5Genesis

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

[H2020 - Grant Agreement No. 815178]

Deliverable D2.1

Requirements of the Facility

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LIST OF ACRONYMS

Acronym	Meaning
5G PPP	5G Infrastructure Public Private Partnership
5G-IA	The 5G Infrastructure Public Private Partnership
AP	Access point
AR	Augmented Reality
BYOD	Bring Your Own Device
CA	Carrier Aggregation
CESC	Cloud-Enabled Small Cell
CO	Central Office
CoMP	Coordinated Multi-Point transmission/reception
CPRI	Common Public Radio Interface
C-RAN	Cloud-RAN
CSP	Content Service Provider
CUPS	Control and User Plane Separation
DoS	Denial of Service
DDoS	Distributed Denial of Service
DU	Digital Unit
eICIC	Enhanced Inter-Cell Interference Coordination
eMBB	Enhanced Mobile Broadband-5G Generic Service
eMBMS	Evolved Multimedia Broadcast Multicast Services
eNB	eNodeB, evolved NodeB, LTE eq. of base station
EU	European Union
EPC	Evolved Packet Core
EUTRAN	Evolved Universal Terrestrial Access network
FDD	Frequency Division Duplexing
gNB	gNodeB, 5G NR, next generation NR eq. of base station
GPP	General Purpose Processor
HetNet	Heterogeneous Network
H-RAN	Heterogeneous RAN
ICIC	Inter-Cell Interference Coordination
ICMP	Internet Control Message protocol
IDS	Intrusion Detection System
IOT	Internet of Things
KPI	Key Performance Indicator
LPWA	Low Power Wide Area
LTE	Long-Term Evolution
LTE-A	Long-Term Evolution - Advanced
MANO	NFV MANagement and Organisation
MCS	Mission Critical Services
MEC	Mobile Edge Computing
MIMO	Multiple Input Multiple Output

Acronym	Meaning
MME	Mobility Management Entity
mMTC	Massive Machine Type Communications-5G Generic Service
MONROE	Measuring Mobile Broadband Networks in Europe.
MPTCP	Multipath TCP
NFV	Network Function Virtualisation
NFVI	Network Function Virtualisation Infrastructure
NSMF	Network Slice Management Function
NR	New Radio
OAI	Open Air Interface
OAM	Operations, Administration & Management
OF	OpenFlow
ONAP	Open networking Automation Platform
ORI	Open Radio Interface
OSM	Open Source MANO
OTT	Over-The-Top
PCell	Primary Cell
PCI	Physical Cell ID
PCRF	Policy and Charging Rules Function
PDCP	Packet Data Convergence Protocol (PDCP)
PoP	Point of Presence
P-GW	Packet Data Node Gateway
PNF	Physical Network Functions
PPDR	Public Protection and Disaster Relief Systems
RAN	Radio Access Network
RRH	Remote Radio Head
RRM	Radio Resource management
RU	Radio Unit
SDN	Software Defined Network
SDR	Software Defined Radio
STA	Station
TCP	Transmission Control Protocol
UAV	Unmanned Aerial Vehicles
UDP	User datagram Protocol
UE	User Equipment
uRLLC	Ultra-Reliable, Low-Latency Communications
WSMP	Wifi Service Management Platform

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EXECUTIVE SUMMARY

The 5G (5G PPP)'s vision towards the next generation of communication networks and services offering ubiquitous, super-fast, reduced-latency connectivity and seamless service delivery in all circumstances, requires high capacity, service-aware mobile infrastructure with elastic, software driven and programmable capabilities. The European Union (EU) has already taken bold steps to develop world-class 5G technological know-how, and is now keen to reap the benefits of public and private investment for the economy and society. The Commission now puts greater emphasis on pilots and experiments in the run-up to 5G, notably through the 5G PPP.

To this end, the 5GENESIS 5G PPP Phase 3 Project, through the proposition of an experimentation Facility to exhibit 5G capabilities and to validate 5G PPP Key Performance Indicators (KPIs), focuses firmly on the urgent drive to facilitate the execution of 5G trials, and in this way to stimulate new connectivity-based ecosystems and to accelerate the digitisation process and the advent of novel business models. This document is the first technical deliverable of the 5GENESIS project and addresses the outcome of its first technical task (Task 2.1), targeting the definition of the requirements of the envisaged 5G Facility. It presents a distilled view of the project's scope and objectives, and highlights the innovations and ambitions that are set to be fulfilled.

Starting with the 5G PPP view of the ecosystem, the experimentation perspective is projected on the established 5G PPP stakeholders, addressing the roles of the experimenter, the experimentation platform operator, technology provider and testers, to reveal interesting permutations that can lead to new business and exploitation potentials. The document then introduces the experimentation Facility that is realised through the five, diverse in terms of capabilities, platforms that participate in the project, and are geographically distributed in Athens, Málaga, Limassol, Surrey and Berlin. It describes the approach to achieve the Facility through the proposition of an experimentation blueprint to serve as the basis for the specification of the target functional architecture, and to serve as a common reference among the member platforms. The blueprint identifies three functional layers, namely 'Coordination', 'Management and Orchestration' and 'Infrastructure'.

On the basis of the Facility blueprint, the requirements analysis work is depicted, maintaining a clear separation among i) the requirements that are fundamental for the Facility realisation and reflect the core generic functionalities expected ii) the enhancements necessary to upgrade the existing platforms and iii) the requirements targeting the support and demonstration of the selected use cases per platform. Furthermore, focus has been put on each one of the 5GENESIS platforms, presenting their technology and topology, target KPIs and use cases towards validating the 5GENESIS Facility and the KPIs per use case. In total ten (10) use cases are planned, to demonstrate eMBB, mMTC and uRRLC services with a variety of applications for video streaming, public safety, cyber-security and maritime communications under dense, ultra-dense or rural conditions.

Having set the 5GENESIS vision and objectives, the designated approach to guide their realisation, the requirements from both the Facility and use cases perspective, this work becomes a common reference among the platforms and serves as a fundamental guide for the subsequent specification and implementation work.

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1. INTRODUCTION

The main purpose of this deliverable is to summarise the outcome of the first technical task of 5GENESIS, Task 2.1, targeting at the definition of the requirements of the envisaged 5G Facility. However, being the first technical deliverable of the 5GENESIS project, the document also presents a distilled view of the project's scope and objectives, and highlights the innovations and ambitions that are set to be fulfilled. It delves into the technological solutions that are part of 5GENESIS, aiming at clarifying how the project will build on the existing technologies and go beyond them. In this context, the deliverable is expected to serve as a fundamental reference guide for specifying the 5GENESIS Facility and determining the subsequent implementation work.

As graphically depicted in Figure 1, the document builds upon a high-level skeleton to explore the main topics of interest for Task 2.1, to ensure that all interdependencies are appropriately considered and analysed.

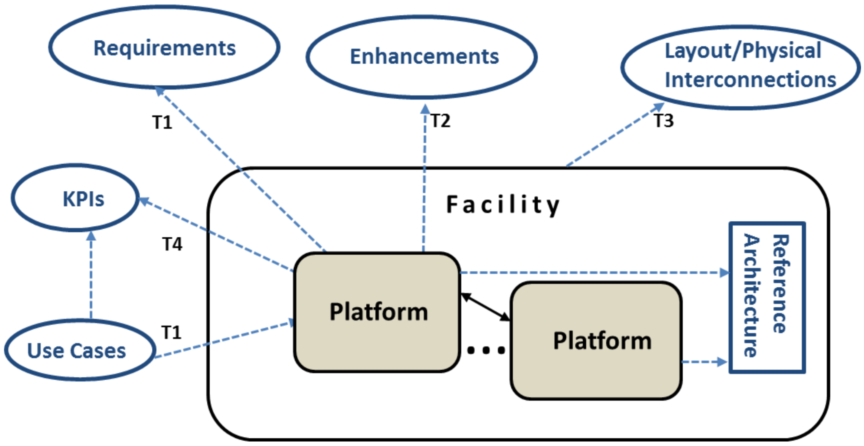

Figure 1: Main Topics and Skeleton of the Deliverable

In particular, the main topics explored in Task 2.1 and presented in this deliverable are:

- **Topic T1**: The description of the use cases and the identification of the requirements on the testbeds to be deployed and demonstrated;
- **Topic T2**: The identification of the enhancements required on a per platform basis (in terms of hardware, functionalities, monitoring and measurement equipment, etc.) towards their alignment with 5G capabilities;
- **Topic T3**: The architectural layout of the overall 5GENESIS Facility, including the individual platforms and their physical interconnections;
- **Topic T4**: The identification and definition of the KPIs that will be validated during the experiments on a per platform basis.

To address these topics while facilitating the flow of information to properly introduce the project's storyline, the document is structured as follows:

- **Section 2** offers a synopsis of the project's vision, objectives, proposed innovations and KPIs, and examines the 5G Ecosystem under the 5G PPP perspective to position the project's work and recommendations. It delves into the proposed architectural approach to tackle the project's target and concludes with a high-level reference blueprint to guide the project's technical developments;

- Section 3 offers an extensive presentation of the functional and non-functional requirements based on the proposed reference blueprint, as identified in order to accomplish an end-to-end, open, extensible and distributed 5G experimentation Facility;
- Section 4, based on the big picture set in previous sections, dives into each platform that constitute the 5GENESIS Facility, and the improvements necessary for their alignment with 5G capabilities in terms of hardware, software updates and functional enhancements. Moreover, it describes the use cases that each platform shall focus on and the KPIs that will be validated per use case.

This deliverable is mainly addressed to:

- The Project Consortium to validate that all objectives and proposed technological advancements have been analysed and to ensure that, through the identified requirements, the next actions can be concretely derived. Furthermore, the deliverable sets to establish a common understanding among the Consortium with regards to: i) the Facility blueprint architecture to be set for reference, ii) the technologies to be utilised, extended and demonstrated per platform, and iii) the 5GENESIS targeted use cases;
- The Research Community and funding EC Organisation to: i) summarise the 5GENESIS scope, objectives and intended project innovations, ii) detail the 5GENESIS Facility testbeds and target use cases that shall be demonstrated and measure provided technological advancements and iii) present the related requirements and associated KPIs that must be tackled to achieve the expected results;
- The general public for obtaining a better understanding of the framework and scope of the 5GENESIS project.

Last but not least, the content of this deliverable is in-line with the guidelines of Deliverable 1.2 "Legal aspects and data management (Release A)".

2. 5GENESIS FACILITY: KEY ASPECTS

This section begins with a concise overview of the 5G concepts that are considered influential for the project's vision and work. It builds on this foundation to present 5GENESIS objectives and ambitions and to highlight the innovations that the project is expected to expand and contribute to, together with the proposed approach to achieve these proficiently.

2.1. 5G Ecosystem: Services, Verticals and Stakeholders

5G is expected to provide a user experience matching the performance requirements of a diverse set of service categories and to deliver increased aggregate, peak network and user experienced data rates, enhanced spectrum efficiency, reduced latency and enhanced mobility support. At the same time, 5G capabilities must include automatic connectivity establishment for a vast range of smart appliances, machines and other objects without human intervention. On top of all that and considering the ICT market and its main stakeholders' demands, 5G must be able to achieve all the stated requirements with limited energy consumption and low network equipment and deployment costs. To address such expectations, and to provide a homogeneous view of 5G services and their requirements, the Standards Developing Organisations (SDOs), mainly ITU and 3GPP, have categorised the **5G services** as follows:

- **eMBB** (enhanced Mobile Broadband) [4] refers to bandwidth intensive services and applications, including Augmented Reality (AR)/Virtual Reality (VR), Ultra-High Definition (UHD) Video sharing in heavily crowded hotspots, TV programs broadcasting, etc. The bandwidth requirements of this type of services are expected to be about 100 Mbps per user, while in some cases it can be in the order of some Gbps, reaching even 10 Gbps (for broadcast services);
- **mMTC** (massive Machine-Type Communications - Massive Internet of Things (mIoT)) [2], refers to massive IoT services extending the Long Term Evolution (LTE) IoT (for example, Narrow Band–IoT) to support huge numbers of devices with lower costs, enhanced coverage, and long battery life. With regard to ITU objectives, 5G will support ten times as many devices per area as LTE. This category includes eHealth, wearables, industrial control and factory automation, and sensor networks;
- **URLLC** (Ultra-Reliable, Low-Latency Communications) - Critical Communications [3] refers to latency sensitive, wireless applications and services, some of which are impossible to be supported by existing network deployments. These services are referred also as "mission-critical" communications or critical Machine-Type Communications (cMTC) (by 3GPP), and include public safety lifeline and situational awareness, industrial automation, drone control, new medical applications, autonomous vehicles, etc. The latency requirements for this type of services are expected to range between 1ms-2ms for the radio interface and less than 10ms for the end-to-end data plane;
- **Network Operation Services** [5] are distinguished by 3GPP as a separate class of services addressing the functional system requirements, including aspects such as: flexible

functions and capabilities, multi-tenancy, energy efficiency migration and interworking, optimisations and security.

Towards moving from the existing (even in 4G) network-specific definition and provisioning of applications and services to the 5G envisioned application-driven, flexible, dynamic network services instantiation, the technical activities of 5G are interrelated with the activities focusing on the analysis of stakeholders and their service requirements. To this end, in order to address 5G applications in a coherent manner, 5G-related activities are converging to mapping applications to specific major **Verticals** (i.e. vertical industries) that include among others:

- **Automotive**, focusing on services provided in high mobility scenarios, IoT applications and services, etc., such as automated driving, road safety and traffic efficiency services, digitalisation of transport and logistics, intelligent navigation, information society on the road, and nomadic nodes;
- **e-Health**, focusing on remotely provided health services with extra low latency and high reliability requirements, such as assets and interventions management in hospitals, robotics (remote surgery, cloud service robotics for assisted living), remote monitoring of health or wellness data, and smarter medication;
- **Energy**, focusing on IoT-based energy monitoring, management, and network control scenarios, such as Grid access, Grid backhaul, and Grid backbone;
- **Media and Entertainment**, focusing on next generation applications and services provisioning, such as UHD media, cooperative media production, highly interactive services, on-site live event experience (Augmented/Virtual Reality video content), immersive and integrated media etc.;
- **Factories of the future**, referring to Industry 4.0 setups and applications and services such as time-critical and non-time-critical process optimisation inside factory, remote maintenance and control, seamless intra-/inter-enterprise communication, allowing the monitoring of assets distributed in larger areas, and connected goods.

It is noteworthy that the public sector, even though not a distinct vertical in 5G PPP terms, is expected to have a major role in 5G adoption as it is envisaged to become an early adopter and promoter of 5G connectivity-based solutions, encouraging the emergence of innovative services, contributing to a critical mass of investment, and addressing issues of importance for society. Migrating public safety and security services from existing proprietary communications platforms to even more secure, resilient and reliable 5G platforms is part of the European Commission's Action Plan of "5G for Europe" [12]. Action 7 of the plan encourages Member States to consider the 5G infrastructure for their advanced broadband public protection and disaster relief systems (PPDR) that typically support services for the police and fire brigades. To this end, in May 2018, a cooperation agreement to foster developments on 5G for public safety stakeholders [13] was signed by the 5G Infrastructure Association (5G-IA), representing the European industry in 5G PPP Research Programme, and the European Public Safety Association.

This transformation from network-oriented to service-oriented deployments is expected to trigger changes in the current market stakeholders and their roles and generate opportunities for the creation of new roles and introduction of additional stakeholders.

Extensive analysis on the envisaged stakeholders has already been performed through the 5G PPP initiative, as depicted in Figure 2.

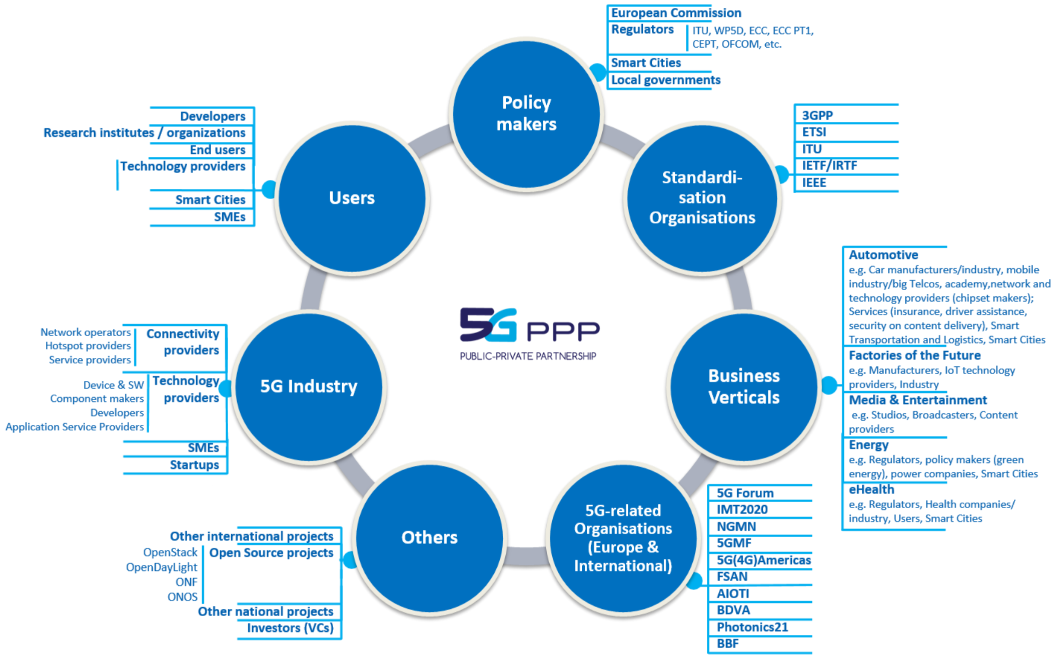

Figure 2: 5G PPP Stakeholders[1]

Building on this view, the key stakeholders being primarily involved in the 5GENESIS business cases are considered to be:

- Business Verticals, from both private and public sectors, which drive the need for 5G services deployments with rigorous demand;
- Connectivity Providers (5G Industry), including network operators, hotspot providers, service operators and site owners that own and operate fully or in cooperation the telecommunication infrastructure and services that shall realise the offered services;
- Technology Providers (5G Industry), SMEs, start-ups, which provide technology solutions, services and applications to be integrated, either to implement the service offerings expected, or even to address the functionality and operation of the platforms themselves;
- Research institutions, academia, and the open source community (others) to ensure the sustainability of the designed solutions through their influence in shaping scientific trends;
- End Users, to consume the services offered and provide the end-user experience feedbacks.

