5G SAMITEA

5G Sofia Airport Mobile PrIvate NeTwork PowEred by A1

D2.2 E2E architecture and technology specifications

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Editor(s):	A1
Author(s):	Evgeniya Petkova (A1); Ioannis Patsouras (WINGS),
Reviewer(s):	Dragomir A. Apostolov (A1); Peter Vigenin (A1); Andreas Georgakopoulos (WINGS); Nelly Giannopoulou (WINGS); Sokratis Barmpounakis (WINGS); Aleksandar Serafimov (Sof Connect)
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Executive Summary

The strategic objective of 5G SAMITEA is to provide high-quality 5G communication services to Sofia International Airport for personal and governmental institutions, to enable efficient, state-of-the-art Mobility, Healthcare and Public Safety SGIs and to support the deployment of 5G EDGE networks as part of the "Path to the Digital Decade" EU policy programme. Sofia International Airport is an SGI provider, entrusted with the safety and well-being of the airport visitors and employees. The 5G SAMITEA Mobile Prtivate Network (MPN), along with the targeted use cases to be validated, will allow for advanceds passengers flow monitoring, airport security monitoring and safe evacuation, as well as required capacity and low latency for handing of emergency and critical situations.

The project builds from one side upon deployment and usage of a new high-quality 5G network in Sofia airport, which is not currently available both regarding coverage as well as functional characteristics, necessary to provide the envisaged services (low latency, priority to emergency personnel, etc.) and from the other side upon the existing A1BG commercial mobile networks to expand with new capabilities as deemed necessary, so that to ensure 5G SAMITEA key objectives delivery according to high-quality specifications set for network planning and optimization. 5G SAMITEA will deliver State-of-The-Art (SoTA) 3GPP Rel.16 Stand Alone (SA) 5G networks, through the deployment of new, and upgrade of existing, equipment on both Airport MPN and A1BG commercial network and is implemented in a two-vision approach, one based on the NSA (Non-Stand Alone) architecture over the existing production EPC (Enhanced Packet Core) core networks and the other planned for subsequent implementation, will exhibit the beyond SoTA SA (Stand-Alone) architecture.

This deliverable, D2.2 "D2.2 E2E architecture and technology specifications", focuses on target architecture for the 5G SAMITEA Mobile Prtivate Network (MPN). It is the second deliverable of the WP2 "Requirements, Architecture & Scope of work" and highlights the concepts, logical and deployment design, and primary features of the existing and targeting 5G SAMITEA end-to-end architectures in Airport MPN and A1BG networks. It starts by presenting the conceptual end-to-end architecture, and the necessary technical developments, and then delves into the specific implementations, taking into consideration the deployment-related architecture and design principles (e.g., topology, high availability, product capabilities), to achieve the proper implementation per case. Reflecting on the requirements reported in the deliverable D2.1, the technical deployment concepts and functionalities addressed and will be further developed and identified in D3.1 providing the E2E Low Level Design, applicable for the 5G SAMITEA implementation on the existinfg NSA and SA networks of A1BG and newly introduced MPN of Airport.

The document includes a complete description in terms of infrastructure and network design architecture in an all-encompassing view including Packet Core Network, IMS Core network, Radio Network, Transport Network Design and describes the overall aproach of the new implementations in existing basic services (such as VOLTE and VoNR).

This document is expected to shape design decisions and parameters that will be subsequently detailed in the relevant design and planning deliverables, with the mission to deliver operational and validated 5G networks by the end of 2027 supporting 5G SAMITEA Use Cases and demonstrating them as part of the project activities.

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List of Acronyms and Abbreviations

TERM	DESCRIPTION
3GPP	The 3rd Generation Partnership Project
5GC	5G Core
5G-NR	5G New Radio
AAA	Authentication, authorization and accounting
AMF	Access and Mobility Management Function
CA	Carrier Aggregation
CNF	cloud-native function
CUPS	Control and User Plane Separation
DC	Data Center
DF	Dark Fiber
DSS	Dynamic Spectrum Sharing
E2E	End-to-End
EC	European Commission
ECC	Electronic Communications Committee
ENB/ENODEB	E-UTRAN Node B (Evolved Universal Terrestrial Radio Access Network Node B
EN-DC	E-UTRAN New Radio – Dual Connectivity
EPC	Evolved Packet Core
EPDG	Evolved Packet Data Gateway
ETSI	European Telecommunications Standards Institute
EU	European Union
FDD	Frequency-Division Duplexing
FO	Fiber Optics
FW	Firewall
GE	Gigabit Ethernet
GHZ	Gigahertz
GNB/GNODEB	gNodeB – 5G Base Radio Access Network Node
GPS	Global Positioning System
GTP-C	GPRS Tunnelling Protocol Control Plane
GTP-U	GPRS Tunnelling Protocol User Plane
GW	Gateway
HLD	High-Level Design
HSS	Home Subscriber Server
HTTP	Hypertext Transfer Protocol
I/S-CSCF	Interrogating Call Session Control Function/ Serving Call State Control Function
IEEE	Institute of Electrical and Electronics Engineers
IMS	IP Multimedia Subsystem
IMSI	International Mobile Subscriber Identity
ITU	International Telecommunication Union
KPI	Key performance indicator
LTE	Long Term Evolution
MHZ	Megahertz
MME	Mobility Management Entity
MPLS	Multiprotocol Label Switching
MPLS-TP	Multiprotocol Label Switching-Transport Profile
MS	Milestone
NB IOT	Narrowband Internet of things
NF	Network Functions

TERM	DESCRIPTION
NR	New Radio
NSA	Non-Stand-Alone
NW	Network
OFCS	Offline charging system
OSC	Open Systems Consultants
O-SDS	Originating service domain selection
PCC	Policy & Charging Control
PCEF	Policy and Charging Enforcement Function
PCF	Policy Control Function
PCG	Packet Core Gateway
PCRF	Policy and Charging Rules Function
P-CSCF	Proxy call control function
PDN	Packet Data Network
PFCP	Packet Forwarding Control Protocol
PGW	Packet Data Network Gateway
PGW-U	Packet Data Network Gateway user plane
PLMN	Public Land Mobile Network
PS	Packet-Switched
PU	Public
QCI	Quality Class Identifier
QOS	Quality of Service
RAN	Radio Access Network
S/PGW	Serving/Packet Data Network Gateway
SA	Stand-Alone
SGW	Serving Gateway
SGW-C	Serving Gateway Control plane
SIM	Subscriber Identity Module
SOTA	State-of-The-Art
SRVCC	Single Radio Voice Call Continuity
TS	Technical Specification
UC	Use Case
UDP	User Datagram Protocol
UDR	Unified Data Repository
UE	User equipment
UL	Uplink
UPF	User Plane Function
UTRAN	UMTS Terrestrial Radio Access Network
VCSCF	Virtual Call Session Control Function
VHSS-FE	Virtualized Home Subscriber Server Front End
VIM	Virtual infrastructure manager
VIM (CEE)	Virtual infrastructure manager (Cloud Execution Environment)
VNF	virtual
VOLTE	Voice over LTE

1. Introduction

1.1. Purpose of the deliverable

The 5G SAMITEA project aims to address the following two **key objectives:**

Objective 1: Extend A1's 5G network (in terms of construction, configuration, and connection with the rest of the network with additional macro-RAN sites, new Distributed Antenna System (DAS), 5G mmWave coverage and with upgrade of existing RAN sites, towards high capacity, reduced latency, and high reliability mobile services for Sofia International Airport areas, up to now under-served and/or with obsolete wireless technologies. Furthermore, dedicated MPN Core will be deployed to fully support Sofia Airport requirements and 5G Industry 4.0 vision. The novel 5G Core and RAN base stations will be connected to cloud and edge computing resources for video surveillance system at Sofia Airport premises and at one of the main A1 datacentres located around 4 kilometers from Sofia Airport. The activities to serve this objective are described in detail in WP2 "Requirements, Architecture and Scope of Work", WP3 "Network Design and Planning" and WP4 "Network Deployment and Integration".

Objective 2: Enable and demonstrate advanced Mobility, Healthcare and Public Safety domain SGIs, provided by WINGS, such as passenger flow monitoring, autonomous apron operations, security monitoring, emergency evacuation, and medical first-aid provision leveraging the new 5G MPN infrastructure that will be implemented for different use case scenarios, static or mobile. The work for this will be carried out within WP2 "Requirements, Architecture and Scope of Work", and WP5 "Testing and Use Cases Validation".

Objectives 1 and 2 refer to the deployment and usage of a high-quality 5G network in Sofia airport, which is not currently available both regarding coverage as well as functional characteristics, necessary to provide the envisaged services (low latency, priority to emergency personnel, etc.)

Delivering project objectives 1 and 2 is not possible with the existing mobile network coverage in the area of Sofia Airport, nor with the deployed Tetra and Wi-Fi networks. In the project description we have analyzed the performance and the applicability of several wireless technologies, and the conclusion is that MPN networks are the most suitable solution in such cases.

This document, deliverable D2.2, addresses the work performed in Task 2.2 "Task 2.2: 5G End-2-End Architecture and Specifications" and builds upon the prior study of the Use Cases (UC) requirements and targeted KPIs performed in Task 2.1 as the basis to design the 5G Mobile Private Network with the necessary specifications. The output of this task is the High level E2E architecture of the Sofia Airport MPN solution, including its interconnection specifications with respective A1BG network domains – core, radio and transport. The HLD will be delivered in two conceptual parts - Non-Stand Alone (NSA) networks and Stand Alone (SA) networks and their respective interconnections will be separetly described and delivered.

