5G access network and various sensor networks beyond the gateway. The gateway software enables virtualization of its different components. In addition, the gateway software can take advantage of MEC technologies with regards to data processing carried out at the gateway. The gateway filters unnecessary data at the edge of the wireless core network and sends only necessary and/or processed data to the network. MEC technologies enable also creating dedicated services where data does not go further than a respective MEC module in order to improve data privacy, e.g. in factory environments.

2.3.3 Existing interfaces to access the facility

The Oulu 5GTN has interfaces that are vendor specific at the moment, hence all interfaces to the facility can only be accessed by the equipment supplier. However, we are working to ensure different interfaces within the network can be accessed by other platforms or facilities in the future.

2.4. AALTO X-Network (AU)

The trial site provided by Aalto University, X-Network, is part of the Finnish national project 5GTNF[8] (5G Test Network Finland). The facility is incrementally built throughout several research projects with academic and industrial partners. It offers trialing support and tailored infrastructure configurations for telecom, vertical industries and scientific community.

2.4.1 Site topology & 5G Architecture

The X-Network trial site is located within the Otaniemi campus of Aalto University (5.2 km^2 wide coverage). The test network offers external companies the possibility to deploy and test 5G-oriented services/features, such as, multi-tenancy mobile operators, network slicing and mobile edge computing. Companies can run their experimental software either in the Aalto Data Center or from their own site via a virtual private network. X-Network is developed and maintained in collaboration with Aalto University, VTT Technical Research Center of Finland and Nokia. It is also connected to other test networks (10 Gbps links) in different locations (i.e., Kumpula, Oulu and Tampere) over the Finnish Universities Networks (FUNET), which is a fiber-based backbone network. The site includes 4G/LTE eNBs, 5G NR gNBs, EPC, 5GC and MEC platforms. Figure 22 depicts the current setup of the base stations in the campus.

[8] http://5gtnf.fi/

Figure 22: X-Network pre-deployment trial site.

2.4.2 5G Platform capabilities & Roadmap

Table 4: X-network infrastructure capabilities

Component	Product/Technology
5G UE/ 4G UE	• 5G UEs to be acquired • Various 4G dongles
5G NR gNB/ 4G LTE eNB	• Nokia AirScale gNB • Nokia LTE • Ericsson NB-IOT
Spectrum	Aalto University has been granted by national regulatory authority, Traficom, the license to 3.5Ghz for 5G test networks
Core network	• Nokia core • Aalto EPC • CMC core
Datacenters and virtualized infrastructure	Virtualized Infrastructure Manager (VIM) • VIM interface (OpenStack API) • Dashboard (Horizon) • Compute (Nova) • Network management (Neutron) • Identity (Keystone)

	Dell PowerEdge compute servers
Transport	• SDN switch (Juniper MX and SW based OVS) • SDN switch (Coriant 8500) • Controller Ryu • The connections between eNB/gNB based on fiber converge in SDN-ready Juniper MX204 edge routing platform with capacity up to 400Gbs where MEC platform is available
MEC	• Nokia MEC • Open MEC platform

Radio Access Network

The X-network trial site operates 4G/LTE eNBs deployed by Nokia in band 7 (FDD 2.6 GHz). The eNB are deployed outdoor as well as indoor. The 5G NR gNBs antenna are Nokia AirScale massive MIMO Adaptive Antenna (MAA) systems. These include a 5G RF unit with an integrated antenna with 128 antenna elements. The antennas support up to 16 MIMO steams/beams. The operating frequency range for the antenna is 3.6 – 3.8 GHz and maximum carrier bandwidth supported is 100 MHz. Furthermore, higher order modulations of up to 256 QAM and 64 QAM are supported in the downlink and uplink, respectively. The baseband unit for the gNB is the Nokia AirScale System Module. Aalto University has been granted by national regulatory authority, Traficom, the license to 3.5GHz for 5G test networks as well as PLMN from 50 to 59. Figure 23 depicts some picture on the deployed gNB in the campus of the university.

Figure 23: Aalto gNB installation in the campus.

In addition, the site also includes a NB-IoT test network (FDD 700 MHz). The platform has been used to support the IoT hackathon 2019 event, hosted by Aalto University. Figure 24 depicts a picture on the installation of the eNB and the area of coverage.

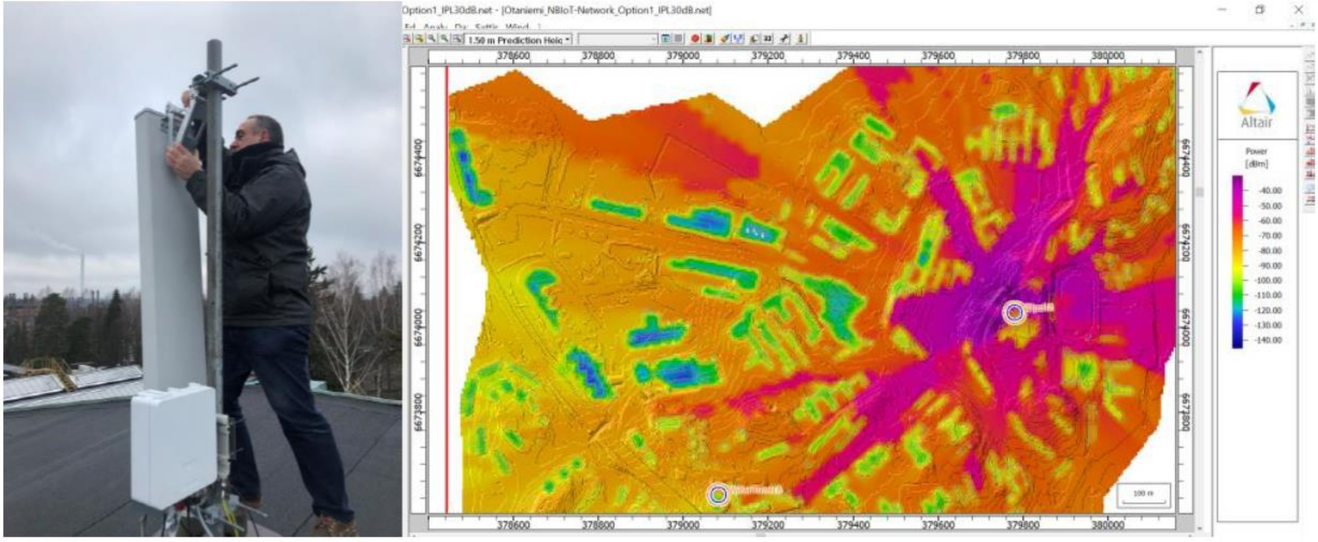


Figure 24: Aalto NB-IoT eNB installation in the campus.