5GENESIS brings the experimentation perspective in the picture, targeting to facilitate the deployment and execution of the vertical industries' services with real-users, through the proposition of a homogeneous interface that can be supported by the various platforms. Such deployment, execution and validation, is called an **Experiment** in the context of the project and assumes the following roles:

[1] https://5g-ppp.eu/wp-content/uploads/2016/06/Stakeholders_clean.png

- **Experimenter**: Executes the experiments on behalf of the vertical industry using the experimenter interface provided by the 5GENESIS platforms. Typically, the experimenter is the integrator of the vertical technologies into the service to be validated on 5GENESIS;
- **Platform Operator**: Hosts, manages and operates the platform's software and infrastructure, including the interface to the experimenters, the telecommunications infrastructure, as well as, the coordination, management, orchestration and monitoring systems;
- **Platform Technology Provider**: All vendors and research institutions that provide software and hardware components to the 5GENESIS platforms;
- **Testers and End Users**: The users of the services deployed in the 5GENESIS platforms by the Experimenter. They can be either individuals or corporate end-users.

It is worth mentioning that we do not foresee a fixed association of these roles to the 5G PPP stakeholders, but rather a variety of combinations is expected, leading to interesting exploitation opportunities and business potentials. While other project deliverables shall drill into the exploitation capabilities of 5GENESIS, some preliminary reflections can already be highlighted for the roles assumed:

- **Experimenter**: Setting aside the end-users, all the identified key stakeholders will be eager to assume the role; business verticals being keen to see fast, reliable and robust solutions quickly; connectivity and services providers to practically validate technology before mass roll-outs; technology providers and vendors to validate beta products; and research institutions to explore new technology trends and prototypes;
- **Platform Operator**: It is obvious that the role shall attract the attention of the connectivity providers (network operators, service providers, hotspot providers and site owners) to exploit underutilised or redundant infrastructures, and generate revenue from noteworthy site locations. Nevertheless, interest from the vertical industry is also expected, when fully owned and privately controlled business cases are considered;
- **Platform Technology Provider**: The inherent need to constantly embrace new components and applications, driven by the experimentation business, leads the 5GENESIS platforms to become an amalgam of applications and components, dynamically interconnected and integrated to offer the service expected. It is thus expected that the role shall be assumed by most key stakeholders, but will be fully exploited by technology providers and verticals;
- **End Users**: The testers of the experiments may be either invited and trained groups, members of the core stakeholders, individuals with specific traits selected as part of the experiment definition, or random crowd. They can be requested to offer their participation for free or with benefits agreed beforehand. Obviously, the marketing approach and necessary incentives to attract the proper end users are important decisions to safeguard the experiments' success.

Exposing the 5G services and measuring offered capabilities with special focus on the 5G core stakeholders' mandate for flexible, on demand and targeted experimentations, are considered key contributions of the 5GENESIS platforms towards early and successful adoption of evolving propositions of 5G business concepts, applications and technology.

2.2. 5GENESIS Vision, Objectives and KPIs

2.2.1. 5GENESIS Vision and Objectives

The EU has already taken bold steps to develop world-class 5G technological know-how and is now keen to reap the benefits of public and private investment for the economy and society [12]. The European Commission puts greater emphasis on pilots and experiments in the run-up to 5G, notably through the 5G PPP, and works towards the deployment of selected 5G trials with a clear EU dimension from 2018 onwards. 5G PPP Programme, Phase 1 projects have mapped the 5G requirements to specific Key Performance Indicators (KPIs) [10] and formulated the overall 5G architecture that will achieve these KPIs. The on-going 5G PPP Phase 2 and 3 projects are extending the work done by Phase 1 projects, by contributing to a selective experimentation of different technologies needed for the validation of the 5G architecture.

The "Genesis of 5G" has thus entered the crucial phase of experimentation, and faces the challenge to validate the 5G network KPIs and verify the 5G technologies with an end-to-end approach as part of the on-going 5G PPP Phase 2 and 3. Adopting the early releases of the 5G Architecture [1], 5GENESIS proposes a 5G experimentation blueprint to serve as a common architectural reference, including an openness framework, with APIs for exposing the Facility to verticals for experimentation. 5GENESIS implements this blueprint as a **Facility,** graphically depicted in Figure 3:

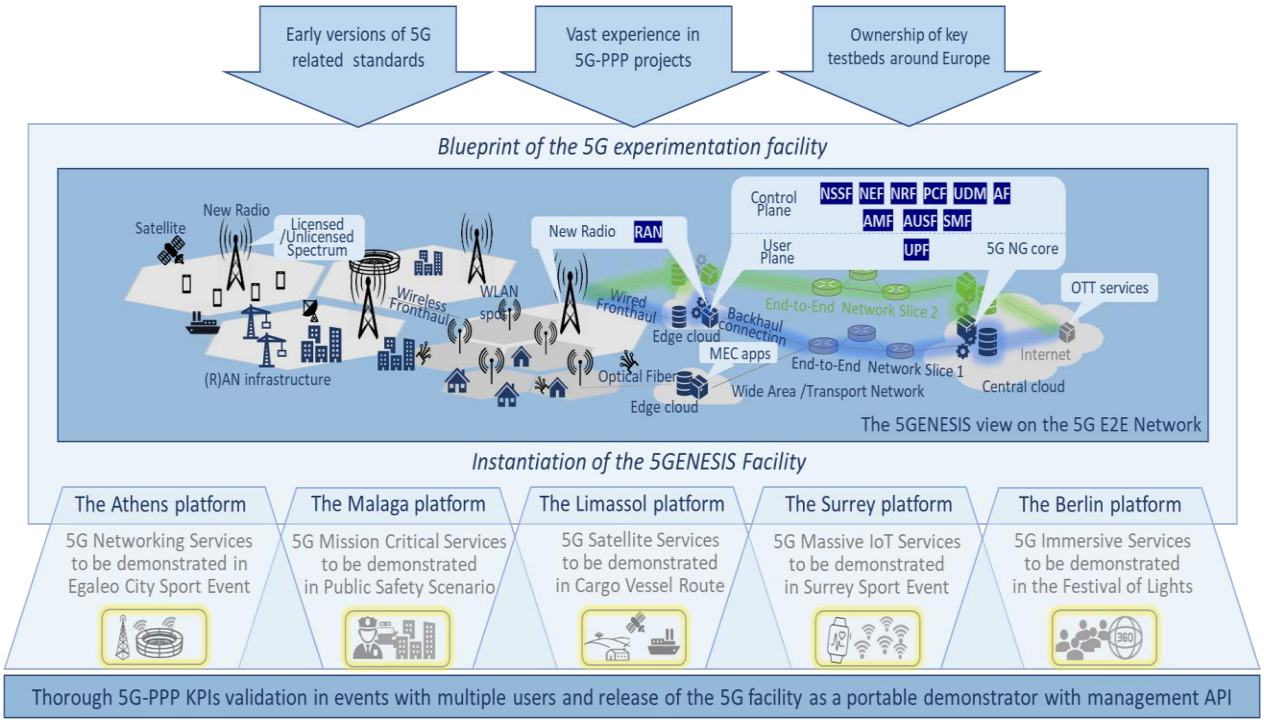

Figure 3: The 5GENESIS End-to-End Facility

The 5GENESIS Facility spans over five (5) - diverse in terms of capabilities, yet fully interoperable - experimentation platforms (see 2.3) distributed across Europe in five cities most of them already identified by the 5G PPP as "5G Trials Cities" [9].

The **Platforms** that constitute the Facility are called:

1. The Athens Platform;
2. The Málaga Platform;
3. The Limassol Platform;
4. The Surrey Platform;
5. The Berlin Platform.

The full set of the objectives addressed by the project are summarised below and will be verified through a wide range of means, such as high quality scientific papers and publications (on the Facility architecture, components and algorithms, actual KPIs, validation and experimentation methods, etc.), integration of clear portfolios of features on the platforms, contributions to related standards and 5G PPP work groups, on-site and remote demonstrations:

- **Objective O1. Design and establish a 5G experimentation blueprint** that unifies diverse 5G components to support verticals over an end-to-end virtualised and sliced network;
- **Objective O2. Develop a 5G Facility** that instantiates the identified experimentation blueprint in 5 interoperable end-to-end platforms;
- **Objective O3. Qualitatively assess and quantitatively validate business, performance, and societal 5G PPP KPIs in representative 5G use cases;**
- **Objective O4. Continuously align with –and contribute to- the evolution of 5G standards**, by adopting an iterative integration and upgrade development methodology consisting of three cycles;
- **Objective O5. Release a portable 5G Demonstrator** to maximise visibility and facilitate dissemination and communication activities.

Addressing the project's objectives in relation to 5G PPP references, all the recommendations defined by the 5G PPP Programme Trials Working Group, as discussed in the Roadmap 2.0 document [8] are considered. Specifically:

- The Facility will be representative of the unique 5G network and service capabilities defined in the 5G PPP vision. Architectural (i.e., slicing) and business-related (including openness to non-ICT ecosystem) aspects are core concepts of Objective 1 and 2;
- The Facility objectives are twofold, on the one hand demonstrate the 5G KPIs and on the other hand serve as enabler of trials and pilots (e.g., ICT-19-2019), through explicit Objectives 3 and 1, 2 respectively;
- Integration and validation are considered at system level. To this aim, availability of open interfaces between the stakeholders is a guiding principle of the implementation;
- Governance, operations (including support) and access enable interworking both from vertical point of view, 5G-infrastructure users and stakeholders, by advocating the related recommendations:

  - Complementarity of the platforms allows overall coverage of the 5G PPP KPIs (at portfolio level). Coordination through 5G-IA WGs beyond (EC) evaluation is considered;
  - Functional and service descriptions exposure will be provided as well as open APIs allowing interworking within and potentially between platform clusters and projects;
  - Platforms integration and development is designed to be incremental (through iterative cycles) ensuring availability towards trials experimentation. Provision of a clear delivery planning (when and what) is scheduled;
  - Both for deployment and scientific objectives, reproducibility properties of the experiment are considered. Effort required for deployment and integration using common and agreed methodology is not underestimated.
- Emphasis is put on the likely impact on standardisation, in particular addressing gaps with respect to the 5G PPP vision.

Last but not least, the project puts special focus on vertical service support by adopting the following recommendations:

- Emphasis on the provision of 5G end-to-end slices, to be implemented by all five (5) platforms;
- Clustering of platform capabilities towards a given class of service of use case environment such as eMBB, mMTC or URLLC, considered in the way the Facility is setup;
- Security threats consideration, protection and remediation are proposed and implemented as a cross platform functionality;
- Size, topology and scalability of the platforms and their subsystems will be expanded so that to be consistent with the functions and services to be demonstrated;
- Leverage domain specific initiatives to support specific verticals, through dedicated task to collaborate with ICT-19-2018 projects.

2.2.2. 5GENESIS Target KPIs

The project addresses and aligns with the known 5G PPP KPIs [10] requirements. Table 1 presents the synopsis of the KPIs that shall be evaluated as part of the project either in lab experiments or through the execution of the use cases. It provides the KPI definition including the values that shall be set as initial acceptable targets.

Based on these definitions, the per platform narrative, provided later in this document in the respective Section 4 subsections, shortly presents with a more specific view the KPIs targeted per platform.

Since the KPIs measurements and validations are a major contribution of the project, subsequent project deliverables will more deeply elaborate on the approach to achieve them.

Table 1: 5GENESIS Target KPIs

Capacity	
Target	1. Absorb 1 Tbps in the equivalent to a smart office (10 Tbit/s/km^2) (lab and field validation in Athens and Málaga platforms) 2. Reach a peak data rate between 1 and 10Gbps for specific deployment scenarios and use cases 3. Deployment and operation of 10 small cells per km2, and support of 10Gbps per RRH in access domain
Ubiquity	
Target	>99,9% spatial availability (with satellite/terrestrial aggregation)
Speed	
Target	1. Stationary, urban pedestrian ≥5km/h and urban vehicular >=30km/h (in the field) 2. Vehicular and high speed >300km/h (in lab with programmable channel emulation)
Latency	
Target	1. ≤10 ms end-to-end (data plane) 2. 2 ms on the air interface (radio interface)
Reliability	
Target	>99,999%
Density of users	
Target	Between 10.000 and 1.000.000 devices per km^2 for specific use cases
Location accuracy	
Target	One meter (1m) in 99% of the cases
Energy efficiency	
Target	>50% reduction in energy consumption in comparison to already available technology (for specific network components)
Service creation time	
Target	Decrease of 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)
Network management CAPEX/OPEX	
Target	>50% decrease in network management CAPEX/OPEX, as assessed by feedback from operators

2.3. The 5GENESIS Approach

5GENESIS works towards establishing a 5G Experimentation '**Facility**', spanning over five, diverse in terms of capabilities, yet fully interoperable, experimentation '**Platforms**'. It aims to achieve this through the proposition of an experimentation blueprint and the specification of the resulting target architecture, to be used as a common reference among the member platforms.

The guiding principles, upon which the project concepts are built, are summarised below:

- 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.

Each one of the platforms participating in the 5GENESIS Facility shall have the flexibility to govern its own physical topology, architecture and particular technological features. Nevertheless, towards harmonizing the different platforms and experimentation infrastructures, elements of the common reference architecture are to be replicated across the five platforms. In this way, each platform can be administratively independent, yet interoperable with the other platforms. A schematic view of the proposed 5-GENESIS Experimentation Blueprint, meant to implement all of the above-mentioned points, is depicted in Figure 4.

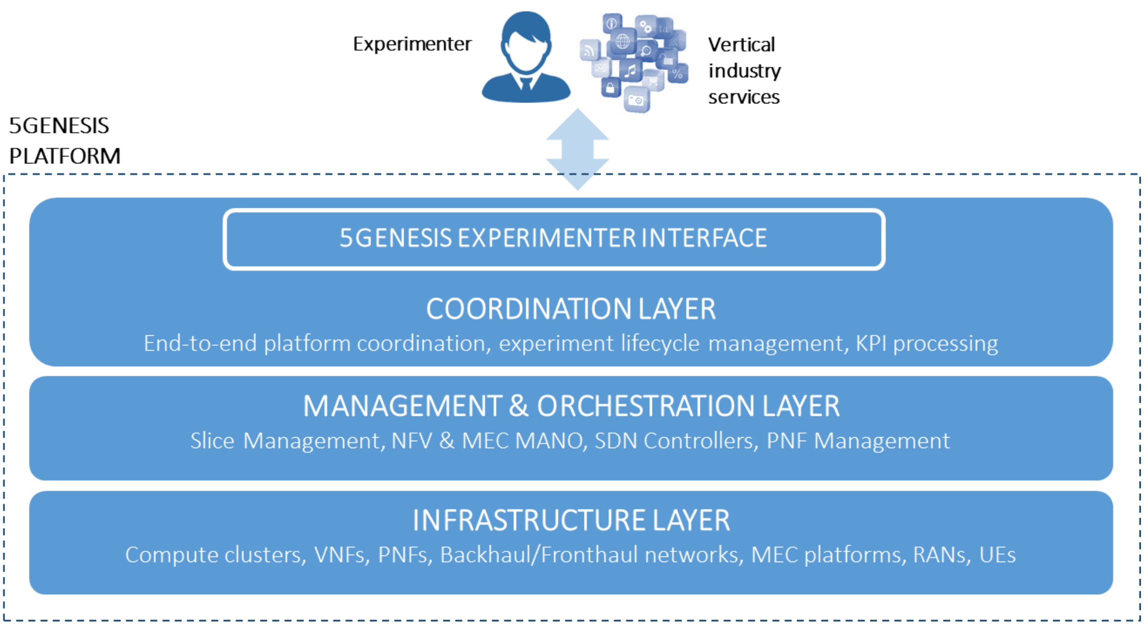

Figure 4: 5GENESIS Experimentation Blueprint

The blueprint foresees three main '**Reference Layers**' that are defined below and shall be further analysed and specified as part of the Facility's design and specification tasks:

- **Platform Coordination layer:** The Coordination layer has the primary role of interfacing with the experimenters, performing the overall coordination of the platform, achieving overall supervision and end-to-end configuration for service deployment and end-user's management and monitoring. It shall contain a number of functional components necessary to facilitate the experiments' execution and validation. Indicative main functional blocks include:
    - 5GENESIS Experimenter Interface;
    - Experiment Lifecycle Management;
    - Measurements and KPI validation;
    - Security Framework;
    - Interface with other platforms.
- **Management and Orchestration layer:** This layer encapsulates all the management and orchestration capabilities that are necessary to deploy, realise and administer the required experiments on the supporting networks. It typically includes the following:
    - Slice Management Module including service automation;
    - Management and Organisation (MANO) components for the Network Function Virtualisation (NFV) and Mobile Edge Computing (MEC) infrastructures of the platform;
    - SDN controllers for the programmable network;
    - Traditional Network Management System functionalities for controlling the Physical Network Functions (PNFs), mostly involving the radio and 5G core components.
- **Infrastructure layer**: It involves the end-to-end components which handle the user traffic. Optionally, in some platforms, this layer will also include Multi-RAT support and Spectrum Management capabilities. The infrastructure layer includes:
    - 5G NG Core network;
    - network function virtualisation infrastructure (NFVI);
    - backhaul network;
    - mobile edge platform;
    - 5G NR base band units and radio heads (i.e. 5G RAN);
    - 5G end-user equipment;
    - Spectrum Management (optional);
    - Multi-RAT interoperability and/or aggregation (optional).