In this context, Deliverable D2.2 offers a comprehensive "bird's-eye view" of the high-level architecture and key structural components of the 5G SAMITEA solution, detailing its deployment across both Non-Standalone (NSA) and 5G Standalone (SA) network environments. Furthermore, it presents an all-encompassing description including the core architecture, the radio access network architecture and transport architecture.

The HLD builds upon the 3GPP specifications and the relevant products release roadmap of adoption from the involved network vendors. Expected outcomes of this task include the existing and new network architecture, network redundancy, communication matrix, new traffic scenarios, deployment of new features and functionalities in the Core and radio domainsAPN and slice design, traffic estimations and capacity, network security and privacy. The output of this Task will drive the Low Level Design processes in Tasks T3.2

1.2. Intended Audience

The dissemination level of D2.2 is public (PU) and hence will be used publicly to inform all interested parties about the 5G E2E high level architecture to be used for the 5G SAMITEA project. However, this document is of special interest to the following groups:

- project consortium itself, as a documented blueprint of the agreed technical scope and development plans and the means to validate that all objectives and proposed technological advancements have been analysed and, through the identified requirements, the next actions can be concretely derived.
- research community, other 5G projects and funding organisations, to summarise the scope, objectives and intended project innovations, describe the 5G SAMITEA UCs and performance targets together with the identified requirements that must be tackled to achieve the expected results to open the floor for fruitful exchange of opinions and collaboration.
- public, to obtain a better understanding of the framework and scope of the 5G SAMITEA project.

1.3. Structure of the document

The main structure of this deliverable can be summarized as follows:

- Section 2 describes the assumptions and scope of the deliverable and covers 5G SAMITEA E2E Network Architecture & Design Features, elaborates on NSA and SA features and specifications, possible scenarios that will be considered as part of the project scope and associated parameters definition. This section provides a description of an end-to-end target architecture with an emphasis on consolidating Airport MPN and A1BG network designs and indicating benefits with respect to the relevant solution approach as well as associated trade-offs. This section is separated in a few subsections, that provide overview and deep dive in A1BG existing and 5G SAMITEA target network architecture of Packet core, IMS core, Radio and Transport domains, illustrating design infrastructure and topology specific solutions. Dedicated subsection addresses the monitoring and performance management. These subsections provide description of the improvements and refinements for each domain considered in the project over D2.2 for both Airport MPN and A1BG networks.
- Finally, Section 3 provides concluding remarks.

2. 5G SAMITEA End-to-End Network Architecture & Design

5G SAMITEA will provide a purpose-built 5G private wireless network to support the Sofia International Airport operations. The project will cover indoor (terminals, operations facilities) and outdoor (apron, perimeter) areas in Sofia International Airport, Bulgaria. Sofia airport has become an external border for Schengen. This is significant for security related purposes and adds value to the 5G SAMITEA project deliverables.

Airport Mobile Private Network is a dedicated enterprise network that allows interconnection of people and things at Airport premesis using state of the art 5G NSA/SA technolog, enabling new applications, supporting business-critical services with a local network on their premises, providing a secure, reliable, and high-available connectivity and differs from a public mobile network by providing private reserved coverage that is subject to agreed resources and local, protected data flow. Moreover, passengers and airport employees will also benefit from the dedicated 5G base station coverage and EDGE cloud and the upgraded services offered by the 3GPP Rel. 16 and 17 [1] features to be delivered by the project's deployments. Currently there is poor mobile network coverage, and a dated TETRA system is used for operational purposes and handling critical situations. 5G SAMITEA's paradigm will thus boost local innovation enabling 5G mm Wave - as well as IoT-based technologies (i.e. mobility and security sensor-based monitoring-like approaches and infrastructure, AGVs/robots assisting travellers) to create a safer and more efficient environment for travellers and employees alike.

In scope of the deliverable are the design documents of the Airport Mobile Private Network solution, based on the HPE Aruba Networking Private 5G Core as Mobile Edge Core, A1BG Shared RAN concept, Transport network and Monitoring and Performance management aproach.

Airport MPN Mobile Core network is designed to fully support the 5G Industry 4.0 vision. The architecture enables the parallel operation of LTE (4G), 5G NSA (Non-Standalone) and 5G SA (Standalone) core functions within a unified deployment. It is implemented as a combo-box model based on the HPE ANW P4/5G (Combo) Core, integrating containerized network functions (CNFs) across dedicated virtual machines and built on commercial off-the-shelf (COTS) hardware. It delivers a secure, fully virtualized, and high-availability infrastructure designed to support both mission-critical operations and emerging high-performance applications across the airport environment. Sofia Airport MPN core include functional entities that implement dual mode Packet Core network functions, IMS core network functions, as well as Mission Critical Push-to-Talk (MCPTT). The MPN Core will be designed and deployed with high capacity, availability and redundancy on multiple levels, avoiding any possible single point of failure such as Infrastructure redundancy, where the different physical components are fully redundant (servers, switches, connectivity), and the networking interconnections are designed for that; Application redundancy, where the different Network Functions (LTE, 5G, IMS) are configured with standard 3GPP redundancy capabilities, or with clustering models;, hypervisor, control and user plane levels.

The A1BG Telco Data Center is the hosting platform where Airport MPN solution in terms of hardware and applications will be hosted privately. This platform provides a highly standardized VMware layer, enabling the hosting of multiple applications on the same hardware. This approach makes the Airport MPN solution deployment cost-effective and flexible, accommodating additional use cases and future scenarios.

Sofia Airport MPN will span over 8 square kilometers, covering outdoor facilities, aprons and buildings with close to 100% outdoor and 98.9% indoor 5G coverage. To address these stringent requirements, the A1BG RAN network will serve as the main and secure access point to the Airport MPN Network Edge, leveraging shared RAN deployment through a MOCN-based functionality (described in section 2.3.3). The Sub 6GHz RAN extensions, the new RAN sites and the DAS system will be deployed in the first two years of the project, while mm Wave radio coverage will be fully completed in 2027 reaching 96.1% outdoor coverage. RAN part of Sofia Airport MPN will be built with 4G/5G Nokia Base Stations.

In order to guarantee 24/7 monitoring, Sofia Airport MPN will be integrated into the A1 MPN monitoring and performance system and will be supervised by A1 first and second level support teams.

The 5G SAMITEA network design of Sofia International Airport focuses on the requirements of the use cases extensively described in D2.1 “Requirements Analysis and Use Case Definition”, that incorporate the demands for the following use cases:

- Enhanced Passengers’ Experience and Flow Monitoring Use Case
  - Crowd concentration estimation
  - Anomaly detection and notifications/alerts
  - Service Robots for Enhanced Passengers' Experience
- Airport Safe Evacuation Use Case
  - Emergency communication at the airport
  - Mission Critical Push-to-Talk (MCPTT) communication solution
  - AR/VR based evacuation
- Airport Security Monitoring Use Case
  - Video Surveillance & Perimeter Monitoring
  - Autonomous Apron Operations

Analysis of the service requirements for achieving high performance delivery of use cases for the radio, transport, Packet, and IMS core systems in order to respond to the technical challenges that are identified. The technical aspects per domain are addressed separately in the paragraphs that follow as 5G SAMITEA End-to-End Network Architecture & Design consists out of 4 main Parts:

- **Airport MPN PS Core (EPC and 5GC) and IMS Network Architecture**

  At the heart of the Airport MPN service is the Mobile Private Edge Core, which ensures secure and private access for customer mobile devices. It carefully manages the assignment of quality, security, latency, and throughput parameters. Placing the Airport MPN Core instance close to the customer's location is crucial for enabling ultra-low latency use cases. Additionally, energy autonomy can be achieved by integrating the Airport MPN Core with the A1BG Telco Data Center power supply backup infrastructure, ensuring that all local services remain operational during a blackout scenario.

- **Radio Network Architecture and Design**

  The A1BG RAN network serves as the key and secure entry point into the Airport MPN Network Edge. It addresses common Wi-Fi challenges such as lack of mobility support, inconsistent high throughput, limited IoT capacity, and high latency. These issues are mitigated through A1's highly standardized and regulated Mobile Access Network. Sharing the Airport Mobile Private Network with the A1BG Public RAN Network (MOCN), is a straightforward approach which will be further enhanced with indoor solutions for specialized use cases and complex building environments.

- **Transport Network Architecture and Design**

  The Transport Network serves as the backbone interconnecting all logical and physical components within the Sofia Airport 5G MPN deployment — including the RAN sites, Network Edge (MPN Core), and the A1BG Core Network (as depicted in Figure 1). It provides the high-capacity, low-latency, and resilient IP connectivity necessary for Non-Standalone (NSA) and Standalone (SA) 5G operations, as well as MOCN-based multi-PLMN traffic segregation.

- **Monitoring and Performance Platform**

The monitoring and performance management platform will enable users to track the status of Airport MPN solution through real-time key performance indicators (KPIs), allowing for quick verification of system performance and review of essential operational statistics.

The logical 5G SAMITEA end-to-end architecture is depicted in Figure 1.