Core network

The core network includes three different virtualized EPC core network implementations which are Nokia core, Aalto core and CMC core (Cumucore). The latter implements a prototype of 5G core architecture including AMF, SMF, UPF, NSSF and NRF. The core network will be running in a datacenter located at the campus.

Multi-access Edge Computing

The connections between eNB/gNB is based on fiber converge in SDN-ready Juniper MX204 edge routing platform with capacity up to 400Gbs where MEC platforms are available. The current testbed includes two MEC platforms. The first MEC is provided by Nokia which is connected to the switch where all the eNB and gNB are connected directly through fiber. Another MEC platform is based on SDN and Linux based virtualization system to run services and applications. This open MEC platform is using SDN to redirect the connections from selected users to the MEC platform where the applications are running. Figure 25 depicts a view of the current network deployment at Aalto University.

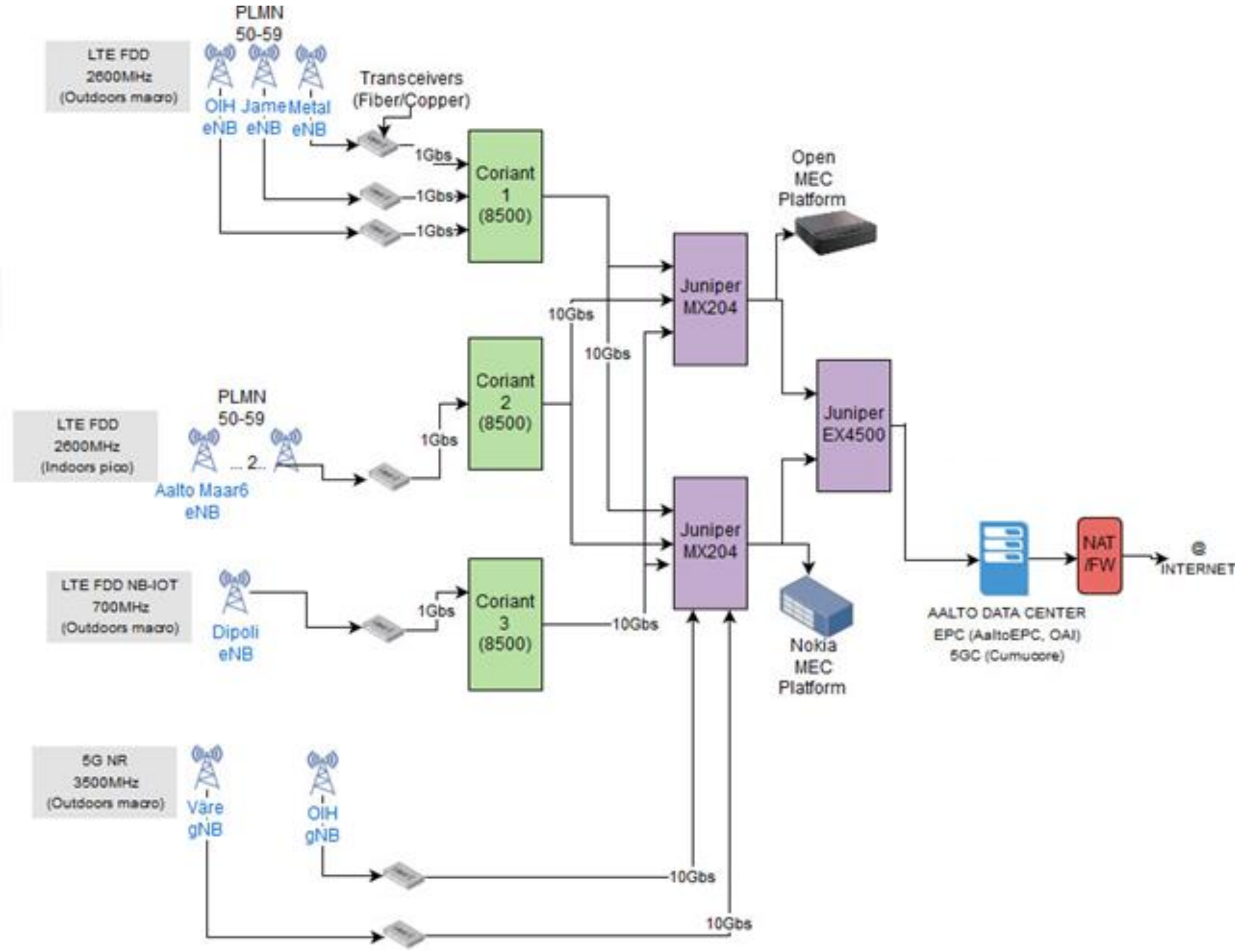


Figure 25: A view of the current/planned network deployment at Aalto University.

2.4.1 Existing interfaces to access the facility

The X-Network facility of Aalto University includes different technologies which are already deployed (4G/LTE eNBs, NR gNBs, 5GC and MEC platforms). However, the current setup can be configured only manually and on site. Although this can be used to accommodate different use cases by pre-configuring the facility as per the target scenarios, the management interfaces would enable more advanced functionalities and also the interaction with the upper layers. Aalto University is developing an orchestrator for enabling end-to-end slicing. Different levels are considered including RAN, transport and datacenters/MECs platforms.

3. MAPPING OF USE CASES TO FACILITIES/PLATFORMS

3.1. UTM 1: Target Platforms, Deployment Objectives & Requirements

This use case will demonstrate a common functionality for all UAV applications, by providing the necessary safe and secure incorporation of drones into the air traffic. The need for UTM systems has been driven by a number of factors such as the recent increase in the number of drones in the airspace, increasing involvement of different governments and emerging regulations, as well as collaboration of key stakeholders for the development of a working architecture.

3.1.1 EURECOM Deployment

3.1.1.1 Objectives, Requirements and Target KPI

In this scenario, we aim to demonstrate a UAV traffic command and control application, which will manage a high number of flying drones. It includes Beyond Visual Line of Sight (BVLoS) drone operations, and entails long-range commercial drone control, for applications such as drone delivery. The command and control application will demonstrate features such as automatic collision avoidance of drones, especially those flying in swarm, which requires sending large amounts of data in near real time to assess the potential risks in the sky and enable an enhanced flight awareness of all types of flying objects. Particular efforts will be drawn in this scenario to the security and integrity of command and control traffic. Indeed, ensuring that a malicious third party is not capable of taking control of operating drones is essential to deploying such unmanned device in urban and critical environments. In addition, one BVLoS application enables secure controlling of the drone (telepresence) using the VR/AR equipment.