The proposed blueprint aims at providing a reference principle to implement the five 5GENESIS platforms in Athens, Málaga, Berlin, Surrey and Limassol while at the same time tolerating flexibility in selecting appropriate, per-case solutions to address modularity, heterogeneity as well as re-usability demands. In this respect, the Coordination layer is expected to share common implementations among the platforms, either with single instantiations (ex. the Experimenter Interface), or separate installations of same solutions; nonetheless some platform dependent modules might also be necessary. On the other hand, the Management and Orchestration and the Infrastructure layers that rely heavily on the underlying network and virtualisation infrastructures are expected to be mainly platform dependent, due to the diversity of the technological bases of the platforms.

It is noteworthy that most of the experiments are expected to be executed in a single platform depending on the capabilities required by the vertical industries. The Experimenter Interface, based on an openness framework to be defined within the project, will guarantee similarity across platforms in the definition of the experiment, the description of necessary resources -such as the slice (including both the virtual network functions (VNFs) and the 3GPP features of the slice) and the computational resources to be initially assigned-, as well as the test cases and metrics to be used and collected for the validation. The main idea is to guide the experimenter in the deployment of an experiment on one platform, and with the same definition constructs to make it possible to deploy parts of that experiment in other platforms as well. Moreover, the project shall also support some interconnection between platforms to run experiments in a distributed way. To achieve that, the Coordination layer assumes a significant role for the distributed deployment, execution and monitoring across several platforms. Obviously, it is also mandatory that the Infrastructure layers have the appropriate physical interconnections in order to provide the data plane for distributed executions.

Considering all above points, the on-going work for design and specification (Project Task 2.2) shall elaborate in all layers of the blueprint, to propose a detailed reference architecture that shall encompass all elements and functional components that are essential to efficiently support the experimentation business and properly realise 5G network offerings and capabilities.

The work plan to implement the 5GENESIS approach is organised around three main phases:

- The Initiation Phase includes the initial design and specifications of the Facility, elaborating on the identification of experiments to be run in each platform and KPIs to be validated;
- The Main Phase refers to the core work of the project, which is the development of the Facility and the interim tests and experiments. This phase includes three main integration cycles, each one lasting for six (6) months. The scope of each integration cycle is to upgrade each test-bed with the latest technical achievements and results from all relevant R&D activities. Each integration cycle will be followed by a three-month testing phase, during which: a) the current release of the Facility will be fully verified, ii) selected experiments will be implemented and relevant KPIs will be validated and iii) the technical specs of the Facility and the implementation plan will be updated, according to the lessons learnt from the integration and testing activities;
- The Finalisation Phase includes the execution of the final experiments on the completed platforms, the large-scale and inter-domain demos, as well as the production of the final documentation of the project.

2.4. 5GENESIS Main Innovations

Through the proposition of the experimentation Facility, 5GENESIS addresses directly the Action 6 of European Commission's "5G for Europe" Action Plan [12]. It focuses firmly on the urgent drive to facilitate execution of the 5G trials, so that to stimulate new connectivity-based ecosystems through experiments and demonstrations and in this way accelerate the digitisation process and the advent of novel business models.

Likewise, the project follows the cooperation agreement between 5G Infrastructure Association (5GIA) and PSC Europe (Public Safety Communications) [13] and supports PPDR deployments on 5G Infrastructure for experimentation practice through the involvement of a local Police department as a key stakeholder in the public safety use case.

However, 5GENESIS mainly commits to provide a 5G end-to-end network Facility so that to exhibit the 5G capabilities and validate 5G PPP KPIs and in this process proposes specific innovations that will be applied to the end-to-end platforms. There are two main areas where the main innovations of 5GENESIS will lead to significant benefits: i.e. the access stratum on one side and the network management on the other; these innovations are presented in the subsections that follow.

2.4.1. Access stratum Innovations

It is noteworthy that 5GENESIS goes beyond the state of the art, and considers spectrum management techniques not only in licensed and unlicensed bands, but also in satellite bands based on the dynamic nature of 5G services. In summary, the ambitions set for access stratum technological advancements are as following:

- **Ambition A1: 5G NR and Wi-Fi integration:** 5GENESIS explores the application of multi-connectivity solutions by aggregation to allow the UE to simultaneously use the licensed and unlicensed spectrum. Such aggregation will increase the data rate and the connectivity in dense urban areas and during very populated events. The solution will be demonstrated for keeping service continuity and high data rate in the uplink for real time video in mission critical services;
- **Ambition A2: User plane and control plane of multiservice access stratum:** It is expected that beyond 5G networks will try to share the millimetre and microwave spectrum as much as possible, while delivering different services. To achieve this goal the topology of parts of the network may have to be reconfigured, so the delivery of a specific service in a specific area does not prevent unnecessarily the use of the same spectrum to deliver other services in other areas. To do such topology adjustments, it is foreseen that all or part of the resource management functions must be located in different places of the network, including the terminal. 5GENESIS proposes to use virtualisation in order to allow the resource management architecture to use centralised, distributed, or a mixture of centralised and distributed resource management functions, which may vary according to the services deployed in a given area;
- **Ambition A3: Dynamic spectrum access for multiservice access stratum:** 5GENESIS attempts to devise a methodology to identify the bands that can be used by the access network or the front-haul, which would allow exploiting, in a given time and place, both the microwave and millimetre wave bands, as efficiently as possible. Moreover, 5GENESIS

shall enhance the velocity of bands' (re-)allocation by exploiting advanced spectrum availability identification techniques. 5GENESIS proposes new or enhanced Radio Resource Management (RRM) algorithms dealing with priority scheduling, channel allocation policy, modulation and coding type that allow achieving the required QoS and increasing the system capacity (bps/Hz/km^2). The novelty lies in considering different TTIs within a standard radio frame according to the different services being deployed;

- **Ambition A4: Integrated Satellite-Wireless Architecture:** 5GENESIS aims to define an integrated Satellite-Wireless architecture for 5G Applications, and in particularly for LTE, to be able to exploit frequency bands that are currently allocated to satellite communication services so that to be able to provide additional bandwidth on demand.

2.4.2. Network and Management Domain

- **Ambition B1**: **Measurement-driven protocol stack optimisations:** The initial performance of the integrated platforms shall be assessed in the first cycle and used as a basis for end-to-end performance enhancements in the next cycles. 5GENESIS shall provide the first empirical study that characterises the interaction between the LTE stack and the IoT protocol stack to be used to optimise protocol interactions on the IoT device for increased energy efficiency;
- **Ambition B2: Orchestration and Management for Multi-connectivity:** In the context of multi-connectivity, optimizing end-to-end performance requires to consider aspects such as best available technology and path selection, best available protocol selection and optimal packet scheduling. Capturing of application requirements and policy-control on the UE side shall be aligned with standardisation activities and be integrated within the 5GENESIS orchestration and management procedures, extending end-to-end slice management to incorporate also higher layer protocols;
- **Ambition B3: Cognitive Network Management:** 5GENESIS addresses all the relevant requirements to dynamically allocate resources to network functions and reconfigure the network according to context changes, such as changing service demands, by addressing challenges like:
  - Providing logical networks through network slicing to improve performance;
  - Enabling services that can be automatically scaled up or down based on demand;
  - Isolation of network resources of a service;
  - Customizing network slices for service requirements, with optimised allocation of physical resources;
  - Interaction of Network Slice Management Function (NSMF) with NFV-MANO to enable management of network slicing.

3. 5GENESIS FACILITY REQUIREMENTS

Having set the 5GENESIS vision and objectives together with the designated approach and reference blueprint to guide their realisation, the next fundamental task is to lead the analysis phase through the proper requirements gathering and assessment.

The analysis was led by the technical manager and the platform leaders and was facilitated by the deliverable's editor through a series of general assembly and targeted conferences involving all project partners, to ensure that the harmonisation, prioritisation and clustering of the requirements, proposed from the technical members, would materialise to balanced directions for the design and specification of an over-arching and all-encompassing experimentation Facility proposition. The target of this work has not been to provide an exhaustive and chaotic list of technical details, but rather to determine the key demands in an agile manner that would allow the design phase to determine the proper means to address them.

During the requirements analysis workshops, a clear separation has been achieved among:

1. the requirements that are fundamental for the Facility realisation and reflect the core generic functionalities expected;
2. the enhancements necessary to upgrade the existing platforms' technology and topology;
3. the requirements targeting the support and demonstration of the selected use cases per platform.

The focus of this section is clearly on the first point, the requirements relevant to the Facility realisation; the others are addressed in Section 4, respectively.

The resulting set of Facility requirements is presented in the subsections that follow, classified as:

- functional requirements, with focus on the functionality expected by the Facility;
- non-functional requirements, addressing operational concerns necessary to facilitate and ensure the functionality envisaged.

3.1. Functional Requirements

Functional requirements are fundamental in addressing the functionality expected by the platforms to achieve the set objectives, and in these terms very diverse by nature. The most constructive approach to properly orient, process and present them has been to cluster them following the directives on layering presented in the 5GENESIS blueprint, as shown in Figure 4.

In accordance, following subsections present the requirements per respective blueprint layer, namely Coordination, Management and Orchestration and Infrastructure. Requirements that span across layers are presented in the last subsection.

3.1.1. Coordination Layer Requirements

The functional requirements that are relevant to the Coordination layer to address the overall coordination of the platform, including the interface with the experimenter as well as the supervision and end-to-end configuration for service deployment and end-user's management and monitoring, are depicted in Table 2.

Table 2: Coordination Layer Functional Requirements

COORD-1	Open APIs towards the Experimenter
Priority	Essential
Description	The Coordination layer shall expose open APIs enabling the Vertical experimenter to access the Facility, define and conduct experiments as well as retrieve the results
COORD-2	Facility and Platform Inventory
Priority	Essential
Description	The Coordination layer shall provide an Inventory listing the experimental capabilities per platform
COORD-3	Experiment Definition
Priority	Essential
Description	The Coordination layer shall provide an experiment descriptor template in order to allow experimenters to describe their experiments. The descriptor could be part of the open API specification. The template shall follow an extensive and well-defined information model
COORD-4	Experiment Pre-evaluation
Priority	Essential
Description	A systematic process and methodology to verify that a requested experiment can be executed by a platform of the Facility without compromising the experiment results and/or the integrity of the platform shall be implemented
COORD-5	Experiment Execution
Priority	Essential
Description	The Coordination layer shall be able to execute an experiment experiment's workflow or control the operation of the experiment over the Facility infrastructure and collect appropriate results
COORD-6	Inter-platform Experimentation
Priority	Optional
Description	The Coordination layer may enable inter-platform experimentation. This is possible via east-west interfaces horizontally across Coordination layer instantiations over

	each platform
COORD-7	Experiment Lifecycle Management
Priority	Essential
Description	The Coordination layer shall be able to provide sufficient control over the stages of experimentation cycle (start, stop, pause etc.) specifically for each experiment but also between consecutive experiments for different experimenters
COORD-8	Inter-experiment Coordination
Priority	Essential
Description	The Coordination layer shall provide mechanisms for the proper prioritisation and coordination of queued experiment requests to fulfil the experimenters' schedule efficiently, minimise idle periods and maximise the use of resources
COORD-9	Southbound Control APIs for Experiment Execution
Priority	Essential
Description	The Coordination layer shall specify the southbound interface necessary to manage and control network and infrastructure elements as seen fit, in order to activate and execute an experiment
COORD-10	KPIs Validation and Evaluation
Priority	Essential
Description	The Coordination layer shall gather and process all experimental data to calculate and validate the target KPIs, as well as, provide automated reporting to the experimenter
COORD-11	Experiment Monitoring
Priority	Essential
Description	The Coordination layer shall provide to the experimenter monitoring information in relation to the experiment execution using agreed metrics measurements and results
COORD-12	Transparency in Experiments Measurements
Priority	Essential
Description	The Coordination layer shall allow the retrieval of raw experimental data to the level of granularity possible
COORD-13	Vertical Experimenter Dashboard
Priority	Essential
Description	The Coordination layer shall provide visual representation of the experiment execution results through a graphical user interface

COORD-14	Experiment Data Storage and Maintenance
Priority	Essential
Description	The Coordination layer shall provide means for storing and maintaining of experiment data for the time interval negotiated between the Platform owner and the Experimenter
COORD-15	**Experiment Data Isolation**
Priority	Essential
Description	The Coordination layer shall ensure that no experimenter is able to access other experimenters' data
COORD-16	**Security Analytics**
Priority	Essential
Description	The platform shall provide the capability to perform near-real-time analytics on the traffic, for the detection and classification of anomalies and/or security incidents. To the full extend, security analytics are necessary for the platform administrators to ensure the soundness of the platform and the confidentiality of the experiments execution. Nevertheless, basic security and hazard assessment conclusions shall be shared with the experimenter as part of the experiment results
COORD-17	**Adaptation for Communication with Management**
Priority	Essential
Description	The Coordination level shall provide appropriate adaptation of the information received by the exposed northbound API (see COORD-1) in order to facilitate communication with the underlying southbound management entities (M&O layer components). The adaptation shall be based on a unified information abstraction model and may be enabled via either plugins, wrappers, or proxies as provided by the southbound exposed APIs
COORD-18	**Profiling Experimentation Configurations**
Priority	Essential
Description	The Coordination layer shall expose to the experimenters predefined options for components' configuration that can be provisioned at a given time for experimentation. These predefined configurations are named Profiles and must be included in the test template descriptor

3.1.2. Management and Orchestrator Layer Requirements

Table 3 summarises the requirements related to the management and orchestration capabilities that are necessary within the platforms to deploy, realise and manage the requested experiments on the underlying supporting network and infrastructure.

Table 3: Management and Orchestration (M&O) Layer Functional Requirements

MANO-1	Resource Catalogue per Service
Priority	Essential
Description	The M&O layer shall expose an interface to list all resources allocated to a specific VNF service, including the data-centre and edge location of each service and the related infrastructure resources used
MANO-2	**Adaptation of Services Scale Up and Down**
Priority	Essential
Description	The M&O layer shall provide interfaces to adapt existing services, so that the control application can scale up and down based on monitoring information for optimisation of the resources
MANO-3	**Flexible and Fast Allocation of Network Resources**
Priority	Essential
Description	The M&O layer shall be flexible and fast in providing requested resources and the whole end-to-end process must be performed in 90 minutes or less
MANO-4	**Distributed NFVI on User or Service Demand**
Priority	Essential
Description	The M&O layer shall support multiple NFVI geographically distributed as PoP (Point of Presence) and must be able to instantiate several VNFs per demand - for example to deploy services as close as possible to the end-users for latency optimisations
MANO-5	**Network Service Composition**
Priority	Essential
Description	The M&O layer shall be able to deploy a network service that is composed by both virtual (i.e. VNFs) and physical (i.e. PNF) components and provide lifecycle control
MANO-6	**Network Slice Definition and Blueprint**
Priority	Essential
Description	The M&O layer shall support the definition of templates describing the key network slice baseline parameters and resources, oriented to specific vertical use cases. This needs to take into account 3GPP slice definitions and 5G NR configuration capabilities

MANO-7	Slice Management
Priority	Essential
Description	The M&O layer shall provide management and operation of network slice creation across technological domains (i.e. Computing, Network and Radio) based on the provided and exposed infrastructure elements capabilities. It is anticipated that the end-to-end network slice could extent among multiple Facility platforms

MANO-8	Slice Isolation
Priority	Essential
Description	The M&O layer shall support resource isolation between resources allocated to concurrent network slices. This requirement depends on the isolation capabilities supported at the infrastructure elements and controllers

MANO-9	Slice Stitching and Inter-platform Slice Coordination
Priority	Essential
Description	The M&O shall support connectivity configuration and traffic steering for slices located on separate platforms with the purpose of creating one end-to-end slice

MANO-10	Coexistence of Multiple Network Slices and/or Services
Priority	Essential
Description	The M&O layer shall allow the co-existence of multiple slices running concurrently over the same infrastructure

MANO-11	Network Slice Support for User Equipment (UE)
Priority	Essential
Description	The M&O layer shall allow the platform operator to configure the information which associates a UE to a network slice and a service to a network slice. Based on the subscription, UE capabilities, the access technology being used by the UE, operator's policies and services provided by the network slice, the M&O layer shall also be able to move a UE from one network slice to another, as well as to remove a UE from a network slice

MANO-12	NFV Management and Organisation
Priority	Essential
Description	The M&O layer shall provide means to orchestrate and manage deployment and operation of NFV Network Services on top of virtualisation capable infrastructures. The solution must follow the recent specification as laid out by ETSI NFV ISG [14]

MANO-13	MEC Management and Organisation
Priority	Optional
Description	M&O layer may provide means to orchestrate and manage MEC applications deployment and operation on MEC enabled infrastructures at the network edge. The solution will follow the recent specification as laid out by ETSI MEC ISG [15]
MANO-14	**Real-time Network Monitoring**
Priority	Essential
Description	The M&O layer shall manage and gather monitoring information across all available platform technological domains (NFV, RAN, WAN) and components (eNB, DRAN etc.) in real-time to facilitate the KPI validation objectives
MANO-15	**Quality of Service (QoS) Mapping**
Priority	Optional
Description	The M&O layer may be able to map quality of service levels to specific configurations within the network slice
MANO-16	**RAN Profiling**
Priority	Essential
Description	M&O layer shall expose a list of possible RAN configurations (aka 'profiles') in order to be exploited by the experimenters
MANO-17	**Continuous Connectivity with Multiple Access Technologies**
Priority	Optional
Description	A mobile or nomadic part of the platform (e.g. a van providing 5G remote island based access) may employ multiple radio technologies for backhauling that can be used in parallel as alternative backhaul links, in order to increase the availability of the system's backhaul while the nomadic platform / van is moving or is stationary deployed

3.1.3. Infrastructure Layer Requirements

This section presents the requirements that are relevant to the Infrastructure layer components, focusing on the core network and NFVI, the backhaul network, the mobile edge platform and the radio heads, as well as the end-user equipment.