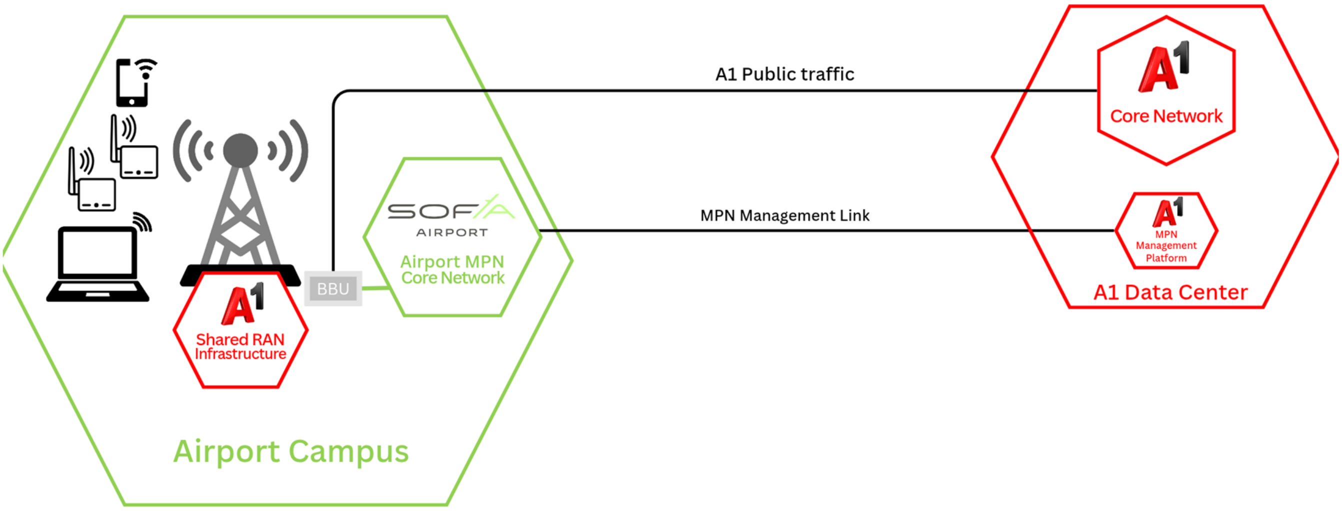

Figure 1: Airport MPN Solution

5G SAMITEA will deliver, as one of its key outcomes, the integration of the novel 5G Core and RAN base stations with the A1's transport and Core Network. The next paragraph presents a concise overview of the A1's Mobile Core Network to to provide context for this integration.

A1BG Mobile Packet Core network is based on the Control and User Plane Separation (CUPS) architecture. Control Plane functions are implemented in PCC (MME, SGW-C, PGW-C) while the User Plane functions implemented - in PCG (SGW-U, PGW-U). The CUPS architecture, shown on Figure 2, allows independent scaling of the User Plane and also deployment of dedicated User Plane for specific Use Cases. The user plane can be connected to one or several control plane PCC nodes that control also the target PCG. Currently comersially supported access technologies are 2G/3G/4G/5G NSA.

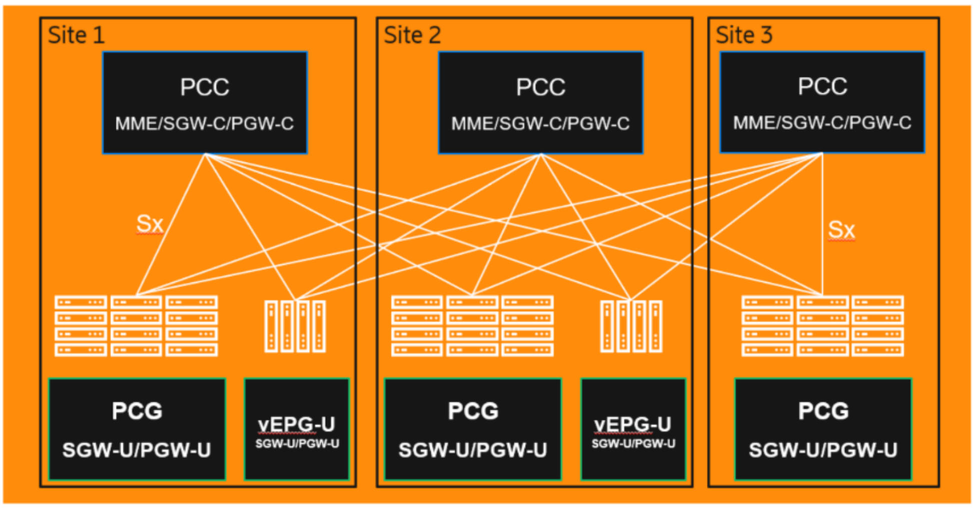

Figure 2: A1BG Mobile Packet Core CUPS architecture

There are three (3) main geo-redundant Mobile Packet Core sites in A1BG – EPC deployed in all three sites in 2+1 redundancy mode.

A1BG 5G Core is based on Ericsson Dual mode 5G Core[1] (DMC) solution that is an implementation of the Ericsson 5G Core Stand-Alone (SA) solution, verified in a reference environment. This solution implements operational automation with management across the full lifecycle of the deployed NFs, handling resiliency and capacity scaling in both directions (up/down).

As of Q4/2024, A1BG has launched a 5G SA network[2], for on top of which the 5G SAMITEA service shall be implemented accordingly.

2.1. Airport MPN PS Core (EPC and 5GC) Network Architecture

The Evolved Packet Core (EPC) is defined in 3GPP Rel. 8 and later as the all-IP based evolution of the General Packet Radio System (GPRS) to support the Evolved UMTS Terrestrial Radio Access Network (E-UTRAN), also known as Long Term Evolution (LTE) radio access or simply 4G.
Similarly, the 5G core is defined in 3GPP Rel. 15 and later, to support the 5G New Radio (5G NR) aiming at fulfilling the objectives that were derived from requirements laid down in the ITU-2020 vision paper on the capabilities and performance needs of the 5G system both from a business and a technical perspective. The 5G core is a fundamental pillar of the evolution of the 5G system to support URLLC and mMTC services while moving toward a digitalized era where business agility, time-to-market and automation will become de-facto industry best-practices.

When mapping to the existing EPC architecture, as shown in Figure 3, the 5GC architecture is simultaneously very similar and very different. The core difference between the EPC and 5G Core is that 5GC network functions are completely software-based and designed as cloud-native, allowing higher deployment agility and flexibility on multiple cloud infrastructures.

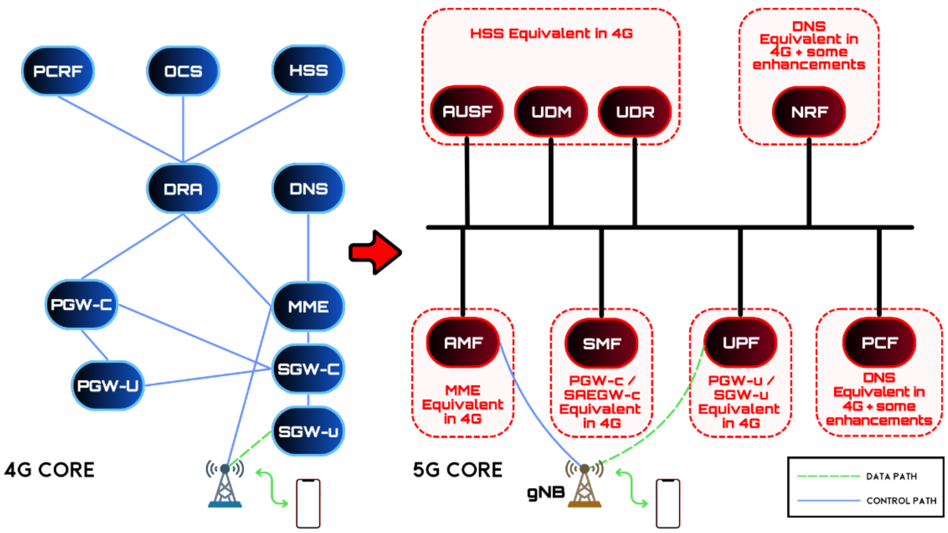

Figure 3: 4G core network component mapping to 5G SA core network components

[1] https://www.ericsson.com/en/core-network/5g-core

[2] https://www.techtrends.bg/2022/10/12/a1-bulgaria-5g-sa-13605/

The user data processing parts, as well as the integration with 3GPP radio access networks, are quite similar between the new 5GC and the traditional EPC network architecture, originally defined for 4G/LTE. Thereafter, the part of the network that contains signaling-only functionality is very different.

The deployment transition from EPC to 5GC needs to pass through different phases of migration, and these phases/migration paths can vary from one operator to another. GSMA has documented an approach for connecting 5GC from the operators' perspective [2]. The key migration options in consideration by 5G SAMITEA are shown in Figure 4:

- Option 1 is a standard LTE deployment option where the eNB is connected to the EPC and the calls are served by eNB for both the data and control planes.
- Option 2 is a SA 5G deployment where the NR (gNB) is connected to the 5G and the user-plane and control-plane are using NR and are completely independent of 4G/Long-Term Evolution (LTE).
- Option 3 has multiple flavors where there are both 4G eNB and 5G gNB connected to the EPC with an Xn interface between the two to exchange signaling as well as data between themselves. Another key aspect to option 3 is that the eNB acts as the master node—that is, the eNB maintains the signaling connection with the core network (S1-MME) for the UE in this option.