Telepresence could be realized in two ways: first person and third person view. First person view may cause motion sickness in the operator/user, even regardless of latencies that could be made small. For this reason, we prefer third person view. This choice is also more appropriate for the case of control or supervision of multiple drones. To simplify the language, in the following description, we will present the case of a single drone, but all can be extended to the case of multiple UAVs. The current location of the drone, the actual covered path (based on previous positioning) as well as the planned path are visualized in the world's digital twin, a replica of the actual environment the drone is moving in. The position of a ground vehicle on a surface is more obvious to an observer, so to achieve a better information about the altitude of an aerial vehicle, a "plumb line" from the drone can be drawn in the digital twin. The virtual world can be scaled, and its central focus point can be translated to allow covering the region of interest and presenting the desired detail level. The viewpoint can also be changed [TIK17]. Already existing custom-made and/or openly available 3D data can be used here. For example, the National Land Survey of Finland[9] has made freely available spatial data from aerial images and laser scans.

In this use-case scenario, the network needs to provide i) a cross-domain network slice for UAV traffic control – a uRLLC slice able to reduce delay and having a high priority; ii) in addition to low latency and high priority, this slice should ensure the authentication of users as well as the integrity and often confidentiality of the conveyed control traffic – in particular, end to end

[9] https://www.maanmittauslaitos.fi/en

encryption of the slice can be a solution that would protect a third party from taking control of the drone; iii) a UAV control applications hosted at the edge; and iv) the possibility to have D2D communications in licensed or unlicensed spectrum (Wi-Fi).

To conclude, the 5G EVE platform will be utilised targeting application components with low-latency requirements, taking advantage of its edge computing and network slicing capabilities, and the 5G features that are currently under deployment based on OpenAirInterface. Regarding the UTM Command and Control scenario, the 5G-EVE computing infrastructure hosted at its trial facility in Sophia Antipolis will be used to deploy various software components as MEC applications. These include advanced anti-collision modules that manage large drone swarms, IoT gateway servers that will be able to collect, and process sensor readings transmitted by on-board units, but also potentially multimedia content streamed by UAVs for realizing telepresence. This use-case scenario has both low-latency and high-bandwidth requirements, which will be accommodated by the deployment of multiple parallel network slices of different types (URLLC and eMBB).

Highlights of 5G infrastructure requirements:
• Low latency
• Multiple throughput guarantee
• High connection density
• High throughput bi-direction EDGE
• High throughput bi-direction end2end
• Control over "In the sky" handovers
• Radio visualization & analyses
• Service workload isolation
• Group mobility
• Computing power on EDGE as a Service
• High processing performance
• Platform/system compliance
• Computation and network resource isolation
• Flexible architecture & capacity elasticity
• Large accommodation
• Prioritization and reservation of system

Table 5 summarizes the target 5G and vertical service related KPIs that will be evaluated in this scenario.

Table 5: KPIs that will be monitored in the 5G EVE facility for the UTM 1 scenario

Target 5G KPIs	UAV vertical KPIs
End-to-end latency of < 1 ms	Time of deployment Number of controllable sensors/actuators Perceived Quality of Experience Latency vs. range Area covered Security

	Broadcast to close UAVs Broadcast to all UAVs

Depending on the specific experiment and the decided trial plan, necessary permissions may need to be acquired by the national CAA. As noted, though, the facility is located outside a residential area, and it is possible to carry out recreational UAV flights in LoS without the need for a permit for ranges up to 50m.

3.2. UTM 2: Target Platforms, Deployment Objectives & Requirements

3.2.1. 5GTN Deployment

3.2.1.1. Objectives, Requirements and Target KPI

The 3D mapping and support visualization scenario for the UTM is targeted as solving signal distortion that occurs due to complex shape of cell towers and signal dissipations at high building and uneven terrains. This will require a network infrastructure that will provide the necessary network slices in achieving the 3D mapping. Basically, to support this use case, two network slicing services will be required from the 5GTN network infrastructure. The uRLLC slice will reduce delay and give high priority with reliability to the UAV traffic control and, since large amount of data (video streams) will be transmitted by the drone, a dedicated eMBB network slice with no specified priority will also be required for swift data reception. These two network slices (eMBB and uRLLC) will be run in parallel with enough isolation and reliability to maintain the required performance level. The University of Oulu 5G Test Network (5GTN) will utilize the existing Virtual MEC and the upcoming 5G core to support uRLLC slice services targeted at the UAV traffic control and to provide easy location awareness of the drones. Also, eMBB slice for high data reception will be achieved on the existing 5GTN LTE band 2.6GHz and future NR band 3.5GHz. The orchestration of different slices within the Virtualized 5GTN core network will be achieved with OSM.

Table 6 summarizes the target 5G and vertical service related KPIs that will be evaluated in this scenario.

Table 6: KPIs that will be monitored in the Oulu 5GTN facility for the UTM 2 scenario

Target 5G KPIs	UAV vertical KPIs
End-to-end latency of < 1 ms 1000 times higher mobile data volume per geographical area.	Time of deployment Number of controllable sensors/actuators Perceived Quality of Experience Latency vs. range Area covered Security Broadcast to close UAVs Broadcast to all UAVs

3.2.1.2. Roadmap Alignment

- Trial will be conducted at the University of Oulu.
- Basic set-up for measurement within the 5GTNetwork can be seen in Figure 26.

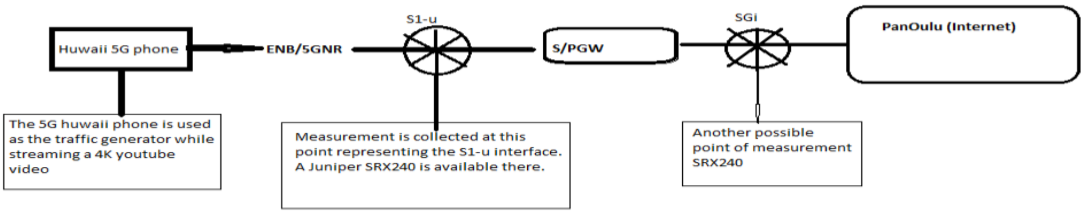


Figure 26: Basic Network setup in 5GTN.

For 3D mapping, (UTM 2)

- Low Latency between trial controller and UAV
- UAV implementation achieved in the University of Oulu
- Oulu 5GTN MEC server will be used for video processing
- Trial Implementation will be carried out at location within the 5GTN
- 5G requirement include the following:
    - Low latency
    - Multiple throughput guarantee
    - High connection density
    - Large variation of communication volume
    - High throughput bi-direction EDGE
    - High throughput bi-direction end2end
    - Control over "In the sky" handovers
    - Radio visualization & analyses
    - Service workload isolation
    - Group mobility
    - Computing power on EDGE as a Service
    - High processing performance
    - Network segmentation with high security
    - Platform/system compliance
    - Computation and network resource isolation
    - Flexible architecture & capacity elasticity
    - Large accommodation
    - Prioritization and reservation of system

The remaining part of this section is comprehensively discussed in D1.3.