Table 4: Infrastructure Layer Functional Requirements

INFRA-1	4G and 5G RAN and Core Coexistence/Backward Compatibility
Priority	Essential
Description	The Facility shall provide 4G and 5G RAN and core components to experiment with use cases involving inter-RAT mobility, aggregation of technologies, non-standalone mode, and other interworking capabilities
INFRA-2	5G Mode of Operation
Priority	Essential
Description	The 5G system (core network, RAN, and UE) shall support non-stand alone and standalone modes of 5G operation
INFRA-3	Flexible Configuration of User Equipment
Priority	Essential
Description	The platforms shall provide both commercial and experimental UEs with open APIs to allow flexible configuration
INFRA-4	Experimentation on the Edge Node
Priority	Essential
Description	The Edge Node of the Infrastructure layer shall allow experimentations in order to be used for the deployment of a use case
INFRA-5	Integration of Measurement Probes for Experiments and KPI Validation
Priority	Essential
Description	The Infrastructure layer shall provide the means to execute measurement probes representing different traffic scenarios and the means to collect the relevant metrics to validate the KPIs for those scenarios
INFRA-6	Infrastructure Control Plane
Priority	Essential
Description	The Infrastructure layer shall have a well-defined control plane and control APIs per element in order to facilitate the integration of new hardware and software components and ensure the sustainability of the Facility. The control APIs would depend on the typology of the element: RAN, core network, transport network, etc.

INFRA-7	Resource Isolation for Slicing
Priority	Essential
Description	The Infrastructure layer shall provide means for resource sharing and multiple accesses support. In addition, it shall provide appropriate mechanisms for isolation of resource usage where applicable
INFRA-8	**Edge Isolation Support**
Priority	Essential
Description	The core network shall be operational in case of backhaul issues. In case of distributed deployment of the core network, components operating on the edge shall maintain the service
INFRA-9	**Virtualised Computing Environment**
Priority	Essential
Description	The Infrastructure layer shall be based on virtualised computing infrastructure to support function virtualisation via virtual machines or containers
INFRA-10	**Virtualisation Infrastructure Management**
Priority	Essential
Description	Each virtualised infrastructure used for NFV shall expose interfaces and APIs that allow the resource management and their orchestration by the M&O layer
INFRA-11	**MEC Infrastructure Deployment and Integration**
Priority	Essential
Description	Platforms shall provide computing and networking capabilities for realising MEC capable nodes. The MEC nodes can either be based on available NFVI deployments or can be MEC specific
INFRA-12	**Bring your Own Device Property**
Priority	Optional
Description	The platform may support the integration of a virtual or physical infrastructure component brought by the experimenter in order to conduct the relevant experimentation and validate KPI related objectives. This may be permitted under certain conditions and safety regulations and is strongly dependent on the actual functionality provided by the component. For example, a new radio component that uses frequency that is not licenced cannot be allowed to be deployed
INFRA-13	**Backhaul Bandwidth**
Priority	Essential
Description	The Infrastructure layer must properly define the radio-frequency spectrum required to achieve 5G throughput end-to-end

INFRA-14	Spectrum Use
Priority	Essential
Description	Regulatory constraints with respect to 5G spectrum use must be respected
INFRA-15	**5G Deployment**
Priority	Essential
Description	The 5G RAN and UE shall support 5GNR links at the 3.5GHz frequency band with a bandwidth of 100MHz
INFRA-16	**QoS Management Interface**
Priority	Essential
Description	The Infrastructure layer shall provide an interface for the vertical applications to be able to control the quality of service for the execution of the experiment
INFRA-17	**Support Bearer Priority Set-up**
Priority	Essential
Description	The Infrastructure layer shall provide the capability for pre-emption of lower priority flows and the vertical applications must be able to request the priority of a flow over another one
INFRA-18	**Support Different Level of Access Priority**
Priority	Essential
Description	The Infrastructure layer shall support the capability to provide different levels of access priority for the vertical applications end-users
INFRA-19	**Provide MCS Location Service**
Priority	Optional
Description	The Infrastructure layer of a platform may provide 3GPP MCS standard [16] location service capabilities
INFRA-20	**Link Aggregation**
Priority	Essential
Description	The platform shall provide means for aggregating capacity by optimally distributing the traffic across heterogeneous backhaul links
INFRA-21	**Support Small Cells and D-RAN**
Priority	Essential
Description	The Infrastructure layer shall provide both small cell and distributed RAN solutions for gNB

INFRA-22	Support Wifi RAT
Priority	Essential
Description	The Infrastructure layer shall integrate WiFi RAT according to 3GPP standards
INFRA-23	Support for Software Defined Networking (SDN)
Priority	Essential
Description	The Infrastructure layer shall support SDN to achieve automation and virtualisation and through network programmability provide flexibility for traffic steering per experiment demand

3.1.4. Cross Layer and End-to-end Requirements

This section accumulates the set of functional requirements that are generic and require attention during the design of all 5GENESIS blueprint layers.

Table 5: Cross Layer Functional Requirements

E2E-1	KPI Validation
Priority	Essential
Description	The platform and all its components shall be able to measure and validate the target KPIs per case
E2E-2	Automation
Priority	Optional
Description	The configuration and control of all the components within the platform may support automation. Unattended execution of the experiments may be supported
E2E-3	Satellite Component Integration
Priority	Essential
Description	The platform shall provide enablers at all layers for the integration and end-to-end management of satellite communications technologies
E2E-4	Optimise User QoS per Service
Priority	Essential
Description	The platform shall enable operators to specify and modify the types of mobility support provided for a UE or group of UE
E2E-5	Support Mobility Management
Priority	Optional
Description	The platform capabilities may consider means to optimise network behaviour (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.

3.2. Non Functional Requirements

Non-functional requirements typically refer to supporting, operational aspects that need to be available to enable or facilitate the envisioned functionality. Typically, they include performance, scalability, reliability, extensibility, maintainability, modularity, interoperability as well as security and privacy characteristics. Such aspects primarily affect the IT systems and network components of the designed solution. It goes without saying that all such requirements are valid and shall be considered during the design of the platforms. Nevertheless, in this section the intention is to highlight the non-functional requirements by defining their impact in the platforms' design and explain the rationale of their usage.

As presented in Section 2.2.2, the 5G PPP KPIs with their specific measurable objectives shall be validated as part of the Facility implementation, as well as, during the execution of the trial campaigns. However, these KPIs are also considered essential non-functional requirements, since the project's objective is to provide an operational 5G Facility to be used from verticals to execute and measure experiments. Each and every platform that constitutes the Facility must be designed, deployed and validated targeting the specific measurable objectives per KPI in scope. In this process, it is anticipated that due to the diversity of the environments each platform supports, different levels of KPI fulfilment will be achieved. As the project progresses, the reached performance against each KPI target will be reported by each platform.

Apart from the Performance KPIs, the Quality of Experience goals of 5GENESIS are also considered important non-functional requirements. These are depicted in Table 6:

Table 6: 5GENESIS Quality of Experience Requirements

NFUNC-1	User Perceived Quality of Experience
Priority	Essential
Description	For use cases where human type communications is involved, the user perceived quality of experience is a significant application-level indicator. An assessment process must be put in place inviting real end-users to participate in order to provide measurements and feedback to improve the service offered
Reference Layer	Coordination
NFUNC-2	**End-2-End Security Guarantees**
Priority	Essential
Description	Security guarantees including security threat identification and security failure isolation specifically as the platforms shall be open for experimentation, are significant considerations for their stability. Security assurances in dense urban environments for demanding content delivery applications must be addressed while at the same time impact on quality of experience must be minimised
Reference Layer	All

NFUNC-3	Performance of the Network Life Cycle Functions
Priority	Essential
Description	The trade-off between the flexibility required in the 5G networking and the constraints and limitations of the virtualisation and MANO frameworks must to be quantified and acted upon. From the network life cycle perspective slice establishment time, VNF relocation and instantiation times, the computational resource usage of the cloudified protocol stack are important performance factors to be measured
Reference Layer	Management and Orchestration, Infrastructure

During the requirements analysis phase, specific non-functional requirements focusing on particular 5GENESIS components, nevertheless with value across all platforms, have been identified. These requirements are presented in Table 7.

Table 7: 5GENESIS Non Functional Requirements

NFUNC-4	Peak Radio Latency
Priority	Essential
Description	The achieved transmission latency, depending on the 5GNR implementation, shall be 2 ms for a single UE/flow
Reference Layer	Infrastructure
NFUNC-5	Service Continuity
Priority	Essential
Description	The Facility shall provide service continuity when using multiple backhaul technologies
Reference Layer	Management and Orchestration
NFUNC-6	Privacy
Priority	Essential
Description	The Facility shall enable processes for guarantying experimenter privacy and consent to cater for GDPR compliance
Reference Layer	Coordination
NFUNC-7	Authentication and Authorisation
Priority	Essential
Description	The Coordination layer shall provide means for authentication and authorisation of experimenters accessing the Facility. Security functions for user authentication and access control are of great importance since the experimentation platforms can be shared among multiple experimenters at a given time and stringent control shall be put in place

Reference Layer	Coordination
NFUNC-8	Network Seamless Authentication
Priority	Essential
Description	The Coordination layer shall provide means for network seamless selection and authentication across all access networks involved in the experiment
Reference Layer	Coordination
NFUNC-9	Operational Stability and Availability
Priority	Essential
Description	The Facility shall offer continuous, uninterruptable operation during experimentation. Any disturbances or anomalies shall be able to be identified
Reference Layer	All
NFUNC-10	Operational Usability
Priority	Essential
Description	The platform shall offer a comprehensive, usable and easy to learn interface for the experimenters
Reference Layer	All
NFUNC-11	Repeatability of the Results
Priority	Essential
Description	The platform shall guarantee that the experiments' results are repeatable achieving accurate evaluation under the same platform configuration status
Reference Layer	All
NFUNC-12	User Density Simulation and Scaling
Priority	Essential
Description	The platform shall in principle be able to support high user density, i.e. in terms of the number of users within the coverage area of a cell. For experimentation deployments, in which the coverage of a cell is reduced (e.g. due to imposed limitations of transmission power) the absolute number of users per cell area shall be correspondingly adjusted
Reference Layer	Infrastructure

4. 5GENESIS Platforms and Use Cases

The 5GENESIS Facility and its stated objectives are realised through five distinct, diverse and geographically dispersed platforms. While in the previous section the requirements to realise the Facility capabilities have been analysed, this section elaborates into each individual platform to address the underlying technology and topology status, the enhancements foreseen necessary to become part of the perceived 5G Facility and the related innovations to be accomplished. Furthermore, this Section also proposes the specific project KPIs that each platform shall measure, the use cases that will be involved towards validating the 5GENESIS Facility, the KPIs per use case, and the specific requirements that each use case mandates in order to be properly demonstrated.

To harmonise the readability of the information, necessary due to the diversity of the platforms, fixed table templates have been exploited for the classification of the enhancements, the use cases descriptions and the resulting use case specific requirements.

4.1. Athens Platform and Portable Demonstrator

4.1.1. Platform Overview

Athens.5GLink comprises an open 5G Platform, set up in the city of Athens, Greece. The platform evolves into an end-to-end experimental 5G Facility, showcasing features of next generation networks, with particular focus on software network technologies (NFV and SDN) and edge computing for small cell deployments. Athens.5GLink consists of three (3) different sites dispersed over Athens city, as presented in Figure 5:

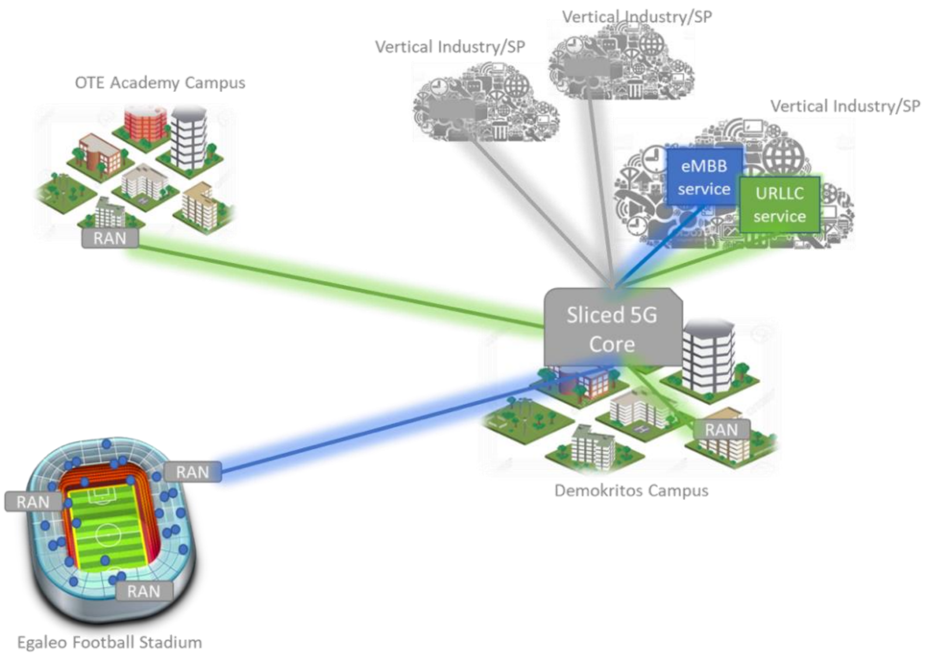

Figure 5: High-level Overview of the Athens Platform

The Athens platform consists of the following sites and testbeds:

- The campus of NCSR "Demokritos", in north-east Athens, is a 150-acre area, combining indoor and outdoor environments, covered by five software-driven 5G wireless nodes and supported by an optical backbone;
- The COSMOTE building (OTEAcademy), in the north of the city, is a multi-functional complex, combining various indoor and outdoor usage scenarios;
- The stadium of Egaleo, in west Athens, that may be used to host demonstrations in a more "realistic" environment and suitable to look into backhaul related issues (i.e. latency, throughput etc.).

Currently the Platform is already formed, following the successful interconnection of all the testbeds in a star formation, exploiting NCSRD site as the central node. There is currently no plan to provide mesh interconnection between the nodes. On the technical part of the interconnection, the link between NCSRD and OTEAcademy sites is realised on top of GRNET[2] optical fiber infrastructure at rates up to 1 Gbps, whereas the link between NCSRD and Egaleo stadium is realised via radio backhaul technology (i.e. UBUQUITI PRISM AC GEN2 at 5GHz Wide Band).

4.1.2. Platform Enhancements and Innovations

The Athens Platform will be enhanced with 5G components and functionality that will upgrade specific capabilities of the current deployment. The summary of these enhancements is provided in the list below and summarised in Table 4:

- **Adaptations for 5GENESIS Coordination layer incorporation:** The 5GENESIS Coordination layer will comprise components that will be the same or similar for each platform. Specifically, for the Athens Platform, southbound APIs and plugins will be developed to accommodate interfacing with the Management and Orchestration components;
- **WAN Infrastructure Management** (WIM), deployed to manage the SDN based WAN infrastructure, supporting slicing features and interconnecting the different domains (i.e. Core NFVI and 5G NC) or used as backhaul between core and edge locations. The WIM will support the management of virtual networks and transport links over the physical infrastructure and will expose northbound APIs in order to interface with M&O layer;
- **Slice Management**, in order to be able to support 5G oriented slicing capabilities over the platform. The solution will be developed within the project and will coordinate the slice creation across all the technology domains available in the platform (i.e. network, computing, radio) exploiting the available capabilities. This enhancement will take into account the virtualisation and slicing capabilities that are exposed at the management/control level in each domain that is part of the end-to-end slice;
- **NFV Orchestration and Management**, for the NFV Infrastructures;
- **MEC Orchestration and Management**, for the MEC Infrastructures;

[2] GRNET is the Greek research and Technology Network that provides Internet connectivity, high quality e-Infrastructures to the Greek Educational, Academic and Research Community

- Automated testing, testing automation will be supported for the virtualised part of the Network Service. The testbed will offer end-to-end testing probes that will be deployed at specific end-points and intermediate locations in the NS graph, in order to be able to execute performance and validation testing;
- **Network Management System**, for the network elements management. This will also provide interface with specific network element management (i.e. Small Cell, gNB, WiFi AP, etc.), wherever applicable;
- Deployment and integration of **5G New Radio** devices operating at 3.5Mhz;
- Deployment of **5G New Radio** compatible **User Equipment;**
- **Integration with contemporary WiFi** radio access technologies (i.e. 802.11ac);
- In the network core part, the 4G core will be sequentially upgraded to 4G+ (i.e. implementing CUPS and virtualisation features for the core components) and then to **5G New Core** (i.e. implementing the 3GPP specifications)
- **MEC** processing nodes providing MEC capabilities at the edge will be deployed in order to support edge processing for the planned use cases;
- **NFV and SDN** enablers are already in-place and operational, in order to carry on with the further requirements for integration with 5G subsystems (e.g. deployment of 4G and 5G core functions, service function chaining and network slicing);
- **Security VNFs** to protect from Intrusion detection and distributed denial of service attacks shall be employed in the access network;
- For the need of experimentation and KPI validations either for the infrastructural components or for the anticipated use cases, **testing and telemetry software** and hardware solutions will be deployed over the platform. These components will support automated execution of tests, collection of measured metrics and evaluation of KPIs according to the decisions of the project.

Table 8: Athens Platform Enhancements per Layer

Platform Enhancements	Coordination Layer	M&O Layer	Infrastructure Layer
5GENESIS Coordination layer incorporation	X		
Security framework instantiation	X		
WAN infrastructure management		X	
Slice management		X	
NFV Orchestration and Management		X	
MEC Orchestration and Management		X	
5G NR			X
5G NR UE			X
Wifi integration			X

Platform Enhancements	Coordination Layer	M&O Layer	Infrastructure Layer
5G Core			X
MEC			X
Security VNFs			X
Testing and telemetry software and hardware	X	X	X

Deploying the above list of platform enhancements, the Athens platform plans to contribute to the following project level ambitions:

- Ambition A1: 5G NR and Wi-Fi integration;
- Ambition B1: Measurement-driven protocol stack optimisations;
- Ambition B2: Orchestration and Management for Multi-connectivity;
- Ambition B3: Cognitive Network Management.