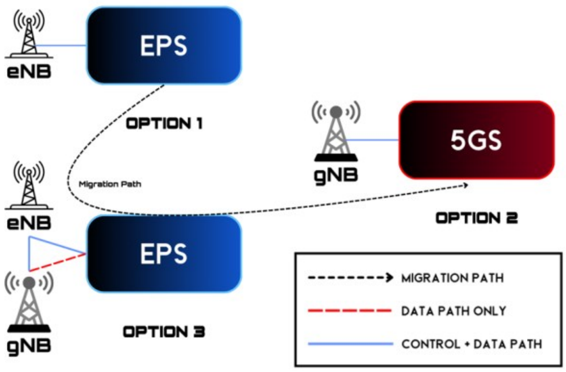

Figure 4: Different migration paths for transitioning from 4G to 5G SA

The migration path followed by A1BG and COSMOTE is: 4G (Option1) ➤ 5G NSA (Option 3x) ➤ 5G SA (Option2)

The introduction of the 5G System (5GS) to provide wide-area services in existing Evolved Packet System (EPS) deployments is a necessary step toward creating a full-service, future-proof 5GS in the longer term and the path selected follows the GSMA recommendations [3]. The EPS and the 5GS must interwork to provide continued services to UEs that move between the EPS and the 5GS. Interworking is important for all services, but it is essential to sensitive services such as Voice and video communication services.

During interworking, some combined entities are shared between the EPS and the 5GS as depicted inFigure 5:

- The HSS and the UDM
- The PCF and the PCRF
- The PGW-C and the SMF
- The PGW- U and the UPF

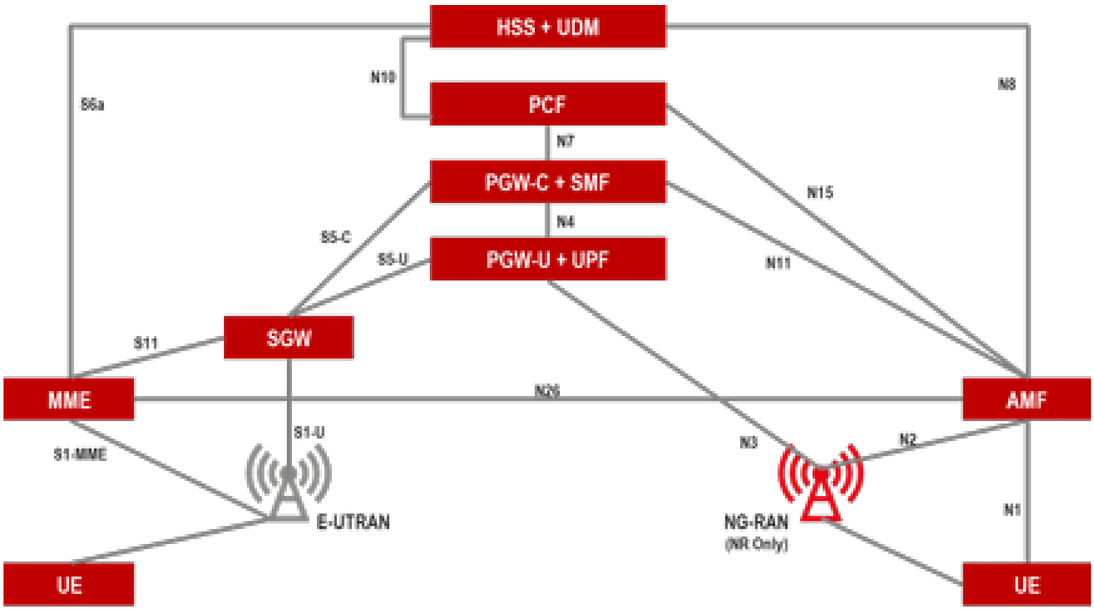

Figure 5: Interworking between the EPS and the 5GS [3]

HPE ANW P5G Core has been designed to fully support the 5G industry vision and at the same time offer a backward-compatible solution for the 4G deployments. Thus far, it implements the following 3GPP standardized network functions (NFs):

- 4G: MME | SGW | PGW | HSS | CGW | PCRF | EIR | SMS-C | BMSC/EMBMS-GW
- 5G: AMF | SMF | UPF | UDR | UDM | AUSF | NRF | PCF | CHF | 5G-EIR | iDNS

The HPE ANW P5G Core is flexibly designed to enable network operators to select the 4G and 5G functions needed for each machine. The product is packaged with enough components to build an operational LTE and 5G network. The solution supports access through 5G NR (SA and NSA). It also supports several deployment use cases such as Multi-Operator Core Network (MOCN) and Mission Critical Push-to-Talk (MCPTT). This includes Voice-over-LTE (IMS VoLTE), support in 4G and 5G NSA and Voice over NR (VoNR) support in 5G SA.

The support for the EPC and 5GC architecture is illustrated in Figure 6 below.

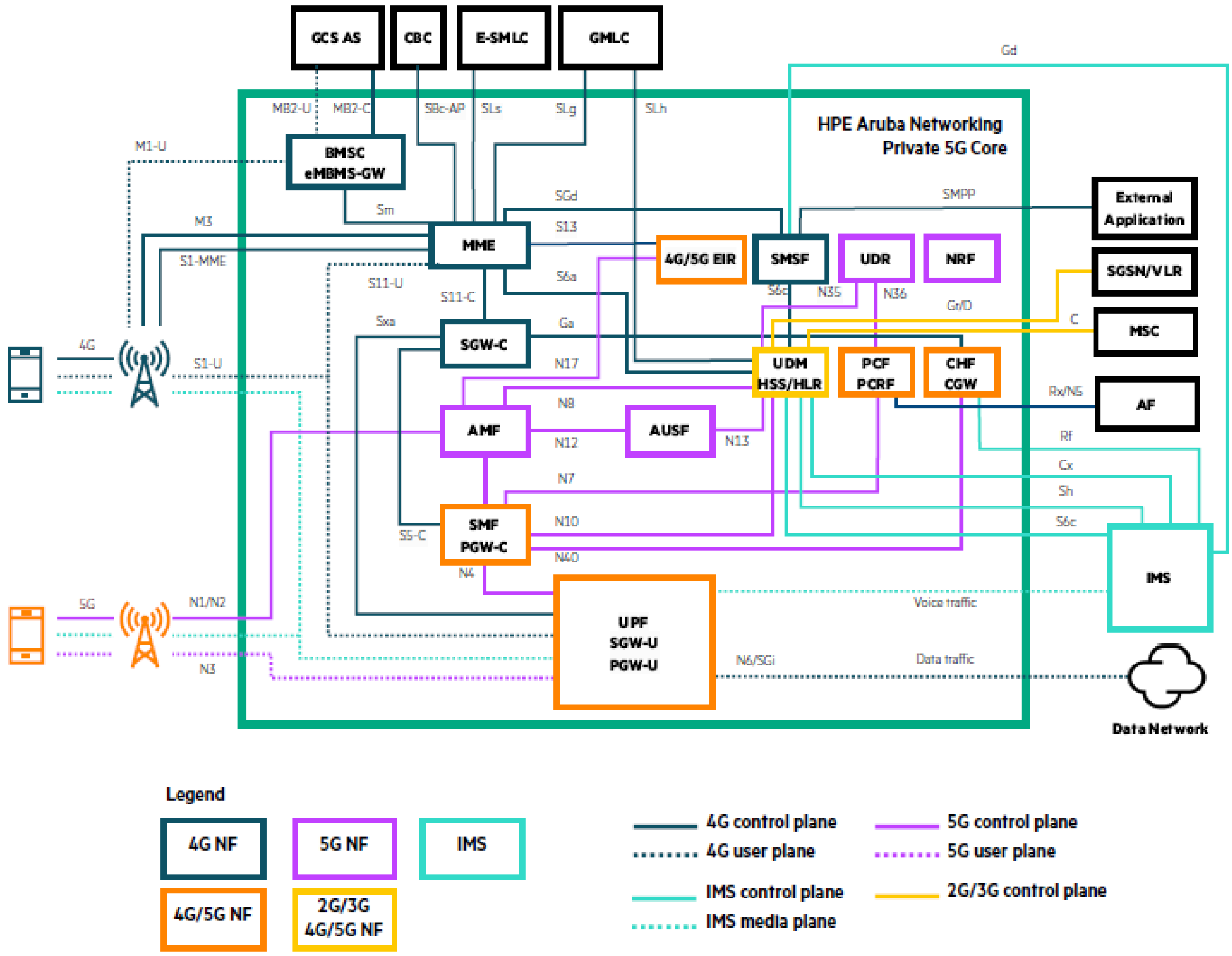

Figure 6: HPE Aruba Networking Private 5G Core architecture: NF view

HPE ANW P5G Core comprises functional entities that implement EPC network functions only (MME, SGW-C, SMSF, BMSC/EMBMS-GW), 5GC NFs only (AMF, AUSF, UDR, NRF, CHF), as well as combined 4G+5G NFs (SMF+PGW-C, UDM+HSS, PCF+PCRF, UPF+SGW-U+PGW-U), described in details in then following two sections: 2.1.1 and 2.1.2.