3.3. UTM 3 Target Platforms, Deployment Objectives & Requirements

3.3.1. X-Network Deployment

3.3.1.1 Objectives, Requirements and Target KPI

The Drone delivery scenario for the UTM is targeted as solving last-mile delivery. The Mavic2 drone takes one medicament (up to 80gr) from virtual Pharmacy and carries it to the personal drone box. The Matrice 210 drone will deliver e-commerce parcel (up to 1kg) to delivery box. Drones use 5G for low latency communicating with delivery boxes IoT sensors to send information related to delivery and to help dropping off the parcel. Drones streams video over 5G if delivery needs remote control. When flying between houses should be used remote control due to bad-GPS position data.
This will require a network infrastructure that will provide 3 network slices:

1. Drone Command and control (C2)
2. Video stream
3. IoT communication.

The uRLLC slice will reduce delay and give high priority with reliability to the UAV traffic control and, since large amount of data (video streams) will be transmitted by the drone, a dedicated eMBB network slice with no specified priority will also be required for swift data reception. The IoT communication slice will ensure fast and reliable communication with delivery boxes IoT sensors. These three network slices (eMBB and uRLLC and NB-IoT) will be run in parallel with enough isolation and reliability to maintain the required performance level. The Aalto X-network will utilize the existing MEC and the upcoming 5G core to support these 3 slices.
Table 7 summarizes the target 5G and vertical service related KPIs that will be evaluated in this scenario.

Table 7: KPIs that will be monitored in the Aalto X-network facility for the UTM 3 scenario

Target 5G KPIs	UAV vertical KPIs
End-to-end latency of < 20 ms 1000 times higher mobile data volume per geographical area. NB-IoT communication enabled	Time of deployment Location accuracy Video stream quality Video stream latency C2 system latency and reliability Security NB IoT communication latency and quality

3.2.1.2. Roadmap Alignment

- Trial will be conducted at the CAFA Tech with partners.
- Basic set-up for measurement within the X-network for drone delivery (UTM 3)
- Low latency between trial controller and UAV
- UAV implementation achieved in the X-Network
- Aalto MEC server will be used for C2 and video processing

- Trial Implementation will be carried out at location within the X-Network
- 5G requirement include the following:
    - Low latency
    - Multiple throughput guarantee
    - High connection density
    - Large variation of communication volume
    - High throughput bi-direction EDGE
    - High throughput bi-direction end2end
    - Control over "In the sky" handovers
    - Radio visualization & analyses
    - Service workload isolation
    - Group mobility
    - Computing power on EDGE as a Service
    - High processing performance
    - Network segmentation with high security
    - Platform/system compliance
    - Computation and network resource isolation
    - Flexible architecture & capacity elasticity
    - Large accommodation
    - Prioritization and reservation of system

3.4. Public Safety 1: Target Platforms, Deployment Objectives & Requirements

3.4.1. EURECOM Deployment

3.4.1.1. Objectives, Requirements and Target KPI

This scenario involves the transmission of HD video from UAVs to a video processing application hosted at the 5G EVE computing infrastructure, with the purpose of identifying forest fires. As such, it requires a high-throughput wireless link, while at the same time edge computing capabilities are desirable for hosting the video analysis application as close to the drone as possible. During the rollout of this scenario, using the orchestration APIs available by the 5G EVE facility, the video analysis application will be dynamically instantiated on top of the 5G EVE infrastructure with the appropriate amount of compute resources to match the application’s processing requirements. An eMBB slice will guarantee the necessary amount of radio resources to sustain the transmission of HD video, and this will be deployed in parallel with a traffic control URLLC slice with strict isolation and security requirements.

5G infrastructure requirements:
• Low latency
• Multiple throughput guarantee
• High connection density
• High throughput bi-direction EDGE
• High throughput bi-direction end2end
• Control over "In the sky" handovers
• Radio visualization & analyses

• Service workload isolation
• Group mobility
• Computing power on EDGE as a Service
• High processing performance
• Platform/system compliance
• Computation and network resource isolation
• Flexible architecture & capacity elasticity
• Large accommodation
• Prioritization and reservation of system

The KPIs that will be evaluated in this scenario are summarized in Table 8.

Table 8: KPIs that will be monitored in the 5G EVE facility for the Public Safety 1 scenario

Target 5G KPIs	UAV vertical KPIs
End-to-end latency of < 1 ms 1000 times higher mobile data volume per geographical area.	Time of deployment Perceived Quality of Experience for the video stream and accuracy of detection Latency vs. range Area covered Security

3.4.1.2. Roadmap Alignment

- The trial will be conducted at the Eurecom site.
- A low Latency between trial controller and UAV is required.
- The Highlights of 5G infrastructure requirements are as follows:
  • Low latency
  • Multiple throughput guarantee
  • High connection density
  • High throughput bi-direction EDGE
  • High throughput bi-direction end2end
  • Control over "In the sky" handovers
  • Radio visualization & analyses
  • Service workload isolation
  • Group mobility
  • Computing power on EDGE as a Service
  • High processing performance
  • Platform/system compliance
  • Computation and network resource isolation
  • Flexible architecture & capacity elasticity
  • Large accommodation
  • Prioritization and reservation of system

3.5. Public Safety 2: Target Platforms, Deployment Objectives & Requirements

3.5.1. EURECOM Deployment

3.5.1.1. Objectives, Requirements and Target KPI

Focusing on disaster recovery, this scenario involves the boarding of 5G small cells on UAVs in order to provide coverage in an underserved area in case of a disaster. A number of UAVs deployed around the 5G EVE premises will be using D2D links to connect with a (mobile) ground station which in turn provides a wireless backhaul towards the fixed 5G EVE RAN infrastructure, offering connectivity extensions and communication services to rescuers and potential victims. UAVs equipped with sensors such as thermal and high definition cameras will be used, respectively, to detect victims and stream real-time video to a control room to help coordinate the efforts of rescuers. As in the other use cases, these applications should coexist with time-sensitive UAV traffic control ones and their components will be hosted in MEC servers in the 5G EVE facility.

5G infrastructure requirements:

- Low latency
- Multiple throughput guarantee
- High connection density
- High throughput bi-direction EDGE
- High throughput bi-direction end2end
- Control over "In the sky" handovers
- Radio visualization & analyses
- Service workload isolation
- Group mobility
- Computing power on EDGE as a Service
- High processing performance
- Platform/system compliance
- Computation and network resource isolation
- Flexible architecture & capacity elasticity
- Large accommodation
- Prioritization and reservation of system

The KPIs to be evaluated in this scenario are summarized in Table 9.