4.1.3. Target KPIs

The Athens Platform KPIs in focus are:

- **Ubiquity**; the use of multi-tenant small cells greatly improves coverage and capacity density for indoor underserved areas and crowded events – using an infrastructure which can be provided by the venue owner and can be fully sliced and shared among many tenants;
- **Latency**; perceived latency is significantly decreased through edge processing and caching;
- **Capacity**; the gain due to the upgrade of the radio front-end to 5GNR, compared with LTE, will be measured and assessed. Furthermore, edge processing significantly relieves the backhaul links, since portion of the user traffic is processed and re-routed locally. This will contribute to avoid backhaul congestion (quite common in several small-cell deployments, which are connected to the core over the best-effort Internet);
- **Service Creation Time**; significant reduction of edge services is to be expected, due to the automation achieved by the cloud-enabled small cell management framework (CESCM).

4.1.4. Use Cases to Validate Target KPIs and Resulting Requirements

The Athens Platform aims at demonstrating three use cases, namely the ‘Big Event’, the ‘Eye in the Sky’ and the ‘Security-as-a-Service at the Edge’, described in the below subsections.

4.1.4.1. Big Event Use Case #1

4.1.4.1.1 Use Case Description

Big Event Use Case	
Target KPI	Low Latency, Coverage, Service Creation Time
5G Service	eMBB
Description	
The 5GENESIS Big Event use case, which will be held at the Egaleo municipal stadium, is aiming at the demonstration of the 5G capabilities in a MEC enabled environment. For this purpose, pioneering applications are going to be developed that drastically augment the creation of content and the experience of the audience in big events (sports, cultural, etc.). In more details, an AR application is going to be developed and installed in the smartphones of the audience. Using the AR application and the camera of the smartphone, the users will be able to focus on any object in the scene (e.g. a particular player in a football much, or a musician at a concert event) and instantly receive information (live statistics of the player or the bio of the performing musician). Furthermore, this application will provide all the available information concerning the football game (game statistics) and will offer the ability to watch replays on demand, or live streams from different viewing angles (installed cameras on the stadium) or even from the camera of users using this app. Finally, the user will have access to a real time panorama streaming of the event or selected replays on demand that will be created on the fly from the streams of the IP cameras. For the needs of this use case multiple IP cameras are going to be installed at the perimeter of the stadium so that to cover the events from various angles. The upstream content from the cameras will be transmitted via the 5G network, aiming to evaluate the front haul requirements of 5G (in delay and jitter) but also to reduce the costs since no extra wiring or network setup is needed for the connection of the cameras. The edge computing infrastructure will be used to i) host part of the AR application, thus reducing the processing overhead at the mobile device, and ii) serve the associated content, thus relieving the backhaul link and drastically reducing the response time (low latency is critical for AR applications). In these compute nodes the core components and services needed for the functionalities of the AR applications are going to run. In particular, it is essential to implement: 1. the component for the calculation of the position and the match statistics of the players; 2. the component responsible for the construction of the panorama video based on the static video streams from the IP cameras; 3. the component responsible for the estimation of the position of each user – area that is scanned by the camera; 4. the backend of the AR application that will orchestrate the operation of the aforementioned components, and organise the content provided to each user's mobile	

device.

4.1.4.1.2 Use Case Specific Requirements

ATH-UC.1-1	MEC Infrastructure At Egaleo
Priority	Essential
Description	The infrastructure available at the Egaleo stadium shall provide at least 2 gNBs with MEC capabilities (collocated with the small cells)
ATH-UC.1-2	**Stadium Radio Coverage**
Priority	Essential
Description	The stadium shall be covered by at least two (>2) Small Cells
ATH-UC.1-3	**Egaleo Stadium Local Distribution Network**
Priority	Essential
Description	The stadium shall provide local Ethernet connectivity to the deployed Small Cells up to 1Gbps
ATH-UC.1-4	**Augmented Reality (AR) Application**
Priority	Essential
Description	The AR application shall provide real-time augmentation over the streamed information

4.1.4.2. 'Eye in the Sky' Applications Use Case #2

4.1.4.2.1 Use Case Description

"Eye in the sky"	
Target KPI	Low Latency, Coverage, Service Creation Time
5G Service	uRRLC, eMBB
Description	
Usually, Unmanned Aerial Vehicles (UAVs) such as drones are controlled using dedicated UHF or 2.4GHz and 5GHz RF channels via remote control hardware. The drone payload often includes a camera that transmits the video back to the control room. However, it is often desirable that the drone control and video is transmitted over the cellular network, to significantly increase the active range of the aerial vehicle. Currently, exploiting 4G technologies, this option suffers from increased end-to-end latency as well as low bandwidth/packet loss, which affect both the responsiveness of the drone control operations, as well as the quality of the video streams which are transmitted. Leveraging on the 5GENESIS 5G Facility capabilities, this use case will test and validate a	

solution that will convey signalling and control data and multimedia streaming data in real-time over the 5G infrastructure at Athens platform. In this context, the validation of this use case will verify that 5G can be a game changer for the so-called “eye in the sky” applications, greatly improving the responsiveness of the drone control and facilitating the transmission of 4K video.

The UAV control link requires ultra-low latency and reliability (i.e. URRLC type of slice) ensuring that the pilot always maintains flight control of the UAV. Multimedia streaming (HD and 4K real-time video) requires the eMBB type of slice. In this context the slice manager should be able to provision both slices and impose traffic steering across the infrastructure. In addition, eMBB applications, such as content delivery to ground control stations during live events, can also leverage the use of UAVs. For these applications a different isolated network slice type, with high throughput and low latency guarantees shall be deployed.

The following two scenarios are currently described:

1. Control the drone over a low-latency 5G slice, also featuring edge computing. If both the pilot and the drone are served from the same radio cell, the edge component will route the control commands directly to the drone, rather than to the core network, thus decreasing response delay. If the control is to be routed across different cells via 5G core components, a low-latency slice will be established, prioritizing the drone control traffic over other applications. The latency from the control stick to the drone’s propeller will be measured using on-board logging software;
2. Transmit HD and 4K real-time video captured by the payload camera to the ground control station over 5G. Similarly, to the drone control traffic, if both the pilot and the drone are served from the same radio cell, the edge component will route the 4K video directly to the control centre. If the control is to be routed across different cells via 5G core components, a low-latency guaranteed-bandwidth slice will be established, prioritising the video over other applications. The latency from the camera to the user’s device will be measured using a combination of network tools and on-board loggers. The video throughput will be measured using network tools.

According to 5G network slicing, virtual isolated end-to-end networks will deployed, based on the requirements for low latency, reliability and high data rates over shared physical RAN. The network flexibility, customisation and resource allocation based on the different needs of “Eye in the sky” use case, maximise the performance and the high Quality of Service (QoS). A Slice Manager decides the network components and the configuration in order to provision the appropriate type of slice. The NSMF that will operate above NFV and MEC MANO and PNFs Management Functions, to support different abstractions of resources and offer access to different management entities.

4.1.4.2.2 Use Case Specific Requirements

ATH-UC.2-1	Navigation of Unmanned Aerial Vehicles (UAVs)
Priority	Essential
Description	The UAV shall be navigated via controller that connects through 5G

	radio
ATH-UC.2-2	NCSRD Radio Coverage
Priority	Essential
Description	The NCSRD campus shall be covered by at least one (>1) Macro Cell
ATH-UC.2-3	UAV Payload
Priority	Essential
Description	The UAV payload capabilities shall accommodate for the additional equipment (testing, 5G radio)
ATH-UC.2-4	UAV Autonomy
Priority	Essential
Description	The UAV shall support autonomy of up to 30 min for full payload operation
ATH-UC.2-5	Multi-Slice Operation
Priority	Essential
Description	The M&O layer shall be able to support provision of 2 slices with different properties for the same end-to-end service
ATH-UC.2-6	Streaming Media End-Users
Priority	Essential
Description	The streaming media service shall be consumed by the UAV control centre

4.1.4.3. Security-as-a-Service (SecaaS) at the edge Use Case #3

4.1.4.3.1 Use Case Description

SecaaS at the edge	
Target KPI	Latency, Service Creation Time
5G Service	All
Description	
The purpose of this use case is to show how the evolved 5G SecaaS services can help to detect and mitigate several types of Distributed Denial-of-Service DDoS attacks and other types of security threats through the use of edge VNFs. The VNFs that will be used for the purposes of this use case are: i) an Intrusion Detection System VNF (vIDS) configured to be off-path to avoid introduction of latency due to processing, and ii) a Firewall VNF (vFW) configured to be in-line to perform actions on the passing traffic. SDN provides the means towards policy-based automation for network devices, which can serve well to achieve	

adaptive security. Network programmability enables the automated security policy enforcement in the case of threatening events, such as the identification of a DoS attack.

For the implementation of this use case, the placement of security functions in the access network is planned, as opposed to the current implementation of LTE networks, where security systems are located in the EPC. For attacks that are originating from mobile users, this placement of security functions results in an early identification and mitigation of the attack, and therefore enables prevention of malicious traffic from entering the backhaul or core network.

Additionally, advanced network insights and anomaly detection will take place through the use of the 5GENESIS cyber-security framework. The cyber-security framework will collect real-time service information from the infrastructure elements (e.g., network flow data, DNS queries, HTTP transactions etc.), stores them in a Big Data infrastructure and analyses them in near-real-time using tailored Machine Learning algorithms. The goal is to identify anomalies (deviations from the normal operation) in the running experiments and network services, which would imply either a malfunction or a security incident. The attacks for demonstration will be chosen to be those that occur more commonly, such as UPD, TCP, and ICMP flooding and amplification attacks. Moreover, attacks will be configured appropriately to simulate real-world security threats that expose features such as botnet forming through Command and Control (C&C) systems and complex techniques to avoid detection such as minimal communication traffic and IP spoofing.

4.1.4.3.2 Use Case Specific Requirements

ATH-UC.3-1	NFVI-PoP Deployment at COSMOTE
Priority	Essential
Description	The COSMOTE site shall contain at least one NFVI-PoP to support deployment of security VNFs
ATH-UC.3-2	**NFV Orchestration**
Priority	Essential
Description	An NFV Orchestrator shall manage the lifecycle of network services, including those related to security, at COSMOTE infrastructure
ATH-UC.3-3	**Security Services**
Priority	Essential
Description	The set of security services introduced as platform enhancements (IDS and virtual FW), shall be used at the edge demonstration
ATH-UC.3-4	**Cyber-security Framework**
Priority	Optional
Description	The cyber-security framework may be deployed collecting monitoring information from the infrastructure elements

ATH-UC.3-5	Security Assessment
Priority	Essential
Description	A set of security attacks and threats shall be selected to test the efficiency of the security solutions deployed at COSMOTE infrastructure

4.1.5. Portable Demonstrator

4.1.5.1. Portable Demonstrator Overview

In addition to the 5GENESIS platforms that are based on fixed infrastructures, the project develops a portable edition of a 5G demonstrator. The aim is to facilitate real-life demos in exhibitions and various events, in locations other than the platforms' host cities, as well as, to offer a packaged solution to vertical industries for experimentation in their premises.

The 5GENESIS Portable 5G Demonstrator will be offered as a "spin-out" of the Athens.5Glink platform, integrating most of its features in a transportable platform, built on an 8U – 10U portable rack on wheels.

The Portable Demonstrator will feature, among others:

- 5G NR radio front-end and equipment, based on Software Defined radio (SDR);
- 5G NG core functions;
- Coordinator platform and NFV and SDN MANO stacks, mirroring all the necessary relevant components;
- OpenStack-based NFVI (also hosting edge and radio or SDR functions);
- SDN switch and software-based edge router and firewall for external interconnection.

Processed and refined demo scenarios related to some of the envisaged use cases across all platforms will be assessed for suitability for the Portable Demonstrator. The assessment shall examine and act upon the limitations and capabilities of the Portable Demonstrator in order to deliver their demonstration.

4.1.5.2. Portable Demonstrator Specific Requirements

ATH-PD-1	Mobility
Priority	Essential
Description	The portable demonstrator shall be self-contained and movable, requiring only power for operation.
ATH-PD-2	Deployment ability
Priority	Essential
Description	The portable demonstrator shall allow for quick deployment of its components
ATH-PD-3	Performance
Priority	Essential
Description	The portable demonstrator characteristics shall comply to the requirements set by the anticipated demonstrators

4.2. Málaga Platform

4.2.1. Platform Overview

The 5GENESIS Málaga Platform aims at the validation of selected 5G KPIs in indoor and outdoor scenarios. Technologies in the platform are focused on integrating 5G with other access technologies (e.g. 4G, WiFi, fiber) with great automation capabilities to execute experiments both unattended and with real users.

The physical infrastructure is mainly hosted and operated by University of Málaga (UMA), Málaga city (Police Department) and Telefonica.

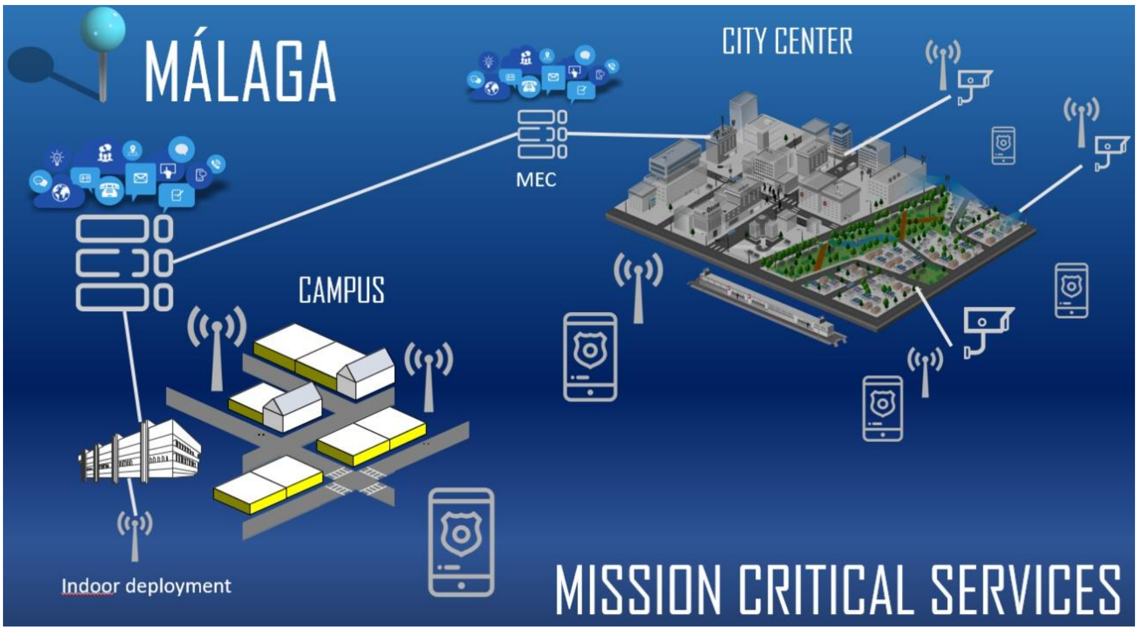

Figure 6: High-level Overview of the Málaga Platform

It is composed by four big areas:

- Indoor fully automated UMA lab for initial testing of technologies and services and for identification of baseline values for KPIs;
- Outdoor UMA deployment for first testing of use cases in a controlled environment with and without real users;
- Outdoor Málaga city deployment for testing with real users, including the possibility of large scale events;
- Edge computing platform at Telefonica premises in Málaga city to connect UMA and Málaga city deployments in order to demonstrate the advantages of MEC capabilities.

4.2.2. Platform Enhancements and Innovations

The technologies available during the project will include fully automated experimentation, 5GNR, LTE-A, NBIoT, LTE-WiFi aggregation, GPS emulation, NFV and SDN in transport and core, edge computing for low latency services. Vertical industries shall be able to deploy their own services in the platform or can connect their remote services to the platform. The Málaga platform shall offer the common 5GENESIS Experimenter Interface to describe services and experiments to be run in the platforms. The platform also exposes some internal interfaces to connect vertical services and devices (most of them are 3GPP interfaces). To achieve these capabilities, the current platform will be enhanced in the following way, also summarised per reference layer in Table 9:

- **5GENESIS Experimenter Interface provision**: this interface will be common to all the platforms and is the main entry point to the Málaga Platform and shall be based on existing Web Portal [26];
- **Experiment life cycle management implementation**, and the main coordination entity that makes use of the Management and Orchestration layer services will be developed based upon existing orchestrator component [27];
- **Automation towards repeatability of experiments**: The existing automation platform [28] will be expanded to automate the new components developed or integrated as part of 5GENESIS. The automation engine will be used for the control of the experiments life cycle and the collection of measurements needed to compute the KPIs during the execution of experiments. The automation platform will be also extended to control the outdoor deployment of the testbed;
- **Slice creation and management** in such a way that several slices can be active at the same time to support concurrent experiments;
- **Automated management** involving MANO solutions to orchestrate all the (software) network components to deploy and to control the life-cycle of the VNFs;
- **Infrastructure extensions** of current testbed [29], [30] to create an indoor 5G end-to-end platform: the design of the testbed allows the integration of 5G NR components provided

by the project's technology providers to complete a 5G lab testbed suitable to validate 5G PPP KPIS in an end-to-end controlled environment;

- **Outdoor deployments** at UMA campus and Málaga City: the deployment of new LTE-A nodes and 5G NR nodes, together with Edge Computing solution and vEPC will create a more realistic environment for low latency and high bandwidth services, suitable to be expanded to cover large-scale events.

Table 9: Málaga Platform Enhancements per Layer

Platform Enhancements	Coordination Layer	M&O Layer	Infrastructure Layer
5GENESIS Experimenter Interface	X		
Experiment life cycle management	X		
Repeatability of experiments	X		X
Slice manager		X	X
MANO		X	X
Indoor 5G testbed			X
Outdoor UMA deployment			X
Outdoor city deployment			X

With the final setup, the platform will contribute to several innovations:

- Ambition A1: 5G NR and Wi-Fi integration;
- Ambition A3: Dynamic spectrum access for multiservice access stratum;
- Ambition B3: Cognitive Network Management.