2.1.1. EPC Core Network Design

4G-LTE and 5G-NSA Core Network is composed by the following network functions:

- **MME (Mobility Management Entity)**: The MME is the signaling entry point for the RAN, responsible for user control plane, radio resource allocation and mobility. The MME is deployed in all active mode on two or more NGC-CP virtual machines. It is required that every eNodeB connects to at least 2 MMEs1, with the S1-Flex capability.
- **SGW (Serving Gateway)**: The SGW is the User-data (user plane) entry point to the EPC. In HPE ANW P5G CUPS solution, the SGW functionality is split. The control plane functionality is implemented in the SGWc network function, terminating all GTPv2-C interfaces. The SGWc is deployed in all active mode on two or more NGC-CP virtual machines. The user plane functionality is implemented in the UPF. The SGWc and the UPF are connected via PFCP protocol on the Sxa interface.
- **PGW (PDN Gateway)**: the PGW is the interconnection point between the LTE network and the external IP world (PDN, Packet Data Network). The User-data tunnel is terminated at the PGW, which also maps the tunnel with the right APN/VRF network. The PGW is also responsible for the UE IP address assignment and

routing. In HPE ANW P5G CUPS solution, the PGW functionality is split. The control plane functionality (PGWc) is implemented in the SMF network function, terminating all GTPv2-C interfaces. The SMF/PGWc is deployed in all active mode on two or more NGC-CP virtual machines. The user plane functionality is implemented in the UPF. The SMF/PGWc and the UPF are connected via PFCP protocol on the N4 interface.

• **UPF (User Plane Function)**: the UPF implements user plane functionalities (packet routing and forwarding, Quality of Service application) at both SGW and PGW, terminating the S1-U, S5-U/S8-U and SGi interfaces. Multiple UPF are deployed in all-active mode or active-standby mode on NGC-UP virtual machines across multiple servers.

• **HSS (Home Subscriber Service)**: This is the "User Database" for credentials, authentication, authorization profiles. The HSS functionality is implemented by UDM, UDR and AUSF network functions. The UDM, UDR and AUSF are deployed in active-active cluster mode, on two NGC-DLF virtual machines.

• **PCRF (Policy and Charging Rules Function)**: the PCRF is responsible for the allocation of static or dynamic Dedicated Bearers, via an internal policies database or the interaction with external Application Servers. The PCRF functionality is implemented in the PCF network function. It is deployed in all-active mode in the NGC-CP virtual machines.

• **iDNS (Internal DNS):** this DNS service is used by the MMEs to discover the network topology, SGWc and PGWc addresses and locations using standard 3GPP DNS procedures. It is also used by the SBI network functions for NRF discovery. It may also be exposed externally in case of roaming; in that case it may be referred to as **eDNS (External DNS)**. The DNS functionality is implemented in the **DNS Service Management (DSM)** network function. It is deployed in active-active cluster mode, on two NGC-DLF virtual machines.

• **DRA (Diameter Routing Agent)**: the DRA is responsible for diameter roaming, improving network scalability and fault tolerance. It is deployed in a ring-topology mode on two or more NGC-SIG virtual machines. The ring topology allows forwarding diameter requests towards another DRA in case of local non-reachability of the destination host.

• **CGW (Charging Gateway)**: the CGW (optional) is used to collect and deliver CDRs to the final consumer. It is implemented by the CHF network function and deployed in all-active mode, co-located with the SMF/PGWc in the NGC-CP virtual machines.

• **EIR (Equipment Identity Register):** the EIR (optional) is used to check the IMEI and IMSI to determine if that device should be allowed onto the network or not. It is deployed in active-active cluster mode, on two NGC-DLF virtual machines.

• **SMSF (Short Message Service Function):** implements the Short Message Service functionality. It implements store-and-forward capability. It handles submission and delivery of SMS over NAS (SMSoNAS) and over IMS (SMSoIP) using the diameter SGd interface.

2.1.2. 5G SA Core Network Design

A 5G-SA (Stand-Alone) Core Network is composed by the following network elements:

• **AMF (Access and Mobility Management Function)**: it manages authentication, connection and mobility management between network and devices. It is deployed in all-active mode in NGC-CP virtual machines. It is recommended for a gNodeB to connect to at least 2 AMF, with the NG-Flex capability.

• **SMF (Session Management Function)**: it performs UE session management, IP address allocation and control of policy enforcement. It is deployed in all-active mode in NGC-CP virtual machines.

• **UPF (User Plane Function)**: the UPF implements user plane functionalities (packet routing and forwarding, Quality of Service application), terminating the N3 and N6 interfaces. Multiple UPF are deployed in all-active mode on NGC-UP virtual machines across multiple servers.

• **PCF (Policy Control Function)**: it controls network behavior for different user policies. It is deployed in all-active mode in NGC-CP virtual machines.

• **AUSF (Authentication Server Function)**: it performs the authentication of the different UEs, authenticating data and keying materials. It is deployed in active-active, on two NGC-DLF virtual machines.

- **UDM (Unified Data Management)**: it is a converged repository of subscriber data information that can be used by multiple Network Functions. It uses the UDR as data storage. It is deployed in active-active cluster mode, on two NGC-DLF virtual machines.
- **UDR (Unified Data Repository)**: it is a converged repository of information that can be used by multiple Network Functions. It is deployed in active-active cluster mode, on two NGC-DLF virtual machines.
- **NRF (Network Repository Function)**: it serves as service repository, allowing service discovery between the different Network Functions. It is deployed in active-active cluster mode, on two NGC-DLF virtual machines.
- **iDNS (Internal DNS)**: this DNS service is used by the SBI network functions for NRF discovery. It is deployed in active-active cluster mode, on two NGC-DLF virtual machines.
- **CHF (Charging Function)**: it is responsible for Pre-Paid and Post-Paid billing. It is deployed in all-active mode, co-located with the SMF in the NGC-CP virtual machines.
- **5G-EIR (Equipment Identity Register):** (optional) is used to check the Permanent Equipment Identifier (PEI) and SUPI to determine if that device should be allowed onto the network or not. It is deployed in active-active cluster mode, on two NGC-DLF virtual machines.

2.2. Airport MPN IMS Core Network Architecture and Design

The IMS system interworks with the HPE ANW P5G 4G-LTE legacy EPC or with the HPE ANW P5G 5G-SA systems, to implement a Voice-over-LTE (VoLTE) or Voice-over-NR (VoNR) solution, respectively.
The architecture of a complete IMS domain solution is summarized in Figure 7.

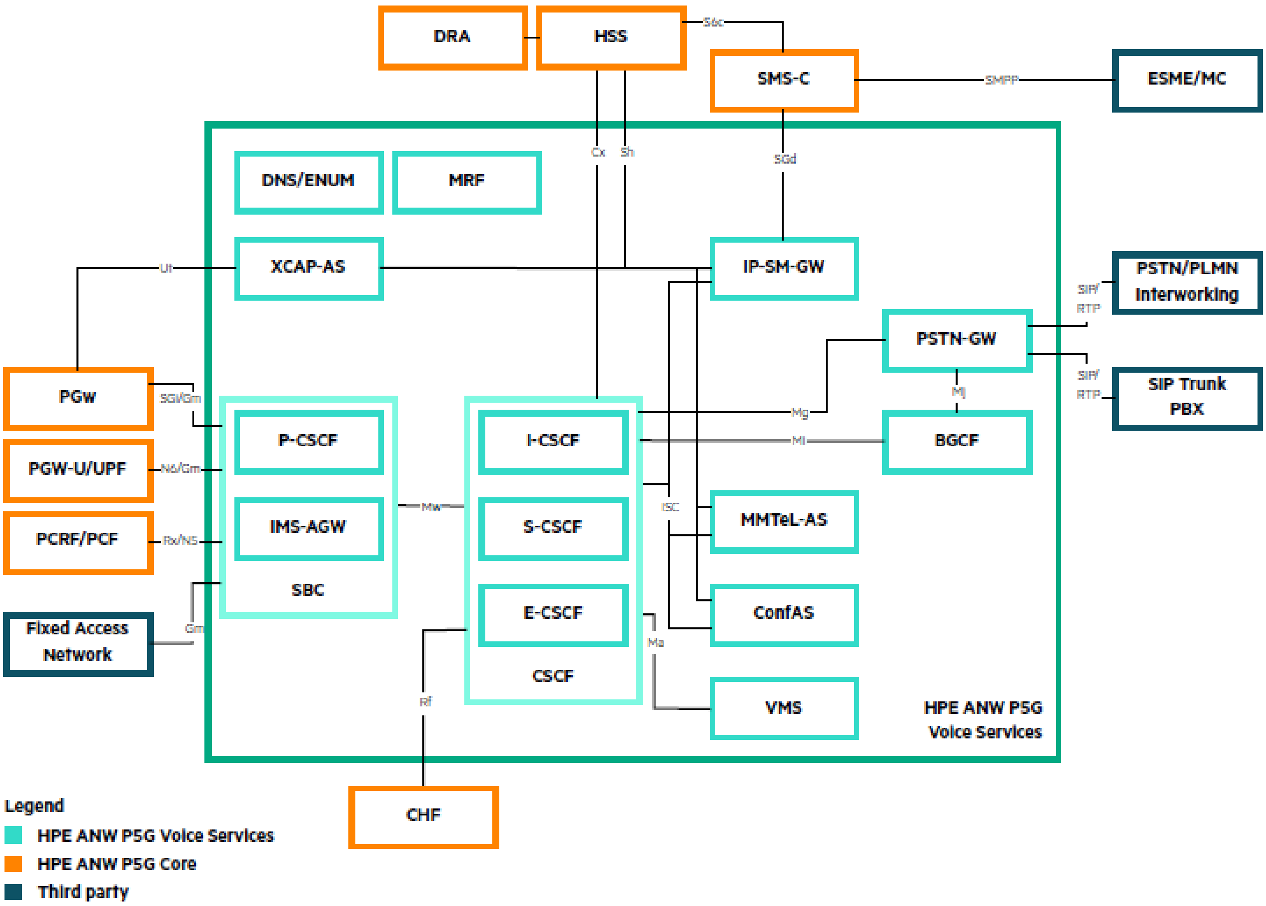

Figure 7: IMS Domain Arcitecture

The HPE ANW P5G Voice Services (IMS Core) software solution is composed of the following network functions.