Table 9: KPIs that will be monitored in the 5G EVE facility for the Public Safety 2 scenario

Target 5G KPIs	UAV vertical KPIs
End-to-end latency of < 1 ms 1000 times higher mobile data volume per geographical area.	Time of deployment Perceived Quality of Experience for the video stream and accuracy of detection Latency vs. range Area covered Security

3.6. Public Safety 3 Police scenario Target Platforms, Deployment Objectives & Requirements

3.6.1. 5GTN Deployment

3.6.1.1. Objectives, Requirements and Target KPI

The use case scenario demonstrates how to remotely pilot and use video analytics for Police tasks, including C-UAS using remote control and video streaming thanks 5G communication.

Police operates with 2 drones: one drone is equipped with 5G smartphone which provides 4K video streaming and second (C-UAS) drone which commands being forwarded over 5G to drone controller. Police are preparing for VIP visit. No Fly Zone is established. Police uses drone that automatically control the areas and stream 4K video to MEC solution and to Police Command Centre where servers automatically analyzing situation (using machine learning algorithm. Also, IoT based ground cameras- sensors send data from some expected hotspots. For machine analyzing 4K video is essential. AI algorithms detects a suspicious activity. Then Police drone detects intruder drone in NFZ. Command Centre take over drones and starts remotely piloted flights to affecting intruder drone and pilot of intruder drone.

This Use case involves monitoring real time event, hence it needs a dedicated uRLLC slice. It also involves transmission of large video data, hence requires a dedicated eMBB slice. Finally, it will need a dedicated mMTC slice since the drones uses IoT telemetry from local IoT devices, which involves ultra-reliable machine type communication. the video processing will be achieved at the cloud using MEC capabilities. To achieve this trial, a network infrastructure that supports the necessary slices and functionalities in this use case is required. The Oulu 5GTN will provide a dedicated MEC server for video process before forwarding data to the cloud, this will reduce the latency extensively. The Oulu 5GTN will utilize the upcoming 5G core to support uRLLC slice services targeted video transmission from deployed locations of drones to the police control center. The dedicated eMBB slice for high data reception will be achieved on the existing 5GTN LTE band 2.6GHz and future NR band 3.5GHz and finally a dedicated mMTC slice for using IoT data from different IoT devices

The orchestration of different slices within the 5GTN virtualized CN will be achieved with OSM.

5G infrastructure requirements:

- Low latency
- Multiple throughput guarantee
- High connection density
- Large variation of communication volume
- High throughput bi-direction EDGE
- High throughput bi-direction end2end
- Control over "In the sky" handovers
- Radio visualization & analyses
- Service workload isolation
- Group mobility
- Computing power on EDGE as a Service
- High processing performance
- Network segmentation with high security
- Platform/system compliance

- Computation and network resource isolation
- Flexible architecture & capacity elasticity
- Large accommodation
- Prioritization and reservation of system

The KPIs to be evaluated in this scenario are summarized in Table 10.

Table 10: KPIs that will be monitored in the 5GTN facility for the Public Safety 3 scenario

Target 5G KPIs	UAV vertical KPIs
End-to-end latency of < 20 ms 1000 times higher mobile data volume per geographical area. Bandwidth Use number of IoT devices	Time of deployment Perceived Quality of Experience for the video stream and accuracy of detection Number of controllable IoT devices Perceived Quality of Experience Security Latency vs. range Area covered Security

3.7. Situation Awareness 1 Target Platforms, Deployment Objectives & Requirements

3.7.1. 5GTN Deployment

3.7.1.1. Objectives, Requirements and Target KPI for Sub-scenario 1

This situation awareness use case sub-scenario involves using 2 UAVs (DJI Mavic and Matrice 600 or 210), to take photos and collect of LIDAR data. LIDAR is a method use for measuring distance to a point or target by illuminating the target with laser light and afterwards measuring the reflected light with a programmed sensor. The data form LIDAR sensor is then processed into a 3D map. The 5G base station are planned on the 3D map and the propagation of 5G coverage is then analyzed through the 3D environment. Thus, the trial focuses on measuring 5G QoS in a 3D environment. The 5GTN infrastructure and implementation environment will be used to achieve this use case. First a dedicated uRLLC slice will be allocated low latency transmission of the terrain, the photos will be process at the 5GTN existing virtual MEC.

5G infrastructure requirements:

- Low latency
- Multiple throughput guarantee
- Large variation of communication volume
- High throughput bi-direction EDGE
- High throughput bi-direction end-to-end

- Control over "In the sky" handovers
- Group mobility
- Computing power on EDGE as a Service

The KPIs to be evaluated in this scenario are summarized in Table 11.

Table 11: KPIs that will be monitored in the 5GTN facility for the situation awareness 1, sub-scenario 1

Target 5G KPIs	UAV vertical KPIs
End-to-end latency < 1 ms Bandwidth MEC computing for 3D mapping	Time of deployment Number of controllable IoT devices Perceived Quality of Experience Security Latency vs. range Area covered

3.7.1.2. Objectives, Requirements and Target KPI for Sub-scenario 2

This situation awareness use case sub-scenario involves the use of a drone (Hepta FX-20) in taking photos, videos and collection of LIDAR data. The collected data are processed to detect defects on overhead medium voltage power lines. Thus, this sub-scenario performs long-range power line inspection. with the aid of a 5G technology, all the collected data can be processed at the MEC and transmitted with very low latency less than 1ms, to give a perfect image forming. The 5GTN infrastructure and implementation environment will be used to achieve this use case. First a dedicated uRLLC slice will be allocated low latency transmission of the terrain, the photos will be process at the 5GTN existing virtual MEC.

5G infrastructure requirements:

- Low latency
- Computing power on EDGE as a Service
- Multiple throughput guarantee
- Large variation of communication volume
- High throughput bi-direction EDGE
- High throughput bi-direction end2end

The KPIs to be evaluated in this scenario are summarized in Table 12.

Table 12: KPIs that will be monitored in the 5GTN facility for the situation awareness 1 sub-scenario 2

Target 5G KPIs	UAV vertical KPIs
End-to-end latency < 1 ms Bandwidth MEC computing for 3D mapping	Time of deployment Number of controllable IoT devices Perceived Quality of Experience Security Latency vs. range Area covered

3.8. Situation Awareness 2 Target Platforms, Deployment Objectives & Requirements

3.8.1. X-Network Deployment

3.8.1.1. Objectives, Requirements and Target KPI

In the scenario “Situation awareness 2”, UAVs will be used to collect IoT data. A number of drones will be considered each equipped with a set of IoT devices (e.g., camera, temperature sensors, humidity sensors, etc.). In order to support this scenario, two network slices will be considered by the trial facility. An uRLLC slice for supporting command and control communication with the UAVs and a mMTC (or eMBB) slice for the data collected by the IoT devices on-board of the UAVs. Moreover, edge computing resources will also be considered to host the control service of the UAV and support the uRLLC slice. The edge server will also host the aggregation service of the collected data from the IoT devices. The X-Network facility will be considered for the trial of this scenario and will make use of the available resources in terms of RAN, MEC and the virtualized CN. The target 5G KPIs and the UAV vertical KPIs are summarized in Table 13.