4.2.3. Target KPIs

The main KPIs validated in the platform are the following:

- **Capacity**: the aggregation of licensed and unlicensed spectrum with some method evolved from LWIP, including 5G NR will increase the density of users, the peak data rate per user and the global traffic in the area;
- **Latency**: latency at IP level for MCS will be demonstrated in the lab and in the field using edge computing solutions and slicing to prioritise traffic;
- **Speed**: latency, availability and the rest of KPIs will be demonstrated in the context of several mobility scenarios (from stationary to high speed);
- **Availability**: the provision of multiple connectivity with the aggregation (LTE, 5G NR and WiFi) will increase availability of the network connection;
- **Service creation time**: the automated orchestration of VNFs and slicing will reduce the time to create, to deploy and to setup services;

- **Network management CAPEX/OPEX**; the automated orchestration of VNFs and slicing are also expected to contribute to the reduction of management cost;
- **Other KPIs**, such as the user level KPIs defined by 3GPPP for MCS.

4.2.4. Use Cases to Validate Target KPIs and Resulting Requirements

The Málaga Platform plans to demonstrate three use cases, namely 'Wireless Video in Large Event', 'Multimedia Mission Critical Services' and 'MEC-based Mission Critical Services'.

4.2.4.1. Wireless Video in Large Scale Event Use Case #1

4.2.4.1.1 Use Case Description

<table>
<tr><th colspan="2">Wireless Video in Large Scale Events</th></tr>
<tr><td>Target KPI</td><td>Capacity, Availability, Service Creation Time</td></tr>
<tr><td>5G Service</td><td>eMBB</td></tr>
<tr><td colspan="2">Description</td></tr>
<tr><td colspan="2">Málaga Police is currently operating about 20 cameras in the city centre to monitor large scale events which will be improved in terms of area covered and video quality supported.

The cameras are connected to the main control room with a combination of fiber and radio link technologies. The system is effective enough to increase security in the area; however there are two specific gaps that could be addressed by 5GENESIS. One gap is the need to deploy new cameras on the fly based on new events located in areas not covered by the cameras. The use of 5GNR modems to connect portable cameras will make easier the adaptation of the deployment to the specific events. The second gap is the need to broadcast high quality video from specific cameras to the police present in the area (using tablets or smartphones) in order to help them to recognise specific people or objects. Both scenarios will benefit from using specific services deployed and orchestrated in the platform as VNFs.</td></tr>
</table>

4.2.4.1.2 Use Case Specific Requirements

MAL-UC.1-1	Portable Cameras
Priority	Essential
Description	Portable cameras with long duration batteries and 4G and 5G NR modems shall be available
MAL-UC.1-2	**User Equipment**
Priority	Essential
Description	Portable tablets or smartphones with 4G and 5G connectivity shall be available

MAL-UC.1-3	Broadcast Support
Priority	Essential
Description	Broadcast support for video streaming to a subset of UEs in the area of the same gNB shall be available
MAL-UC.1-4	**Mobile Edge Computing**
Priority	Essential
Description	MEC support to avoid the video travelling the full data path through the core network to the control centre and then back to the UEs is necessary

4.2.4.2. Multimedia Mission Critical Services Use Case #2

4.2.4.2.1 Use Case Description

Multimedia Mission Critical Services (MCS)	
Target KPI	Capacity, Latency, Reliability, and Density of Users
5G Service	uRLLC, eMBB
Description	

Mission Critical Services (MCS) solution allows smartphone public safety users to access professional communication in groups and in private calls, as shown in the figures below:

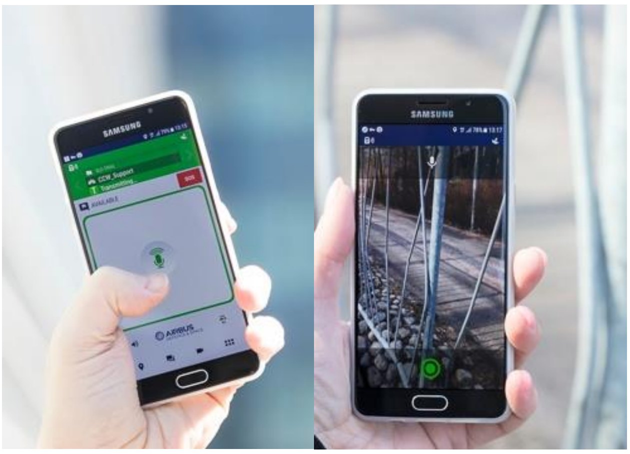

Figure 7: Málaga Platform Use Case #2 MCS Professional Communications

Voice services, instant messaging, video communication, location mapping, and emergency calls will be used to validate some of the Málaga platform targeted 5G KPIs. The following services are enabled in this use case:

- Group and individual calls
- Group and individual messaging
- Group and individual multimedia messaging

- Group and individual video calls
- Emergency calls
- Location and map services

The platform will allow the creation, through the experimenter interface, of several slices to demonstrate how they can provide benefit for public safety use cases. The MCS application and server communicate with the platform:

- at the data level for the Mission Critical Services traffic
- at the control level with the network quality of service functions to enable different priority levels for different users and different communication types

Through this use case, apart from the identified target KPIs, the project's Quality of Experience requirements will be addressed and evaluated by real users, i.e. the Málaga Police Department based on the following:

- Being able to allow the coordination of public safety teams demanding real time communication in the field:
  - Smartphone users access secure, real-time communications groups and exchange voice and video with their teams and with a central command
  - Photos, videos, spoken communication and location data is transmitted by teams in the field
  - Central command assists tactical leaders in having a more complete view of the situation and thus taking informed decisions
  - Decision making is improved with additional information
- Improving the mission critical organisations' efficiency and effectiveness thanks to the MCS messaging features, for example by:
  - sharing a picture of a person or a suspect
  - sharing video of an accident
  - receiving a map location from a field user
- Maintaining unbroken visual and spoken communication between team members during the public safety operations.

4.2.4.2.2 Use Case Specific Requirements

MAL-UC.2-1	Mobile Access to Network
Priority	Essential
Description	The Mission Critical Services mobile application, installed on smartphones, must be able to access to the 5G network for data transmission
MAL-UC.2-2	Server Access to Network

Priority	Essential
Description	The Mission Critical Services servers must be able to access the 5G network core network for data transmission
MAL-UC.2-3	**Access to Network Bearer Control**
Priority	Essential
Description	The Mission Critical Services server must be able to control the network bearers using the Rx interface as defined in the 3GPP 29.212 [17], 29.213 [18] and 29.214 [19] and the N5 interface as defined in 3GPP 29.512 [20], 29.513 [21] and 29.514 [22] documents. This allows the bearers set up, modification and closure, bearer priority and pre-emption

4.2.4.3. MEC-based Mission Critical Services Use Case #3

4.2.4.3.1 Use Case Description

Target KPI	Capacity, Latency, Speed, Availability, Service Creation Time
5G Service	eMBB
Description	
The MEC-based MCS use-case aims at demonstrating the benefits and drawbacks of the MCS service provisioning and placement in circumstances where architecture with MEC capabilities is involved. To this end, the use-case will involve two different instances of its VNFs: one heading to UMA (non-MEC) and the other heading to the Málaga City Centre where the MEC server of Telefonica is placed. MCS scenarios are considered where big amount of first responders (Málaga festival or another selected event by the police of Málaga) are using the deployed service in the centre of Málaga over the combination of radio accesses (4G and 5G). Thus, both 4G+ and 5G UEs will be involved in accordance to the testing period and 5G UEs' availability. All UEs will run an MCS application in order to have access to MCPTT calls, MCVideo calls or MCData transmissions. In the server side, the MCS service will be deployed as VNFs in a single slice depending on the end-user profile (e.g. police of Málaga, pedestrians). Regardless the packet core (4G or 5G), the MCS service will be integrated in order to manage the QoS signalling and default and dedicated bearers for each kind of service (MCPTT, MCVideo or MCData). Since both MEC-based MCS service and non-MEC service will be used, the use-case will analyse the differences considering service-level KPIs (end-to-end access-time, token request until response times, availability). Taking into account the inclusion of both MEC mechanism and probably eMBMS capabilities it is expected that the utilised resources will be reduced for the same traffic conditions by using	

unicast channels for each UE.

In the same way, the data rates will remain unchanged while the service latencies and access times are expected to greatly improve. In this envisioned scenario, the use-case will try to address a solution for either of the following circumstances:

1. One of the main improvements of MEC-based services against non-MEC-based services is that the end-to-end latency is drastically reduced and most of the times this improvement is almost directly mapped to an enhancement of overall service KPIs and end-users QoE (oriented to first-responders in our case). Therefore, MCS that required higher capacities and guaranteed bit rates (e.g. MCVideo), could greatly improve their KPIs
2. Related to the previous scenario, under certain crowded or loaded conditions, only the fact of involving a MEC-server may not be sufficient and a split of the traffic could be the most appropriate option in order to achieve the best overall performance. To this end, the project will use both the MEC-server path and the path to the end-server located at UMA so as to balance the traffic

The aforementioned use-case options and circumstances will help measure the appropriateness of 5G components as well. In this context, important 5G components such as the orchestrator will play a fundamental role in the management of traffic needs and the coordination of every component in the end-to-end path with special impact on the deployment time and service access time

4.2.4.3.2 Use Case Specific Requirements

MAL-UC.3-1	OAM Interface to Manage MCS-related Procedures
Priority	Essential
Description	The platform shall provide an Operations Administration and Management (OAM) interface to allow modifications and management of MCS-related procedures such as client profile management, groups management, calls management and so forth
MAL-UC.3-2	Calling Capabilities over 5G
Priority	Essential
Description	The platform shall provide standard calling capabilities (private and group) according to the 3GPP standard. The calls shall be end-to-end in terms of 5G, involving all new 5G components (UE, NR and packet core)
MAL-UC.3-3	Multimedia Calling Capabilities over 5G
Priority	Essential
Description	The platform shall provide standard multimedia calling capabilities according to the 3GPP standard. The calls shall be end-to-end in terms of 5G, involving all new 5G components (UE, NR and packet core)
MAL-UC.3-4	Data Capabilities over 5G

Priority	Essential
Description	The platform shall provide standard data sending capabilities according to the 3GPP standard. The data flows shall be end-to-end in terms of 5G, involving all new 5G components (UE, NR and packet core)
MAL-UC.3-5	Slice Instantiation Based on User Profile
Priority	Essential
Description	The platform shall support instantiation of slices depending on the end-user profile (policemen, pedestrians, paramedics, firemen)

4.3. Limassol Platform

4.3.1. Platform Overview

The Limassol 5G platform will integrate several infrastructures in the city of Limassol, Cyprus, in order to form an interoperable multi-radio Facility, combining terrestrial and satellite communications with the ultimate aim of efficiently extending 5G coverage to underserved areas. To that end, the Limassol 5G platform will employ NFV and SDN enabled satellite communications as well as tight integration of different access and backhaul technologies, in order to achieve the following innovative features: i) ubiquitous coverage with reduced latency, ii) support for multi-radio slicing, iii) 5G throughput enhancement via air interface aggregation, where necessary and iv) dynamic spectrum allocation between satellite and terrestrial. Figure 8 depicts a high-level topology of the Limassol platform, highlighting the main assets involved.

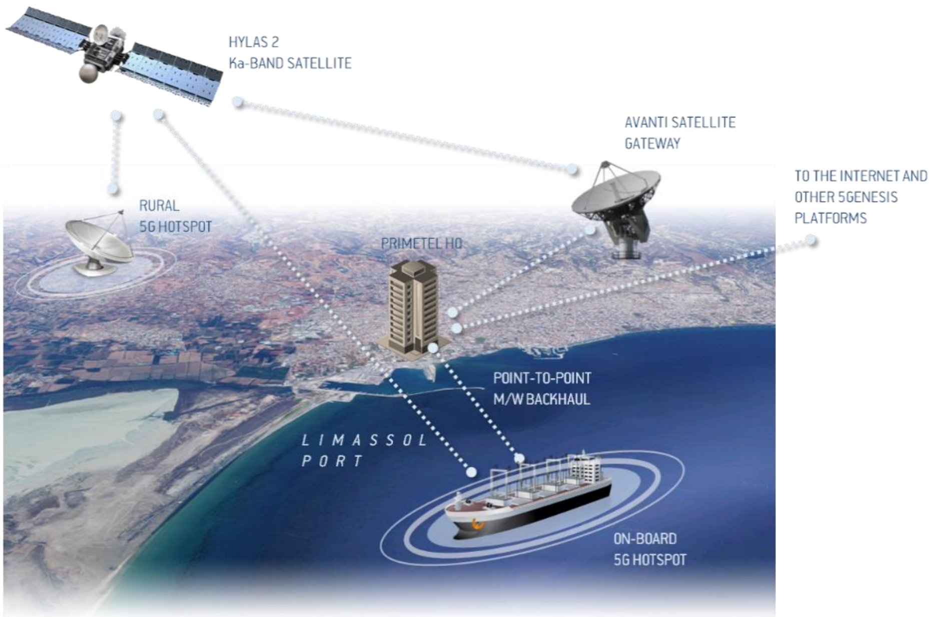

Figure 8: High-level Overview of the Limassol Platform

The key infrastructures on which the platform will be built are:

- **The Avanti Satellite Gateway at Makarios Earth Station.** The Avanti Ground Earth Station facility in Cyprus will be used to provide managed SATCOM services over its HYLAS 2 and HYLAS 4 satellites using a professional grade network platform supporting efficient transport of cellular traffic, as well as management interfaces and APIs via its cloud operational support system (OSS) and network platform (NMS);
- **The Primetel R&D experimental testbed in Limassol**. It is located in the company's central building close to the Limassol port. The PLC testbed will act as the core node of the platform by: i) hosting, in its private Data Centre, all the management components and services for the platform, ii) providing the interconnection to the Satellite Gateway and the Internet, as well as to the other 5GENESIS platforms.

4.3.2. Platform Enhancements and Innovations

For the Limassol testbed, the 5GENESIS work plan includes all the activities necessary to upgrade and integrate the existing infrastructure and sites in order to constitute an integrated 5G-capable testbed. In particular, the following enhancements, also summarised per layer in Table 10 are foreseen:

- **Interconnecting the sites:** This involves mainly interconnecting the PrimeTel testbed with: i) the Avanti Gateway and ii) with other 5GENESIS testbeds for inter-domain experiments. (Infrastructure plane activity);
- **Deploying the EPC and 5G NG core functions** at the PrimeTel testbed. These will focus mostly on session establishment and mobility management. This development will be fully aligned with the 3GPP specifications (Infrastructure plane activity);
- **Establishing the terrestrial backhaul link:** The backhaul link will be set up between the PrimeTel building and the remote (on-board) network, based either on point-to-point WiFi or legacy LTE connectivity (Infrastructure plane activity);
- **Installing and integrating the 5G NR components:** These will be implemented on SDR platforms for both the gNB and the UE. This development will be fully aligned with the latest possible 3GPP specifications. (Infrastructure plane activity);
- **Enabling NFV and SDN capable satellite communications:** In order to integrate the SATCOM components (ground station and terminals) seamlessly into the 5G context, they need to be upgraded with SDN and NFV capabilities. That is: i) certain network elements in the SATCOM delivery chain need to become SDN-enabled, ii) the satellite gateway needs to be enhanced with an NFVI-PoP and iii) the satellite terminal needs to become SDN and NFV capable. For these tasks, 5GENESIS will leverage previous work done in the frame of ESA CloudSat and H2020 ICT VITAL projects;
- **Adapting and integrating the NFV and MEC MANO** stack for hosting and managing VNFs at the core and the edge. This will be built on the Open Source MANO (OSM) platform, integrated and adapted to manage the satellite-specific VNFs (see below). The implementation will follow the ETSI ISG NFV and ETSI ISG MEC family of standards. (Management and Orchestration plane activity);
- **Adapting and integrating the Security Framework**, employing a mixture of centralised and distributed resource management functions and leveraging Big Data technologies and

analytics (Apache Spot, Apache Spark and Hadoop) for enhancing network security. (Coordination plane activity);

- **Adapting and integrating the Spectrum Management** components, based on a mixture of centralised and distributed resource management functions and focusing on dynamic spectrum sharing between satellite and terrestrial (Infrastructure plane activity);
- **Adapting and integrating the WAN Optimisation and Link Aggregation** virtual functions, achieving i) WAN throughput acceleration using TCP acceleration and Data Redundancy Elimination and ii) satellite and terrestrial link bonding. (Infrastructure plane activity);
- **Coordination plane activity** for developing, installing and integrating the upper-layer coordination functions: The coordinator platform for the Limassol platform will be developed for the needs of the project and tailored to match the specificities and particular features of the platform;
- **Establishing the northbound API to the experimenters**, exposing the methods and the parameters relevant to the features of the platform. This activity will take benefit of the common components developed as part of the Coordination plane activity;
- **Adapting and integrating the IoT interoperability service,** work provided in the frame of H2020 project INTER-IoT, is an E2E service that provides IoT platforms and systems interoperability whose components are distributed into the platform, including edge and core locations, and facilitates communication, processing and homogenisation of sensor data (Infrastructure plane activity).

Table 10: Limassol Platform Enhancements per Layer

Platform Enhancements	Coordination Layer	M&O Layer	Infrastructure Layer
Coordination plane activity	X		
Security Framework	X		
WAN Optimisation and Link Aggregation		X	
NFV and MEC MANO		X	
Sites Interconnection			X
Spectrum Management			X
Deploy EPC and 5G NG Core			X
Install 5G NR			X
Establish Terrestrial Backhaul			X
NFV and SDN-capable satellite communications			X
IoT Interoperability Service			X

The technical developments of the platform are intended to address specific innovative aspects (see Sec. 2.4) such as:

- Ambition A3: Dynamic spectrum access for multiservice access stratum;
- Ambition A4: Integrated Satellite-Wireless Architecture;
- Ambition B2: Orchestration and Management for Multi-connectivity.