- **P-CSCF (Proxy CSCF)**: the entry point from the PDN to the IMS subsystem; it terminates the SIP signaling from UE; it is in charge of media relay control and QoS policy control via Rx interface.
- **I-CSCF (Interrogating CSCF),** in charge for S-CSCF selection and request routing.
- **S-CSCF (Serving CSCF)**: the central node for the signaling plane, in charge of user registration and call control.
- **E-CSCF (Emergency CSCF):** (optional) handles emergency calling.
- **MMTel-AS (Mobile Telephony Application Server), or TAS**: handles telephony applications and supplementary services.
- **XCAP-AS (XML Configuration Access Protocol Application Server):** (optional) handles configuration of supplementary services from UE via Ut interface. The Ut interface is implemented in UNP using a dedicated “xcap” APN/DNN in the 4G/5G core.
- **Conference-AS (Conference Application Server):** (optional) implements 3GPP 3-way conference functionality. It is deployed in primary-secondary mode. All calls go through the primary Conference AS. Only in case of failure of the primary Conference AAS, the secondary is used.
- **IP-SM-GW**: (optional) converts SMS signaling from SIP to Diameter SGd and vice-versa, enabling SMSoIP functionality.
- **BGCF (Border Gateway Control Function)**: (optional) handles routing for breakout calls.
- **PSTN Gateway**: (optional) handles interconnection to/from an external PSTN SIP Trunk or PBX, for inbound/outbound calling. It manages both the SIP signaling and the RTP media. It is exposed externally on North-South interfaces on a dedicated VLAN.
- **IMS-AGW**: terminates the RTP media from the UE and performs the media relay functionality.
- **DNS Server**: the DNS server is used by the network functions co-located in the VM to resolve the SIP endpoints from hostnames and URIs. The DNS server may be exposed externally towards UEs in order to resolve public IMS endpoints, e.g. the XCAP-AS Ut address.

2.2.1. Voice-over-LTE (VoLTE) functionality

VoLTE provides high quality voice service through enhanced voice codes and mechanisms for fallback to circuit switched networks (single-radio voice-call continuity - SRVCC) like 2G and 3G. The most relevant components of an IMS core system are P-CSCF, S/I-CSCF, TAS, MRF, BGCF, MGCF, HSS, IBCF – see Annex B: IMS component List. 4G/5G Core engages IMS through the Sgi (PGW) and Rx (PCRF) interfaces, where the UE selects a P-CSCF based on the discovery procedure. When NSA is deployed with NR, 4G/5G Core is adapted for 5G, and the IMS architecture or procedures are not impacted. The UEs must handle the dual connectivity to support NSA Option 3 and to get access to eNB and en-gNB simultaneously. Figure 8 below shows the logical architecture.

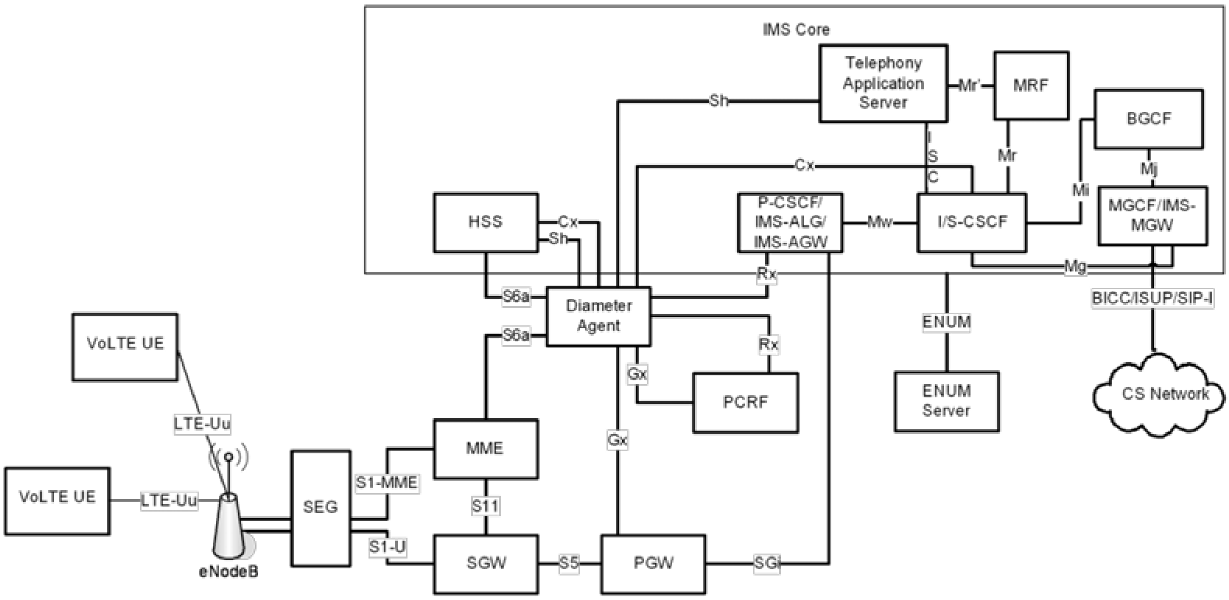

Figure 8: IMS Logical Architecture [5]

2.2.2. Voice-over-NR (VoNR) functionality

For 5G-SA voice-centric devices, according to 3GPP specification, the UE needs to be registered to the IMS network to be able to stay attached to the Core Network and to access data-only functionalities. UPF engages IMS through the N6 interface, and PCF engages IMS through the N5 interface. When SA is deployed with NR, 5GC handles signaling and media for IMS. UEs that only support SA Option 2 connect to gNB and perform Voice over 5GS (Vo5GS) according to the standard GSMA NG.114 IMS Profile for Voice, Video and Messaging over 5GS [4].

In both scenarios, PCO is handled by PGW or SMF towards the UE to provide the proxy discovery mechanism with a list of the available P-CSCFs. Figure 9 shows the 4G and 5G deployments that are supported for non-standalone (NSA) with GSMA Option 3 and standalone (SA) with GSMA Option 2 to support VoLTE and VoNR use cases of a Voice-over-NR network in the HPE Aruba Networking P5G Unified Network Platform solution, comprising the IMS and the 5G Core Network.

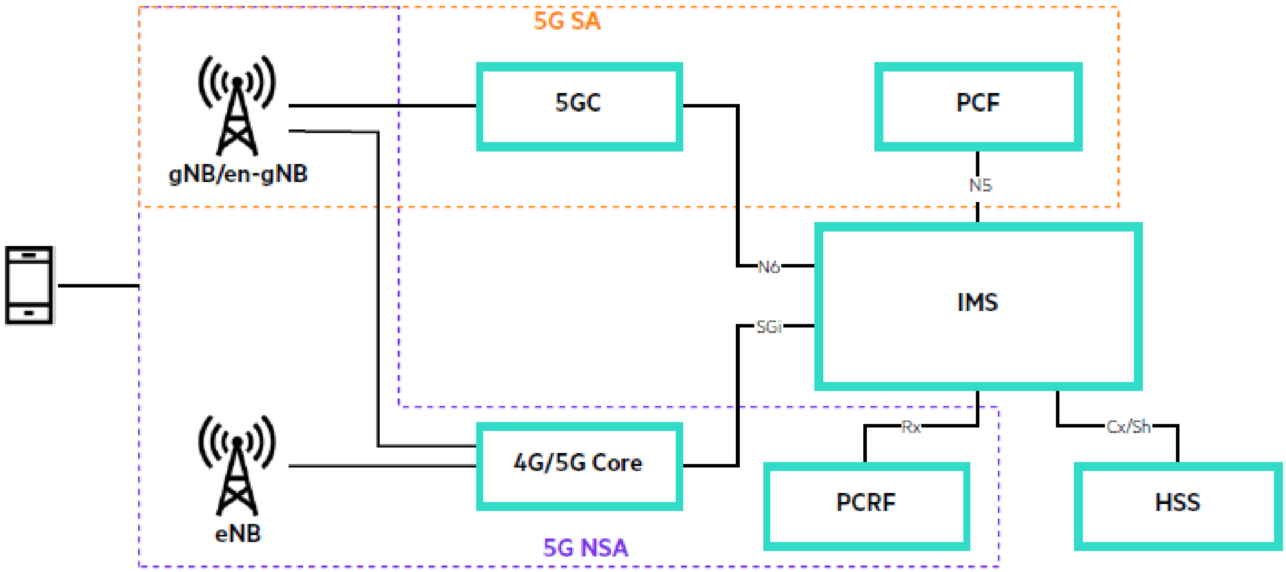

Figure 9: HPE ANW P5G VoiceServices deployment scenario in 4G/5G

2.2.3. Mission Critical Push-to-Talk (MCPTT) communication solution

The installation of an MPN 5G in Sofia Airport network is motivated by the need for enhanced technological capabilities. Its low latency and high bandwidth facilitate remote control functionalities, enabling swift and responsive management of operations and systems. This ensures seamless connectivity and efficient control, essential for real-time decision-making and optimized performance in various critical operations at the airport.