Table 13: KPIs that will be monitored in the X-Network facility for the situation awareness 2 scenario

Target 5G KPIs	UAV vertical KPIs
End-to-end latency < 1 ms Bandwidth	Time of deployment Number of controllable IoT devices Perceived Quality of Experience Security Latency vs. range Area covered

3.9. Situation Awareness 3 Target Platforms, Deployment Objectives & Requirements

3.9.1. 5GTN Deployment

3.9.1.1. Objectives, Requirements and Target KPI

This situation awareness scenario involves location of UE in a locality where global navigation satellite system is not working to support UAV operation. Thus, a flying UAV will collect data for 5G services within the area and collected data will be further analyzed for map creation. Basically, to support this use cases, more than two network slicing services will be required from the network infrastructure. A uRLLC slice will be required for minimal transmission delay and increase priority for UAV traffic control and, since large amount of data (video streams) will be transmitted by the drone, a dedicated eMBB network slice with no specified priority will be required for swift data reception from the drone. Also, other slices can be created to cover services. The University of Oulu 5G Test Network (5GTN) will utilize the existing Virtual MEC and the upcoming 5G core to support uRLLC slice services targeted at the UAV traffic control and to provide prompt analysis of the UE location and the coverage area within the 5GTN edge. drones. Also, eMBB slice for high data reception will be achieved on the existing 5GTN LTE band 2.6GHz and future NR band 3.5GHz. The orchestration of different slices within the 5GTN virtualized CN will be achieved with OSM.

Table 14 summarizes the target 5G and vertical service related KPIs that will be evaluated in this scenario.

Table 14: KPIs that will be monitored in the Oulu 5GTN facility for the situation awareness 3 scenario

Target 5G KPIs	UAV vertical KPIs
End-to-end latency of < 1 ms 1000 times higher mobile data volume per geographical area.	Time of deployment Perceived Quality of Experience for the video stream and accuracy of detection Security Latency vs. range Area covered

3.10. Connectivity during crowded event, Target Platforms, Deployment Objectives & Requirements

3.10.1. 5GENESIS Deployment

3.10.1.1. Objectives, Requirements and Target KPI

This use case scenario focuses on connectivity during crowded events. We will showcase how UAVs with 5G small cells can help to improve and extend connectivity in a highly crowded environment, e.g. a stadium during large event. The UAV will onboard a small cell, and coordinate with the macro cell, to offload traffic to the 5G Core Network.

The scenario will take place at the Egaleo Municipal Football stadium, part of the 5GENESIS Athens trial facility, during a crowded event, e.g. football match, football training session or other sporting activities. The event will have a significant number of attendants, with several 5G UE devices to demonstrate the capabilities of the 5G!Drones system. Spectators will connect to the locally deployed 5G network, part of the 5GENESIS Athens site, at the stadium. As more spectators connect to the network, it will increase the load in the link, and the performance will degrade. In this step, 5G equipped drones, with 5G small cells on board, will be deployed in order to enhance the connectivity capabilities of the current infrastructure.

The demonstration assumes that the Egaleo municipality, (which is frequently in charge of cultural events, either of athletic nature in its stadium, or music concerts and other performances in its parks and open air theatres, as well as parades in the city centre), shall own and operate a portable UAS system comprising of UAVs, small 5G cells and other communication equipment necessary to support the broadcast and connectivity requirements required to guarantee the smooth event operation, independently of the location. At the same time, as the event will have a significant number of attendants, a “hotspot” traffic profile needs to be supported, to deal with the high user density at restricted in size areas. The perceived UAS mobile unit can also help enhance the connectivity service offered to the spectators through the 5G small cell that it will on-board. The trial for this demonstration shall be executed on the Egaleo stadium during a football match of the Egaleo city team.
The portable system to be deployed will consist of UAVs with 5G small cells on board that will be deployed on top of the current infrastructure. One drone, dedicated for patrolling shall scan the area, provide video feed to the event organizers and have the capability to relay alerts based on sensor or image recognition feedback. Furthermore, some stand-by drones shall be ready to take action based on the incident identified (e.g. large concentration of a fans group in a specific stand of the stadium, fireworks, lack of connectivity). If necessary, the newly deployed small cells will provide additional and enhanced connectivity to current and new users, spread across the football stands. The small cells mounted in the drones, will be distributed across the area, in order to share connectivity evenly and reduce interference noise. Finally, secure communication and authentication are vital to communicate with large variety of devices, and enable secure communication with a group of resource constraint drones, this use case will integrate lightweight orchestration mechanisms that will offer both scalable and high-speed communications.

The scenario requirements in respect to the trial facility are summarized in Table 15.

Table 15: Requirements of the Connectivity during crowded event scenario aligned to the 5GENESIS Athens trial facility

Requirement	Reference Layer	Priority	Description
Open APIs towards the experimenter	Facility	Essential	The facility should expose open APIs enabling the Vertical experimenter to access the facility, define and conduct experiments as well as retrieve the results
Facility capabilities	Facility	Essential	The coordination layer should provide a list of experimental capabilities.

Experiment execution	Facility	Essential	Need to Support faster and more flexible allocation of network resources (E2E Deployment in 90 minutes or less).
Experiment execution	Facility	Essential	The platforms should provide both commercial and experimental UEs with open APIs to allow flexible configuration.
Experiment execution	Facility	Essential	The network shall allow operators to optimize network behavior (e.g., mobility management support) based on the mobility patterns (e.g., stationary, nomadic, spatially restricted mobility, full mobility) of a UE or group of UEs.
Drone experimentation	Drones	Optional	Need to Support faster and more flexible Drone deployment and operation, per needs of the trial demonstration.
Drone operation management	Drones	Essential	The Drones shall be able to provide sufficient control over the stages of experimentation cycle over the deployed 5G network
Experiment Execution	Drones	Essential	The drone should provide standard multimedia transmitting capabilities over IP. The transmission should be end-to-end in terms of 5G, involving all new 5G components (UE, NR and packet core).
	Facility	Essential	The facility should expose open APIs enabling the Vertical experimenter to access the facility, define and conduct experiments as well as retrieve the results
	Facility	Essential	The coordination layer should provide a list of experimental capabilities.
	Facility	Essential	Need to Support faster and more flexible allocation of network resources (E2E Deployment in 90 minutes or less).
	Facility	Essential	The platforms should provide both commercial and experimental UEs with open APIs to allow flexible configuration.