4.3.3. Target KPIs

The KPIs which the Limassol platform will focus are:

- **Ubiquity**; almost ubiquitous coverage is expected thanks to the use of the SATCOM component;
- **Latency**; the virtualised data plane components, locally deployed in the remote network, are meant to significantly alleviate the high satellite latency;
- **Reliability**; the multi-radio bandwidth aggregation in the backhaul segment, powered by SDN and NFV, will help to eliminate the effect of network outages by rapidly switching to failover links;
- **Capacity**; in respect to:
  - **Data rate**; the multi-radio bandwidth aggregation in the backhaul segment, powered by SDN and NFV for multipath delivery, will combine the high data rate of 5G backhauls with Ka-band SATCOM in order to deliver data rates much higher than the ones currently experienced in maritime rural access scenarios;
  - **Multicast Capacity**; the impact of the use of efficient multicast services over the satellite link to offload high data rate traffic from cellular unicast services to devices.
- **Service creation time**; service virtualisation and end-to-end automation is expected to radically reduce service creation time, especially for satellite services.

4.3.4. Use Cases to Validate Target KPIs and Resulting Requirements

The Limassol Platform shall focus on two use cases: maritime communications and capacity-on-demand in rural or underserved areas and plans to demonstrate the respective use cases, namely 'Maritime Communications' and '5G and IoT in Rural Areas".

4.3.4.1. Maritime Communications Use Case #1

4.3.4.1.1 Use Case Description

5G Maritime Communications	
Target KPI	Coverage, Latency, Reliability, Capacity
5G Service	eMBB
Description	
Satellite networks provide the only means of ubiquitous connectivity for long-range	

transportation media. Cargo vessels, with international routes far beyond the coverage of terrestrial cellular networks, typically use SATCOM for connectivity, mostly for voice, vessel-to-office communication, as well as typical Internet access for the entertainment of the crew.

While these type of services are commonly offered by dedicated devices on-board or via short-range WiFi networks, this use case will show how the integration of SATCOM and 5G can help to deploy full-scale 5G communications and services on board. In particular, this use case will involve the deployment of a “5G hotspot” in the sea, either on a ship or an offshore facility, using satellite as backhaul and 5G RAN and edge services to allow i) access by the personal 5G terminals of the crew (BYOD case) and ii) localised session handling between two or more on-board terminals. In particular, the platform will be able to demonstrate direct communication between the 5G terminals on the ship, as well as, local access to vessel services (Local Break-out function). The focus will be on eMBB services on-board, demonstrating slices with different characteristics for crew entertainment and vessel-to-office communications.

Moreover, virtual network functions related to multi-link optimisation and aggregation will be deployed, to boost throughput and reduce latency when the vessel is close to the shore, which allows employing a secondary backhaul channel (e.g. the port’s WiFi or microwave point-to-point or LTE provided by a terrestrial operator). The link aggregation VNFs will share the traffic between the satellite and terrestrial backhaul in an optimal manner.

The test site shall be a tanker and the network to be installed shall offer local 5G connectivity and interconnection with the core or backbone network via wireless links (when close to the shore) or satellite connections (when in the open sea).

4.3.4.1.2 Use Case Specific Requirements

LIM-UC.1-1	Mobile Satellite Connectivity
Priority	Essential
Description	The platform shall provide Ka-band satellite backhaul, using dedicated bandwidth and a steerable antenna, suitable for use on route
LIM-UC.1-2	Terrestrial Backhaul
Priority	Essential
Description	The platform shall offer a terrestrial backhaul channel for communications close to the shore
LIM-UC.1-3	Mobile 5G Hotspot
Priority	Essential
Description	The platform shall feature a complete 5G hotspot to be installed in the vessel, featuring an edge platform and a 5G gNB
LIM-UC.1-4	Localised Device Communication
Priority	Essential

Description	The platform shall be able to demonstrate direct communication between the 5G terminals on the ship, as well as local access to vessel services (Local Break-out function)
LIM-UC.1-5	Vessel installation
Priority	Essential
Description	The on-board 5G hotspot shall fulfil all necessary particularities in order to allow installation on the vessel
LIM-UC.1-6	Satellite and 5G integration
Priority	Essential
Description	The platform shall feature the capability to deploy SDN rules and VNFs within the satellite network

4.3.4.2. 5G Capacity-on-demand and IoT in Rural Areas Use Case #2

4.3.4.2.1 Use case Description

Target KPI	Capacity, Latency, Reliability
5G Service	eMBB, mMTC
Description	

SATCOM is commonly engaged to extend data connectivity to areas not well covered by the terrestrial cellular infrastructure (rural or underdeveloped areas, etc.). The support of cellular backhauling as well as remote sensor networks are common application scenarios. However, most services are currently restricted to plain Internet connectivity and are independent from 3G or 4G services. A tight integration with 5G will enable seamless session management, dynamic provision of virtualised services (VNFs, edge applications etc.) at the core and at the edge, as well as software-defined networking over SATCOM.

This use case foresees the ad-hoc deployment of a “5G hotspot” in areas not (adequately) covered by the existing cellular network infrastructure. Possible application scenarios include (1) cellular backhauling e.g. capacity boost for a flash crowd event, or the dynamic provision of network slices for multimedia services for large-scale events, as well as, (2) enhanced support for remote sensor networks (IoT services). The focus will be both on eMBB and mMTC communications, employing slices of different characteristics.

This use case will also involve features such as:

- the dynamic spectrum sharing between satellite and terrestrial, based on a mixture of centralised and distributed resource management functions;
- the deployment of core and edge virtual services for the efficient handling of IoT traffic, implementing functions such as protocol conversion, bottom-up communication transfer and data semantic contextualisation and translation. Additionally, an interoperability

middleware will be provided, in order to provide uniform access to data from heterogeneous IoT platforms. In this way, the sensor data coming from the different sources (e.g., rural sensor networks, on-board ship sensors and network management systems) can be managed and accessed through a unified point;

- detailed analytics on the traffic to detect and classify security incidents, based on Big Data and Machine Learning technologies.

4.3.4.2.2 Use Case Specific Requirements

LIM-UC.2-1	Mobile Satellite Connectivity
Priority	Essential
Description	The platform shall provide Ka-band satellite backhaul, using dedicated bandwidth and a portable antenna, suitable for ad-hoc deployment
LIM-UC.2-2	Mobile 5G Hotspot
Priority	Essential
Description	The platform shall feature a complete 5G hotspot to be deployed, featuring an edge platform and a 5G gNB
LIM-UC.2-3	Satellite and 5G integration
Priority	Essential
Description	The platform shall feature the capability to deploy SDN rules and VNFs within the satellite network
LIM-UC.2-4	Spectrum Management
Priority	Essential
Description	The platform shall feature dynamic spectrum sharing between satellite and terrestrial
LIM-UC.2-5	IoT interoperability
Priority	Essential
Description	The platform shall feature functions for enhancing IoT communication and interoperability

4.4. Surrey Platform

4.4.1. Platform Overview

At the core of the SURREY platform is the 5G Innovation Centre's (5GIC) unique state-of-the-art 5G trials and demonstration testbed. The architecture is designed to employ the best of evolving NFV and SDN implementations and features, in order to address known shortcomings of today's 3GPP based architectures (Release 15). The distributed architecture is able to inter-connect with and support different RAN configurations (C-RAN, D-RAN or hybrid-RAN), according to available transmission options. The testbed in its current form covers the whole of the main campus of the University of Surrey, which spans an area of around 4km^2. The current deployment consists of more than 40 cell sites implementing around 66 outdoor cells of which 3 cells are umbrella cells implementing the C-plane and the remaining cells are small cells implementing the user plane functions. The RAN segment of the testbed is illustrated in the map overlay in following Figure 9.

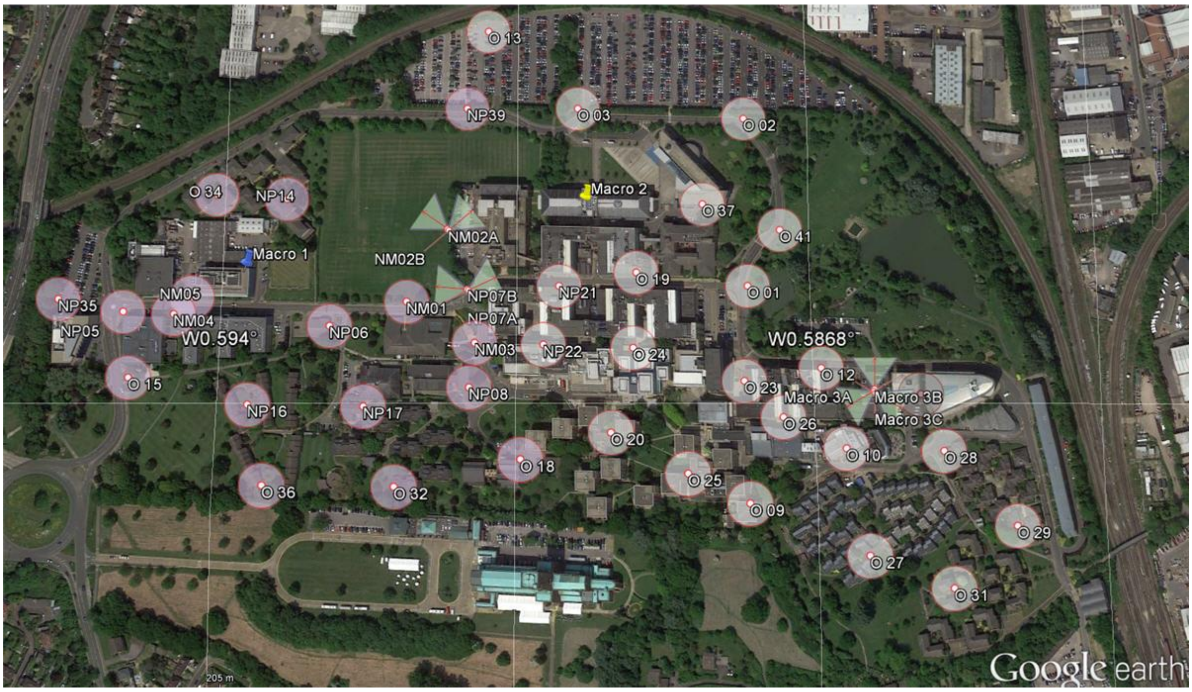

Figure 9: High-level Overview of the Surrey Platform

The current set-up of the testbed is as follows:

- The Outdoor deployment consists of
  - 4G ultra-dense LTE-A TDD C-RAN comprising 44 sites (66 cells) all operating at 2.6 GHz (BW = 2x 20 MHz ; 4x4 MIMO);
  - 1x 4G FDD site operating at 700 MHz ; (BW = 10/20 MHz ; 2x2 MIMO);
  - 8x 5G NR TDD sites (7 eMBB + 1 URLLC), operating at 3.5 GHz (BW = 100 MHz; 64x64 MIMO). 28 GHz (PtP), 60GHz (PtMP) mmWave and satellite backhauling are also supported.

- The Indoor deployment (LTE-A based C-RAN) consists of:
  - 6x TDD and 6x FDD cells over 2 floors;
  - Wi-Fi Aps.
- The Core Network (CN) supports separate 4G and 5G core segments
  - NR cell clusters are operated as 1x Macro and 4x Small-cells/cluster;
  - 4G cell clusters are operated as 1x Macro and ~15x Small-cells/cluster;
  - Additionally, there are currently two commercial 5G UEs available for experimentation;
  - The 4G segment is based on an Rel-14 CUPS EPC;
  - The 5G segment supports virtualised core functions and Rel-15 features such as Context Awareness, simplified control plane and supports non-3GPP security authentication;
  - The testbed also supports edge computing on the premises (co-located with the access nodes deployed at the campus) to demonstrate MEC (already deployed) capabilities.

4.4.2. Platform Enhancements and Innovations

To be able to implement the planned use-case scenarios a set of technologies and features will be added to the Surrey Platform. These, also depicted in Table 11 per layer, include:

- **RAN Enhancements**: RAN enhancements though integration of new gNBs and NR UEs delivered during the project;
- **NB-IoT and LoRa**: The Surrey platform will integrate the existing UNIS-wide LoRa deployment. NB-IoT and LoRa nodes will incorporate Monitoring Nodes and Probes to support NB-IoT and LoRA;
- **WiFi and 5G NR**: The WiFi network will be tightly coupled with the 5G NR deployment and the Surrey test facility;
- **Integration of the WSMP** (WiFi Service Management Platform): mainly to manage connection between 3GPP and Wi-Fi (i.e., for LWA based traffic steering), and policy management solution in the core network;
- **Integration of the IoT GW**: The solution supports gateway functionality and monitoring functions with GUI management interface. The requirements from the platform side relating to virtualisation environment, IoT devices' protocols, and the preferable protocol for gateway output (called as interoperability protocol), will be addressed;
- **E2E Slice management**: Integration of policy management in the Monitoring Nodes and Probes, enabling the incorporation of dynamic control of higher layer protocols for E2E slice management.

Finally, NFV and SDN enablers are already in-place and operational, and provide services such as virtualisation, service function chaining and network slicing.

Table 11: Surrey Platform Enhancements per Layer

Platform Enhancements	Coordination Layer	M&O Layer	Infrastructure Layer
Indoor 5G New Radio infrastructure			X
Outdoor 5G New Radio infrastructure			X
E2E slicing and slice management			X
Non-3GPP access technology			X
NB-IoT and LoRa nodes supported by 5GC			X
Integration of the WSMP			X
Policy management solution			X
Integration of the IoT GW application	X		X
Interconnection between 5GENESIS Platforms	X		X
Support for blueprint based instantiation of trials	X	X	X
Adapting and integrating the NFV MANO solution in the testbed		X	
Support for deploying services on multi NFV infrastructures		X	X
Security and Privacy	X		

With the abovementioned extensions, the Surrey Platform aims to fulfil the following set of ambitions within 5GENESIS:

- Ambition A1: 5G NR and Wi-Fi integration;
- Ambition A3: Dynamic spectrum access for multiservice access stratum;
- Ambition B1: Measurement-driven protocol stack optimisations;
- Ambition B2: Orchestration and Management for Multi-connectivity;
- Ambition B3: Cognitive Network Management.

4.4.3. Target KPIs

The KPIs which the Surrey platform will focus on are:

- **Latency for infrequent small packets**: The latency can be significantly decreased through edge processing and caching;
- **Reliability**: Communication reliability can be ensured thanks to availability and support of multiple radio access technologies;
- **Density of Users**: High density of UE or device per m^2 or km^2 will be supported;

- **Energy Efficiency**: Energy efficiency means to sustain a certain data rate while minimizing the energy consumption. This KPI can be measured e.g. by providing better "area traffic capacity" in 5G, compared to 4G, but not increasing RAN energy consumption (in the process);
- **Service Creation Time**: service virtualisation and end-to-end automation is expected to significantly reduce service creation time.

4.4.4. Use Cases to Validate Target KPIs and Resulting Requirements

The SURREY platform will demonstrate effective massive IoT and multimedia communications in a multi-RAT and multi-spectrum licensing scheme environment. The aim of the platform is to validate use-case specific 5G KPIs during large scale events.

4.4.4.1. Massive IoT for Large-Scale Public Events Use Case #1

4.4.4.1.1 Use Case Description

Target KPI	Capacity, Latency, Reliability, Service Creation Time
5G Service	mMTC
Description	
The core scenario planned will be a public large-scale event taking place on the University of Surrey Stag Hill Campus in Guildford. The campus hosts usually some 16000 students and 2000 staff and the university holds regular large events, including graduation ceremonies and open days during which some 2000-4000 visitors are on campus as well. The plans are to equip a subset of people on campus with devices that can access and make use of the Surrey platform, the range of services that will be provided is a mix between high data rate multi-media services (upload and download) and a continuous flow of low bandwidth sensor readings collected through body and environment sensors that are densely deployed. The target is to achieve the ITU target density of 1 million devices per square kilometre (which translates, at an even distribution to 1 device per square meter). For this we plan to use between 50 and 100 real NB-IoT capable devices and emulation (using a traffic emulator on the Surrey platform) of approximately 500,000 devices, covering together around half a square kilometre. The services provided and delivered over the infrastructure will be a mix between massive MTC and eMBB delivered over the same infrastructure. We will collect, analyse and process the multimedia and sensor content in real-time.	

4.4.4.1.2 Use Case Specific Requirements

SUR-UC.1-1	Support IoT Connectivity Protocols
Priority	Essential
Description	The Surrey platform shall support connectivity to IoT sensors which will provide data under various IoT protocols (CoAP, MQTT, HTTP, and UDP) to proxy VNFs, to enable interoperable data collection and visualisation by the INFOLYSIS IoT GW application/solution
SUR-UC.1-2	IoT Dynamic Control and Traffic Steering
Priority	Essential
Description	The Surrey platform shall support software defined networking, required for dynamic control and traffic steering at transport level, for different vertical slices of IoT protocol proxies
SUR-UC.1-3	5G N3IWF Interface Support
Priority	Essential
Description	The AP/AP-controller shall support 5G N3IWF interface as specified in 3GPP rel.15 TS23.501 [24] and TS24.502 [23] specifications
SUR-UC.1-4	5G N2, N3 Interface Support
Priority	Essential
Description	The 5G NR radio base-station shall support 5G N2, N3 (AMF and UPF) interfaces towards 5G core network as specified in 3GPP rel.15 TS 38.401 specification [25]
SUR-UC.1-5	Policy Engine Support at MANO level
Priority	Essential
Description	The Surrey platform shall support policy engine at MANO level and shall interface to the Surrey platform management Orchestrator, via middleware layer
SUR-UC.1-6	NB-IoT and LORA Support by Monitoring Nodes
Priority	Essential
Description	The Monitoring Nodes and probes MONROE node shall be extended to support NB-IoT and LoRA interfaces
SUR-UC.1-7	Policy Framework to Facilitate E2E Slicing
Priority	Essential
Description	The Monitoring Nodes and probes shall support policy framework to enable end-to-end slicing

4.5. Berlin Platform

4.5.1. Platform Overview

The Berlin 5G platform shall integrate the infrastructure of the Fraunhofer FOKUS Berlin 5G Playground, the IHP testbed, and a temporary outdoor deployment at the Humboldt University in the Berlin city centre. The Berlin platform focuses in 5GENESIS on the provisioning and evaluation of the 5G network core, mmWave backhauling, and attached commercial off the shelf 5G NR devices upon availability. Figure 10 shows the three components of the Berlin platform.