The integration of push-to-voice and push-to-video functionalities acts as a robust fallback mechanism, designed to overcome the limitations of traditional professional radio systems and public communication networks. These capabilities enable instant voice and video interactions, ensuring uninterrupted connectivity even in scenarios where standard communication channels may fail. By incorporating these features, the system guarantees reliable, real-time communication among operational teams—improving coordination, efficiency, and responsiveness, particularly during mission-critical or emergency situations where rapid information exchange is essential.

The Mission Critical Push-to-Talk (MCPTT) and Push-to-Video applications, combined with a centralized video surveillance system, will play a vital role in strengthening security and optimizing operational processes at Sofia Airport. These tools will support both routine operations and emergency response scenarios, providing secure, real-time communication and situational visibility. Access to and utilization of such information will adhere strictly to Sofia Airport's internal information security policies and procedures, ensuring full compliance with Bulgarian cybersecurity regulations. Furthermore, Push-to-Talk (PTT) and Mission-Critical Voice Communication serve as essential coordination tools for response and operations teams during critical events. They enable secure, instantaneous, one-to-many voice communication, allowing the swift dissemination of commands, situational updates, and emergency alerts. This functionality enhances situational awareness and operational readiness by minimizing communication delays and facilitating efficient collaboration among multiple agencies operating in dynamic, high-stress environments.

Mission Critical Push-to-Talk (MCPTT) as part of 5G SAMITEA scope is based on Alea Mission Critical Push-to-Talk (MCXPTT) solution, designed to provide both standard Push-to-Talk (PTT) and mission-critical communication capabilities. The solution will be integrated within the Sofia Airport ANW P5G Mobile Private Network (MPN). The Alea XPTT solution delivers a Push-to-Talk over Cellular service that enables instant, secure, and reliable communication for mobile and distributed teams. It is designed to enhance coordination and safety by providing real-time voice, messaging, and media exchange capabilities over Mobile private network. The system consists of a web-based management platform and a mobile application, allowing continuous interaction between administrators and field users. Through the web platform, administrators can supervise and manage users and groups in real time. They can add or remove users, assign permissions, monitor user activity, and track locations through GPS-based visualization. The intuitive interface supports one-to-one and group calling, multimedia sharing, emergency alerts, and location tracking, ensuring efficient field coordination and improved situational awareness. Combining the simplicity of traditional PTT communication with the benefits of Internet-based services such as file, photo, and video sharing, presence information, and instant messaging allow users to stay constantly connected with their teams and supervisors, regardless of network type or geographical location. The Alea MCXPTT solution features a scalable, secure, and flexible architecture and by integrating all communication functions—voice, messaging, and multimedia—into a single platform, Alea MCXPTT will improve operational efficiency, enhance safety, and support mission-critical performance. When combined with Airport 5G MPN infrastructure, it will provide a robust and modern communication framework optimized for next-generation industrial and transport applications.

2.3. Radio Network Architecture and Design

The main objective of the radio network design activity in the scope of the project is to determine the number of new RAN sites to be built and number of existing RAN sites to be upgraded to meet the 5G SAMITEA use cases requirements, and this subject is described in Deliverable 2.1. To fulfill the use case requirements, A1BG 4G/5G Mobile RAN network coverage and capacity will be extended and will be granted to Sofia Airport MPN. The new DAS system will improve indoor coverage and capacity at Sofia Airport. The DAS system should provide coverage in all public areas of Sofia airport – Terminal 2, as well as additional, requested by the airport management, staff only areas (e.g. Baggage). DAS should support 2x2 MIMO for the following frequency bands: 700/800/900/1800/2100/2600 MHz and 5G at 3400 - 3600 MHz band coverage in Departures, Arrivals, and gate areas. DAS should include an uninterruptible power supply, monitoring system for active modules and antennas with low visible impact in public areas.

The installation of new RAN sites and upgrades of existing ones are necessary due to the high bandwidth demand for HD cameras and drones. This technology provides the necessary infrastructure to support the transmission of high-definition video feeds and real-time data essential for surveillance cameras and drone operations. The enhanced bandwidth of 5G ensures seamless, high-quality video streaming and swift data transfer, critical for efficient monitoring and surveillance within the airport premises. As part of project 5G rollout, A1BG will deploy a high capacity 5G mmWave network across the airport environment. This deployment is a key step in enabling next-generation use cases that demand ultra-fast connectivity, minimal latency, and high bandwidth—capabilities that mmWave spectrum is uniquely suited to provide.

2.3.1. Mobile Connectivity Technology

LTE (Long Term Evolution) represents a significant advancement in mobile communication technology. Also known as E-UTRAN (Evolved Universal Terrestrial Access Network), LTE was introduced in 3GPP Release 8 and serves as the access component of the Evolved Packet System (EPS).

The LTE access network consists of a network of base stations, known as evolved NodeBs (eNB), creating a flat architecture. There is no centralized intelligent controller; instead, the eNBs are typically interconnected via the X2 interface and connected to the core network via the S1 interface. Figure 10 shows the high-level Architecture of the 4G RAN concept.

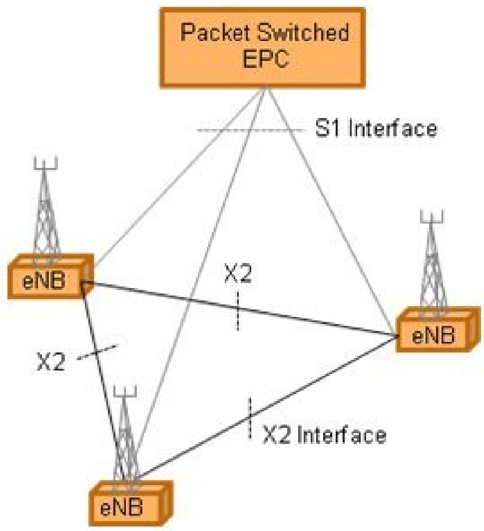

Figure 10: 4G RAN Architecture

Building on the technological foundations of LTE, 5G New Radio (NR) introduces enhanced flexibility and performance to support the advanced service requirements of Industry 4.0 and Health 2.0. These improvements ensure higher efficiency, ultra-reliability, and scalability across a wide range of industrial and enterprise use cases.

- Enhanced Mobile Broadband (eMBB):

5G delivers significantly higher data rates, achieving theoretical downlink speeds of up to 50 Mbps outdoors and 1 Gbps indoors, with uplink speeds reaching 25 Mbps outdoors and 500 Mbps indoors. This capacity enables new enterprise applications requiring high throughput and low latency.

- Ultra-Reliable Low-Latency Communication (URLLC):

Designed for mission-critical operations, 5G provides >99.999% reliability and end-to-end latency below 50 ms, supporting advanced use cases such as remote-assisted surgery, industrial automation, and autonomous vehicles.

- Massive Internet of Things (mIoT):

5G supports extremely high device densities, making it ideal for smart cities, industrial IoT deployments, and large-scale connected environments, where thousands of sensors and devices must communicate efficiently and reliably.

To support diverse deployment scenarios, 5G NR accommodates a broad spectrum of carrier frequencies and channel bandwidths. These are divided into two operational ranges — FR1 (sub-6 GHz) and FR2 (millimeter wave) — providing the adaptability required to meet varied network performance and coverage needs.

The 5G network can be deployed in two different architectures, depending on the type of interactions with the LTE network. 3GPP introduces two types of 5G networks based on interactions with the LTE network:

- the 5G non-standalone (NSA) option 3x architecture, where the 5G radio is complemented by the LTE radio and served by the LTE core.

The Non-Standalone (NSA) architecture represents an intermediate phase in the evolution toward full 5G deployment. In this configuration, the 5G New Radio (NR) access network operates in conjunction with the existing 4G LTE Core Network (EPC), enabling operators to introduce 5G capabilities without a complete overhaul of the core infrastructure.
In the NSA setup, the 5G NR base station (logical node “en-gNB”) connects to the 4G LTE base station (logical node “eNB”) via the X2 interface. Originally introduced before 3GPP Release 15 to link two eNBs, the X2 interface was enhanced in Release 15 to support connectivity between eNBs and en-gNBs, thus enabling seamless coordination between 4G and 5G radio access nodes.
This architecture provides dual connectivity through both the E-UTRAN (4G) and NR (5G) access networks — a setup referred to as EN-DC (E-UTRAN New Radio Dual Connectivity). EN-DC allows user devices to simultaneously connect to both LTE and NR, combining their bandwidths and improving throughput, coverage, and user experience while leveraging the reliability and maturity of the existing LTE core network.
Figure 11 illustrates the architecture of 5G non-standalone deployment of NR.

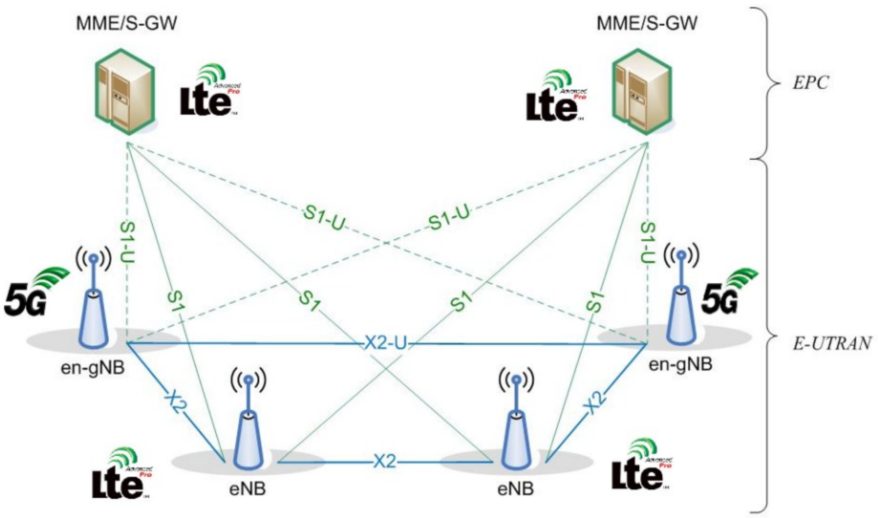

Figure 11: 5G Non-Standalone Architecture of NR

- the 5G standalone (SA) option 2 architecture, where the 5G radio is served by the 5G core and can interwork with the LTE network.