	Facility	Essential	The network shall allow operators to optimize network behavior (e.g., mobility management support) based on the mobility patterns (e.g., stationary, nomadic, spatially restricted mobility, full mobility) of a UE or group of UEs.
	Drones	Optional	Need to Support faster and more flexible Drone deployment and operation, per needs of the trial demonstration.
	Drones	Essential	The Drones shall be able to provide sufficient control over the stages of experimentation cycle over the deployed 5G network
	Drones	Essential	The drone should provide standard multimedia transmitting capabilities over IP. The transmission should be end-to-end in terms of 5G, involving all new 5G components (UE, NR and packet core).

The KPIs that will be evaluated in this scenario are summarized in Table 16.

Table 16: KPIs that will be monitored in the 5GENESIS Athens facility for the Connectivity during crowded event scenario

KPI	Target Values	3GPP Targets
Capacity	>50 Mbps Reach a peak use data rate between 50Mbps and 1Gb/s for specific deployment scenarios and use cases for each user supported in the system. The 50 Mbps as a minimum target value is in line with the 3GPP targets that foresee ~30 Mbps uplink data rate for a 4K video streaming, without audio. Considering that multiple cameras are planned to be used or an 360 camera in order to provide immersive experience for patrolling purposes, the minimum peak rate of 50Mbps is valid for concurrent use of two cameras, while for advanced setups, such as 360 cameras or even 8K cameras, higher data rates are targeted, with maximum up to 1Gbps.	3GPP consolidated KPIs for UAV considers an uplink data rate between 4MBps and 9MBps for video streaming for the provision of HD video streaming. Considering the case of 4K video, the target value is increased further, reaching 30 Mbps (since 3GPPP recommends 120Mbps for a 4*4K surveillance system)

Latency	>= 10 ms Latency is important for the accurate control of the UAV in the case controlling it over the mobile network (e.g. with 5G radio interface). Considering that various parameters may influence the KPI value, such as the height and the speed of the drone, an average case for control latency requires 20 msec delay according to the 3GPP target values for different services, such as 8K video live broadcasting, Laser mapping and HD patrol surveillance and remote UAV controller through HD video. Considering also the uRLLC capabilities of 5G networks, the target KPI for the proposed use case is	3GPP considers different target values for control latency based on the planned service. The proposed target value is 20msec, which covers a great variety of services, considering that provides an accurate control environment for the UAV.
Service Creation Time	The proposed use case can serve and adapted to a great variety of services. Therefore, it is very important the service creation time to be low in order to be possible its fast match to different vertical industries. Considering the proposal made by 5G-PPP, in our use case we aim at decreasing the service creation time by at least one order of magnitude, compared to 4G. Clear improvement of the level of automation of service-related processes (i.e. activating group communications in MCS, patrolling etc.)	The target KPI value proposed by 5G-PPP is the reduction of the average service creation time from 90 days to 90 minutes. This allows the agile creation and deployment of services, making possible the fast response of the mobile network to the needs of the vertical industries.

Trial facility limitations and their risks are summarized in Table 17.

Table 17: Trial Facility limitations and their corresponding risks for the connectivity extension scenario

Trial Facility Limitations	Risk
5G NSA availability	Low
Drone Control over 5G	Medium
UTM Availability	Medium
Local authority license for UAV flight	Medium
Drone 5G equipment:	
• 5G Small Cell (gNB)	High
• Relay link	
• 5G UE	Low

	Low

3.10.1.2. Roadmap Alignment

The roadmap alignment description for achieving the proposed use case scenario can be seen in Table 18.

Table 18: Roadmap Alignment

Trial Facility Milestone	
Deploy 5G NSA testbed	Q1 2020
Preliminary integration of UAVs in the facility	Q1 2020
Initial demonstration of related use case to the facility	Q2 2020
Integration of 5G Drones Trial Controller	Q3 2020
Initial Integration of 5G!Drones UAV components	Q4 2020
First Trial demonstration in Egaleo Stadium	Q1 2021
Final integration of 5G!Drones UAV components	Q2 2021
Final demonstration of 5G!Drones	Q1 2022

4 CONCLUSIONS

This Deliverable provided a description of the 5G trial facilities to be used in 5G!Drones project. It describes the site topology and 5G architecture for each of the facilities, respectively. The current capabilities of each of the platforms were described, providing an outlook on the facilities roadmap. A more detailed roadmap for each of the facilities will be described in Deliverable D1.3. The use cases of Deliverable D1.1 were tied in with the facilities where the respective use case trials are planned to be conducted. Furthermore, Initial roadmap alignments for test facilities and use case scenarios were provided and a more detailed description will be provided in Deliverable D1.3. Last, the description of the required facility enhancements to support the identified uses cases were given some initial considerations in this document while the work will be extensively described in Deliverable D1.3. Regulatory aspects regarding the facilities' ability to support the use cases will be carried out in D1.4.

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APPENDIX: 5GENESIS ATHENS PLATFORM TECHNICAL DETAILS

Athonet 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 can run on either centralized or highly distributed on public cloud (e.g. AWS, Azure, Google, IBM, Oracle) or private cloud (e.g. telco cloud), enterprise data centers or on standard COTS servers running on Intel or ARM.
The existing platform is a full 4G mobile core that implements 3GPP defined network functions including MME, PGW, SGW, PCRF and HSS. Being a commercial solution, it can be connected to commercial OSS/BSS systems which enforce regulatory obligations and billing by means of standard interfaces, i.e., X1, X2 and X3 for lawful intercept and Bx and Gy for charging.
Athonet, depicted in Figure 27, 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 can be controlled using 3rd party management systems through the following integration items:

- SNMP for KPI and performance monitoring;
- SNMP traps for alarm indication;
- RESTful API 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.

Figure 27 ATHONET Virtualised EPC Server.

Athonet, as illustrated in Figure 28, provides LTE Broadcast solution, the eMBMS, which is the simplest and most cost-effective way to deploy LTE Broadcast services to deliver video, software updates and other broadcast applications. The software solution can be (i) centralized to connect to an existing MNO network or (ii) distributed to specific locations (e.g. stadium) to create localized LTE Broadcast hotspots without affecting the existing network. The eMBMS solution includes the Mobility Management Entity (MME), MBMS Gateway (MBMS-GW) and Broadcast Multicast Service Center (BMSC). It can be deployed in conjunction with our distributed EPC, for best user experience, or as a standalone implementation.

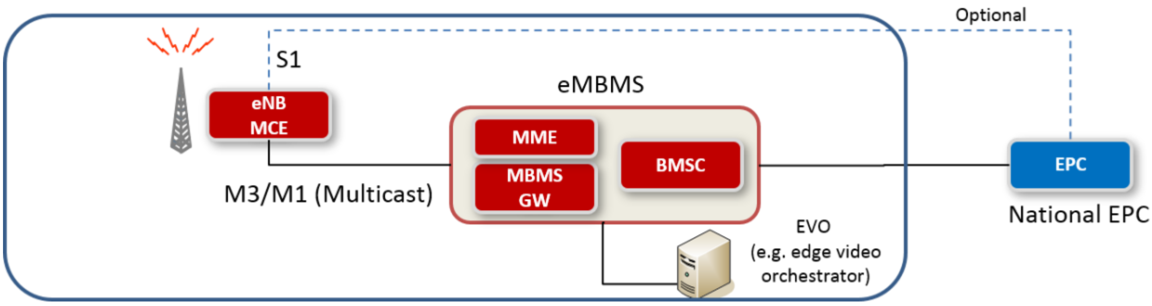

Figure 28 Athonet eMBMS component architecture.