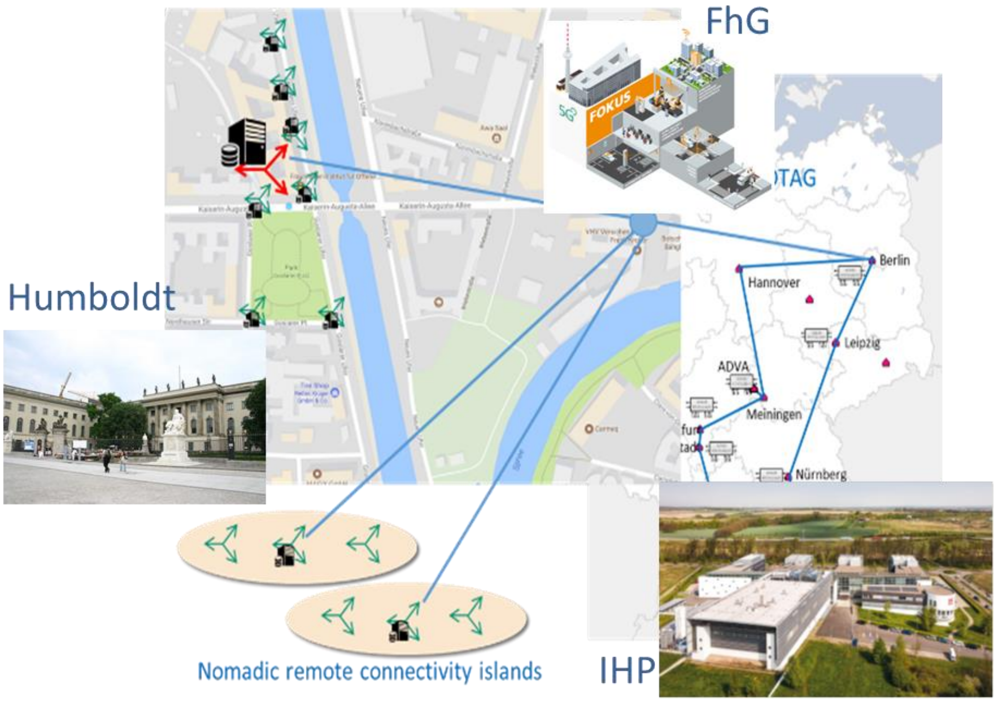

Figure 10: High-level Overview of the Berlin Platform

The key infrastructures on which the platform will be built are:

- The FOKUS Berlin 5G Playground, which encompasses a 5G core network with a multi-radio facility for indoor and outdoor heterogeneous radio access, support of ultra-low latency communication for industrial deployments, an indoor automotive testbed, and capabilities to deploy remote nomadic 5G islands to cover, e.g. additional dense urban areas;
- The IHP research laboratory, which provides a testbed for dedicated characterisation of mmWave components as well as long term measurements in different outdoor environments. The laboratory includes an anechoic chamber and a large portfolio of mmWave measurement equipment. Outdoor deployments allow for the verification of beam training and ranging capabilities, and for the impact of severe weather (e.g., heavy rain, snow) on the reliability and performance of mmWave outdoor links;

- A temporary nomadic outdoor deployment at the Humboldt University Berlin, which is used in 5GENESIS for conducting experiments involving a large number of users, e.g. at large scale events such as the Festival of Lights in Berlin.

In addition, the Berlin 5G platform will connect to a carrier-grade German-wide fiber network allowing conducting experiments that involve real long-haul backbone connections between parts of a deployed 5G network. As a final integrated environment, the Berlin 5G platform will focus on the evaluation of the 5G network core integrated to innovative mmWave and fiber-based backhauling and edge compute capabilities in addition to commercial 5G NR technologies. To that end, the Berlin 5G platform provides the following innovative features: support for i) network slicing, ii) edge computing, iii) heterogeneous wireless and wired backhauling for high throughput and low latency including link aggregation, iv) indoor and outdoor connectivity using 5G NR and non-3GPP access technologies such as WLAN and LoRaWAN.

4.5.2. Platform Enhancements and Innovations

As part of the integration activities at the Berlin 5G platform, the work plan includes the extension of the infrastructure as well as the upgrade and replacement of existing components with that state of the art. In particular, the following enhancements are foreseen, summarised per layer as:

- 100 Gbps distributed core infrastructure: The existing network core infrastructure will be replaced with a leaf-spine based, distributed, multi-tenant 100 Gbps switching infrastructure capable of handling several parallel instantiations of trials;
- Indoor 5G New Radio infrastructure: A distributed 5GNR small cell infrastructure will be deployed in the parking deck of Fraunhofer FOKUS to allow for testing private 5G network deployments, automated driving in a secured environment, as well as seamless transition of users from dedicated indoor 5G deployments to outdoor 5G coverage. The extension will follow the commercial availability of 5GNR small cells provided to Fraunhofer, also considering an initial LTE-based deployment which can be upgraded towards 5GNR support;
- Outdoor 5G New Radio infrastructure: The Berlin Platform will be upgraded towards providing outdoor 4G and 5G radio coverage around the FOKUS premises, including operation in the 700 MHz, 2600 MHz and 3700 MHz bands;
- mmWave-based backhauling: mmWave-based outdoor connections will be permanently deployed at IHP premises to allow for long-term testing of 60 GHz small cells. In particular, to allow experiments for advanced beam-steering and beam-tracking. The mmWave backhaul links will be interconnected to the FOKUS part of the Berlin Platform. In addition, the Berlin platform will be enhanced with commercial and experimental 60 GHz backhauling equipment suitable for nomadic remote deployments;
- Non-3GPP access technology: The 5G Playground will be enhanced with non-3GPP access technologies to be integrated with the 5G Core implementation. Corresponding technologies, such as WiFi, will be deployed at the parking deck, indoor, and outdoor at the FOKUS campus to achieve an overlapping coverage of 4G, 5G, and non-3GPP access

technologies. Besides, a LoRa-WAN system will be integrated in the Berlin Platform to allow for future trials involving 5G and non-5G access;

- **Compute-and-storage and edge compute capabilities**: A multi-tenant capable compute-and-storage infrastructure will be provided to the Berlin Platform in order to support parallel trials sharing the same physical infrastructure. The corresponding installation will cover a small-scale data-centre-like installation within the FOKUS 5G Playground as well a mobile deployment suitable for nomadic remote islands, e.g. at the Humboldt Campus for the 5GENESIS trials during the Festival of Lights;
- **Dedicated firewall deployments**: Security constrains of Fraunhofer and IHP require the installation of dedicated hardware providing firewall services for the Berlin Platform. Corresponding hardware will be installed and blue-print-based firewall configurations will be defined to facilitate the interconnection of the Berlin Platform with both, other 5GENESIS platforms, as well as IHP and Humboldt University;
- **Dedicated long-haul fiber interconnectivity**: The Berlin Platform will be enhanced with a state-of-the-art dense wavelength division multiplexing (WDM) system, to be connected to a German-wide fibre network. This will allow to configure experiments at the Berlin Platform, which involve 5G network deployments physically separated across the country, i.e. incorporating delays and throughput limitations as found in a commercial fibre backbone. Additionally, the system will allow interconnecting additional industry, SMEs, and R&D sites attached to the fibre backbone. The backbone will initially provide long haul links of 100 Gbps;
- **Dynamic provisioning of nomadic remote islands**: The existing 5G Core implementation and related toolkits will be enhanced towards dynamic provisioning of installations of a 5G Core at remote islands. Such deployments may be either permanent or nomadic, as for example required by the 5GENESIS trials conducted during the Festival of Lights;
- **Integration of IHP and Humboldt University as remote islands**: IHP will be permanently connected to the FOKUS premises to form a seamless trial environment including 4G and 5G, advanced mmWave backhaul, and non-3GPP access. In addition, the Humboldt site will be connected towards the Berlin Platform to conduct the 5GENESIS trials during the Festival of Lights. The integration will consider all three premises acting as separate administrative domains and may consider the integration under one administrative domain;
- **Interconnection between 5GENESIS Platforms**: A VPN-based interconnection between the Berlin Platform and the other 5GENESIS platforms has to be developed and implemented. Corresponding firewall blueprints must be specified and made available to trials (either 5GENESIS trials or third party trials) requiring the 5GENESIS Facility as a whole. The interconnection must be based on the assumption that each interconnected platform is operated under a different management domain;
- **Multi-tenant support**: The Berlin Platform will be enhanced by multi-tenant support in order to let verticals use the platform in isolation at the same time: verticals shall be able to use the platform simultaneously without interfering with each other, making a sequential usage possible depending on the availability of physical resources;

- **Support for blueprint-based instantiation of trials**: The feasibility of a three-tier-based instantiation of customer trials at the Berlin Platform will be evaluated. Given the technical feasibility, the Berlin Platform will be extended to support blueprints for separating the physical infrastructure (tier 0) into several isolated "wall-garden" infrastructures (tier 1) which can then be configured and used for a given trial (tier 2). The extension will uphold security requirements as such as that the management of tier 0 and tier 1 will solely be controlled by the entity providing the infrastructure, the Fraunhofer FOKUS;
- **Adapting and integrating the NFV MANO solution in the testbed**: The NFV MANO solution for the Berlin platform has to be integrated and adapted in the testbed;
- **Support for dynamic deployment of the 5G Core Implementation**: An EPC based 5G Core implementation shall be deployed on the testbed;
- **Support for deploying services on multi NFV infrastructures**: The network services can be deployed on different NFV infrastructures in order to enable edge benefits;
- **Security and Privacy**: The goal of the experimental evaluations and the trials is to collect comprehensive data on user-specific KPIs. This includes information on connectivity, data rate, receive power (RSSI), bit error rate (BER), application data, user trajectory and others. Potentially, this information can infringe the privacy of users of the Berlin platform. Therefore, measures for ensuring privacy of the users have to be developed and applied. One of the research directions of the Berlin testbed is to evaluate and implement privacy-enhancing technologies (PETs) that can be applied to the acquired information to protect user privacy while maintaining data utility. Proper implementation of such PETs can help to maintain the platform's GDPR compliance. Based on their application to the test-bed's collected information, the investigated PETS will be assessed for their potential contribution to privacy protection in the overall 5G architecture. Furthermore, security risks will be evaluated and appropriate measures to prevent misuse of the testbed infrastructure have to be developed and applied.

Table 12: Berlin Platform Enhancements per Layer

Platform Enhancements	Coordination Layer	M&O Layer	Infrastructure Layer
100 Gbps distributed core infrastructure			X
Indoor 5G New Radio infrastructure			X
Outdoor 5G New Radio infrastructure			X
mmWave based backhauling			X
Non-3GPP access technology			X
Compute and storage and edge compute capabilities			X
Dedicated firewall deployments			X
Dedicated long haul fibre interconnectivity			X

Dynamic provisioning of nomadic remote islands	X	X	
Integration of IHP and Humboldt University as remote islands	X		X
Interconnection between 5GENESIS Platforms	X		X
Multi-tenant support	X	X	
Support for blueprint based instantiation of trials	X	X	X
Adapting and integrating the NFV MANO solution in the testbed		X	
Support for dynamic deployment of the 5G Core		X	
Support for deploying services on multi NFV infrastructures		X	X
Security and Privacy	X	X	

With the abovementioned extensions, the Berlin Platform will fulfil and execute the following set of ambitions within 5GENESIS:

- Ambition A1: 5G NR and Wi-Fi integration;
- Ambition A2: User plane and control plane of multiservice access stratum;
- Ambition B2: Orchestration and Management for Multi-connectivity;
- Ambition B3: Cognitive Network Management.

4.5.3. Target KPIs

Within 5GENESIS, the Berlin platform will focus on the evaluation of the following KPIs related to the performance of the 5G core:

- **Speed**: support of stationary or walking pedestrians in an urban environment (approx. 5km/h);
- **Reliability**: multi-RAT and link aggregation with respect to the 5G mmWave backhauling used in deploying the nomadic remote island will be assessed in terms of network outages;
- **Density of Users**: number of users provided service to during a large-scale event;
- **Service Creation Time**: the capability of the 5G Packet Core will be assessed in terms of latency involved in dynamically deploying computational capabilities at the edge and virtualised network functions.

4.5.4. Use Cases to Validate Target KPIs and Resulting Requirements

Within 5GENESIS, the Berlin platform will demonstrate one use case: connectivity in a dense urban deployment to be demonstrated during the Festival of Lights Berlin focusing on the evaluation of the 5G core network.

4.5.4.1. Dense Urban 360 Degrees Virtual Reality (VR) Streaming Use Case #1

4.5.4.1.1 Use Case Description

Dense Urban Use Case: realizing 360deg VR streaming	
Target KPI	Capacity, Latency, Reliability, Service Creation Time
5G Service	eMBB
Description	
The "dense urban use case" brings network connectivity via the Berlin 5G platform to thousands of tourists visiting the Festival of Lights in Berlin. To that end, the 5G Berlin platform provides a temporary nomadic connectivity island at Humboldt University, to which visitors can connect (and hence experience Internet connectivity provided by the platform). The focus of the use case for dense urban environments is the evaluation of target KPIs related to the performance of the core network. The deployed nomadic remote islands provide edge compute and storage capabilities local to the event location, and thus add a second layer of MEC to the one existing at the main 5G Berlin platform located at FOKUS. The nomadic remote islands are connected via mmWave backhaul links (and subsequently via fiber cables) to the main 5G Berlin platform. They provide access to the public via non-3GPP access technologies such as WiFi and, upon availability, via 5G NR. This allows conducting experiments with thousands of users in order to evaluate the target KPIs related to the 5G core performance, which is the focus of the use case. Extension plans for experiments at public events will be considered once the penetration of 5G NR end user devices has reached a critical mass. Apart from providing regular Internet connectivity to the users, which they can use for any Over-The-Top (OTT) application, the use case leverages the deployed infrastructure for transmitting 360deg video streams from the event. To ensure guaranteed QoS to the "creators" of the video, regular Internet access (public users) and video creation may be separated in different network slices. As such, the "dense urban use case" shows the following benefits: • Demonstrate to future European R&D projects, industry and SMEs that the Berlin platform can be used for 5G evaluations involving a large number of public users; • The chosen 360deg VR application is of interest to the city of Berlin and local (media) business, which is likely to increase the visibility of the trial; • It allows evaluating the performance of the platform and the 5G PPP KPIs for that use case in a realistic urban environment during a large-scale event.	

As part of the latter evaluation, the trial provides insights on how 5G advances the state-of-the-art regarding the following research topics:

- MEC to reduce latency;
- VNFs to support slicing;
- Reduction of service creation time;
- Link aggregation across multiple RATs to increase reliability.

The use case related services are of type eMBB, including considered bandwidth and latency requirements. The expected number of simultaneous sessions (users or IoT) or slices and tenants at peak time per Service is 100. The use case will target a maximum of 1 user per m^2 for an area of 150x150 m. The use case will support moving pedestrians at maximum speed of 5 Km/h.

4.5.4.1.2 Use Case Specific Requirements

BER-UC.1-1	Media Application Integration
Priority	Essential
Description	Application hardware (360 deg. Camera) server and client (android) application fully deployed and integrated in the platform
BER-UC.1-2	**Reliable Connectivity**
Priority	Essential
Description	At least two connections (independent backhaul links) for backhauling the nomadic remote installations at Humboldt University for the Festival of Lights are available
BER-UC.1-3	**Media Application Integration on UE**
Priority	Essential
Description	Video client (android app) fully deployed and integrated in the platform. The app is available for download via the android app store
BER-UC.1-4	**Inter-cell Distance for Backhaul**
Priority	Essential
Description	Backhaul links of approx. 200m are supported via mmWave technology

5. Summary and Conclusions

The “Genesis of 5G” has entered the crucial phase of experimentation, and faces the challenge to validate the 5G network KPIs and verify the 5G technologies with an end-to-end approach as part of the on-going 5G PPP Phase 3. Exposing the 5G services and measuring offered capabilities with special focus on the 5G core stakeholders’ mandate for flexible, on demand and targeted experimentations, is considered a key contribution of the 5GENESIS platforms towards early and successful adoption of evolving propositions of 5G business concepts, applications and technology.

The purpose of this deliverable is to summarise the outcome of the first technical task of 5GENESIS, Task 2.1, targeting at the definition of the requirements of the envisaged 5G Facility. It has gone through 5GENESIS’s proposal for a 5G Experimentation ‘Facility’, spanning over five (5), diverse in terms of capabilities, yet fully interoperable, experimentation ‘Platforms’ and, in order to realise that, has proposed an experimentation blueprint as the basis of the analysis tasks and the subsequent specification of the target functional architecture.

This document presents the conclusions of the requirements’ gathering, harmonisation, and prioritisation activities on the basis of the proposed blueprint, targeting not to an exhaustive and possibly chaotic list of technical details, but rather to a balanced set of focused demands, formulated in an agile manner for the design phase to properly address them.

The deliverable also offers insight on each individual platform, describing the underlying technology and topology status, the enhancements foreseen necessary to become part of the perceived 5G Facility and, in this process, reveals the innovations each aims to accomplish. It delves into the specific 5G PPP project KPIs that each Platform targets to measure, the use cases that will be deployed towards validating the 5GENESIS Facility and the KPIs per case, and the specific requirements that each use case mandates in order to be properly demonstrated.

Being the first technical deliverable of the 5GENESIS project, the document offers a digested view of the project’s scope and objectives, a concise description of the 5GENESIS Platforms topology, and clarifies the approach that the project shall build upon. In this context, the deliverable is expected to serve as a fundamental reference guide for specifying the 5GENESIS Facility and determining the subsequent implementation work that shall be documented in full detail in the technical deliverables to come.

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