Athonet provides the main Core Network component of the Athens platform deployment. Athonet's 4G+ Core supports some additional functionalities to those provided by the 4G such as:

- Serving Gateway Local Break Out (SGW - LBO) which is a software function/VNF that, deployed close to the RAN, provides a local secure network for placing locally offloaded content and services. Since most traffic load, in some cases 60-70%, is video traffic, this solution allows content to be cached and served locally. This improves user perceived quality and reduces the amount of backhaul required in a network. It may also enable new business with content providers and other low latency services. The SGW-LBO is a modified SGW function which has been enhanced by Athonet to allow traffic to be broken-out and steered locally to support
  - caching of video and other content
  - other applications that require low latency or local offload (smart city, autonomous cars, etc.).

  The benefit of this approach is that it allows specific traffic (not all traffic) to be offloaded for key applications that are implemented at the network edge without impacting the existing network or breaking network security. It also provides a bridge and upgrade path to 5G where the User Plane Function can be deployed flexibly at the network edge.
- Control and User Plane Separation (CUPS), which means that control plane and user plane functionalities can be distributed between central and edge-clouds or hardware nodes to enable hybrid-cloud, fog-computing or MEC type deployments.

During the project, the core component will be continuously enhanced with the latest features needed for the fifth-generation network deployment. When the platform is considered 5G ready, the EPC will be upgraded to 5GC. Control Plane will run locally at a Kubernetes cluster and the available equipment will be configured to host the User Plane Function.

OpenAirInterface Evolved Packet Core (EPC)

Eurecom's OAI-EPC is an open source experimentation platform licensed under Apache v2, implementing the Mobility Management Entity (MME), Home Subscriber Server (HSS), Serving and Packet Gateways (S-GW & P-GW) and respective interfaces, as shown in Figure 29. Eurecom is constantly evolving the software in cooperation with the community to provide functionalities such as [17]:

- Multi-PDN (SPGW).
- MBMS Gateway (MME).
- NB-IoT support.

In the context of the Athens Platform, OAI-EPC will be deployed on a Virtual Machine (OAI-vEPC), utilizing the Kernel-based Virtual Machine (KVM) solution. KVM is a virtualization technology for Linux on x86 hardware platforms, turning Linux into a hypervisor and allowing the host machine of running multiple virtual machines (guests), each having private virtualized hardware.

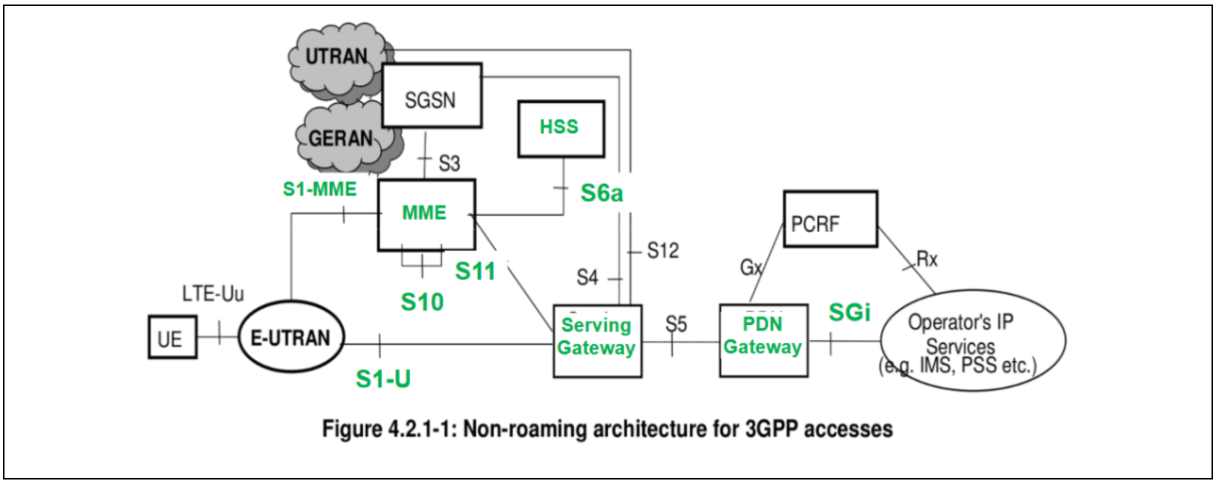

Figure 4.2.1-1: Non-roaming architecture for 3GPP accesses

Figure 29 OAI-CN Architecture Overview [16].

Eurecom is constantly evolving the software in cooperation with the community to provide functionalities such as [17]:

- Multi-PDN (SPGW).
- MBMS Gateway (MME).
- NB-IoT support.

In the context of the Athens Platform, OAI-EPC will be deployed on a Virtual Machine (OAI-vEPC), utilizing the Kernel-based Virtual Machine (KVM) solution. KVM is a virtualization technology for Linux on x86 hardware platforms, turning Linux into a hypervisor and allowing the host machine of running multiple virtual machines (guests), each having private virtualized hardware.

Amarisoft Evolved Packet Core

Amarisoft Core Network is a proprietary solution which is widely used at NCSRD campus LTE deployment. This solution implements the MME component with built-in SGW, PGW and HSS and supports several eNBs with standard S1 interface (S1AP & GTP-U protocols). Handling of UE procedures like attach, authentication, security configuration, detach, tracking area update, service access, radio bearer establishment, paging is also supported. UEs can use USIM cards with XOR, Milenage and TUAK algorithms for identity authentication.
Amarisoft software can be deployed in all commercial servers and virtualized cloud environments.
Amarisoft Core supports lots of features such as Multimedia Broadcast Multicast Service (MBMS), Multi-Operator Core Network (MOCN) and Narrow-Band IoT. MOCN in particular is a key capability that shall be used widely in our future deployments about LTE Network Slicing. In this sharing approach the Amarisoft Access Network is shared between two Cores (EPCs) by broadcasting several Mobile Country Codes (MCC) and Mobile Network Codes (MNC) in the System Information of a radio channel.
The Core component can also be accessed via a remote API. The protocol used is WebSocket as defined in RFC 6455 and the messages exchanged are in JSON format. API can be used for monitoring and configuring the Amarisoft EPC.