In the 5G SA option 2 architecture, the 5G radio cells and the core network are operated independently from the LTE network. This means that the 5G radio cells are used for both control plane (C-plane) and user plane (U-plane). The gNBs connect with each other through the Xn interface, and the gNB connects to the 5G core network using NG-U and NG-C interfaces. The standalone option can be deployed as an independent network using handovers between LTE and 5G for service continuity. The advantage of the standalone option is the simplification of the network and improved efficiency.

Figure 12 illustrates the NSA and SA architecture options:

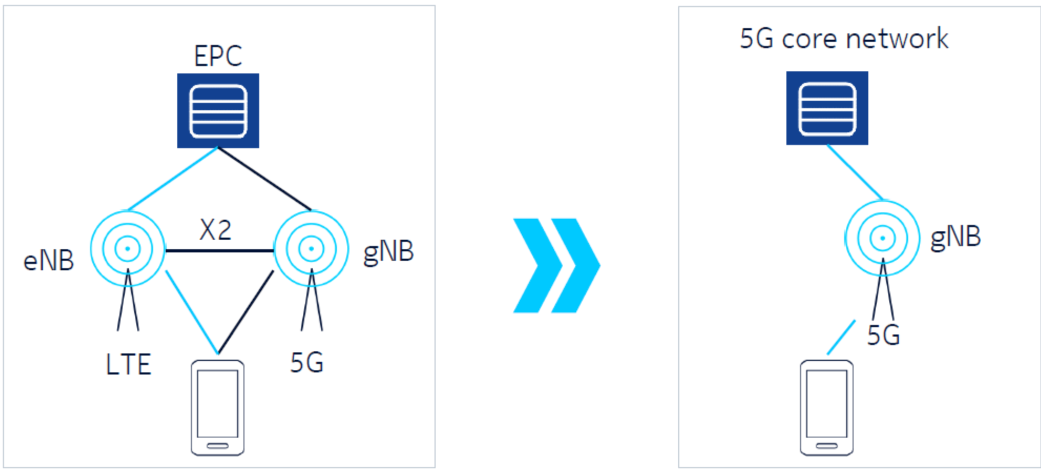

Figure 12: NSA and SA architecture options

SA layering strategy depends on available spectrum and use cases and one of the main strategies is the layering of spectrum across different frequency bands. This layering approach allows operators to balance between network coverage, capacity, and performance. The key spectrum bands used for 5G can be categorized into three groups: low-band, mid-band, and high-band, each of which serves a distinct purpose in the network:

- Low-band spectrum, under 1 GHz, such as 700 MHz, 2100 MHz is crucial for providing broad coverage. It penetrates buildings well and extends over long distances, making it ideal for rural areas or regions where wide coverage is necessary. In these areas, it assures connectivity for IoT devices and enhances basic mobile broadband services as well as Voice (VoNR) and reliable Uplink.

- Mid-band spectrum, particularly in the range of 1-6 GHz, like the 3.5 GHz band, offers a balance between coverage and capacity. It can carry higher data rates than low band while still providing sufficient coverage for suburban and urban environments. This makes mid-band spectrum essential for handling the high data demands of urban populations. Mainly used for Mobile Broadband (MBB) and Fixed Wireless Access (FWA).
- High-band spectrum, or millimeter wave (mmWave) frequencies, such as 26 GHz and above, provides the highest data speeds but has a very limited range and poor building penetration. High-band frequencies are mostly deployed to provide hotspot coverage and Ultra-Reliable Low-Latency Communications (URLLC) on very dense urban areas where large numbers of users demand high data throughput, such as in stadiums, airports, or central business districts. mmWave is being used to offer multi-gigabit per second speeds in these environments, enabling high-data applications like streaming, augmented reality, and smart city technologies.

2.3.2. Overview of RAN architecture and infrastructure

The A1BG Radio Access Network (RAN) infrastructure is implemented on the Nokia AirScale Solution, a modular and multi-technology platform supporting multi-RAT coexistence, enabling concurrent operation of LTE and 5G carriers within the same baseband and radio infrastructure. Depending on the site configuration, the RAN node can be software-upgraded or hardware-extended to accommodate future spectrum bands or increased capacity demands. The base station's architecture consists of the following core hardware elements:

System Module (Baseband Unit – BBU): Hosts the digital baseband and computing resources required for Layer 1–3 processing, radio scheduling, encryption, and mobility management. The System Module aggregates traffic from multiple radio units and interfaces with the transport network via high-speed fiber Ethernet interfaces. The System Module is a versatile component capable of handling multiple generations of mobile technology, including 2G, 3G, 4G, and both standalone (SA) and non-standalone (NSA) 5G, depending on the equipped hardware and specific needs.

Radio Modules (RRUs): Contain the RF front-end, including power amplifiers, duplexers, and filters for the supported frequency bands. The modules perform analog-digital conversion and transmit/receive operations. Each RRU connects to the System Module via Single Mode Fiber (SMF) links (up to 10 km distance).

Power Supply Unit (PSU): Provides the regulated –48 V DC power required by the RAN hardware. The PSU includes surge protection and AC input isolation to ensure continuous operation with integrated monitoring for voltage stability, load balancing, and thermal performance. The system incorporates automatic switchover to battery backup in the event of power loss, ensuring uninterrupted operation of radio services.

Battery Backup Unit (BBU): Ensures uninterrupted service during AC grid outages by maintaining power to all active components, including the System and Radio Modules, for the configured autonomy period.

Transmission within the RAN infrastructure is achieved via fiber optic backhaul. The System Module is connected to the A1BG transport network via fiber and can be equipped optionally with a backup line to ensure redundancy and high availability (as described in details in Section 2.4) The logical topology supports link aggregation and failover to maintain service continuity during link degradation or failure. Each Radio Module connects to its corresponding System Module using CPRI/eCPRI over single-mode fiber. This configuration ensures high throughput and low latency for both user and control plane traffic, meeting the strict performance requirements of 5G systems.

This architecture delivers a carrier-grade, scalable, and resilient RAN platform capable of supporting advanced service models, including MOCN-based 5G MPNs. The modular structure allows efficient resource sharing, streamlined integration with transport and core domains, and simplified lifecycle management across multi-technology environments. The System Module manages cell resources for both public and private PLMN identifiers under MOCN configuration, enabling network sharing between the A1BG public and Airport private network deployments. Resource allocation and traffic prioritization are handled according to defined QoS Class Identifiers (QCIs) and 5QI parameters, ensuring service-level compliance across all active users and slices.

To address the expectations and needs identified in the market and industry for existing and new use cases, several concrete targets on service characteristics were defined to serve as A1BG's design goals for the 5G specification work. As the requirements are use-case dependent and quite diverse, it meant that the NR radio technology needed to be designed in a flexible way, so that a wide range of use cases could be efficiently supported. Important requirement is that the NR radio shall be possible to deploy in a very wide range of frequency bands, ranging from 450MHz up to above 52GHz. This is a range that no previous radio access technology (2G, 3G or 4G) has supported. The implemented A1BG RAN network architecture is according to the 3GPP R15 Non-Standalone (NSA) architecture Option 3x. The access links are split in user and control plane parts. The user plane carries the payload traffic, while the control plane carries control signaling for user plane traffic. The NSA option 3x uses the concept of split bearer, where the UE is connected to one eNB that acts as a Master Node and one gNodeB that acts as a Secondary Node. In Dual Connectivity mode a given UE consumes radio resources provided by at least two different network points (e.g., NR access from gNB and LTE access from eNB, Figure 13).

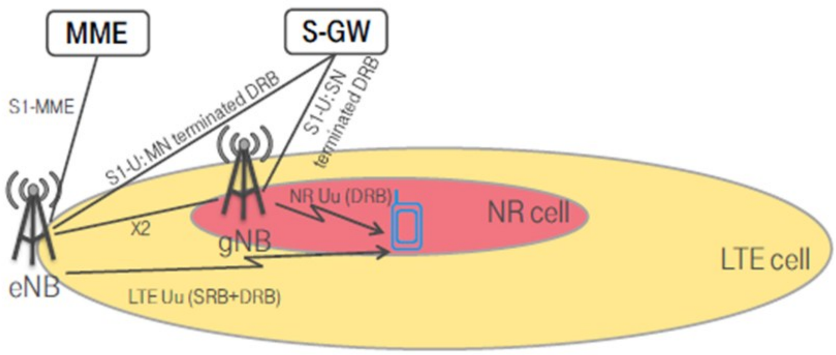

Figure 13: 5G NSA Option 3X

The A1BG 5G network currently operates in NSA mode, utilizing the TDD 3.5 GHz and FDD 700 MHz frequency bands. The 3.5 GHz band, with a bandwidth of 100-120 MHz, is well-suited for 5G NSA due to its balance of capacity and coverage. Over the next 12-24 months, A1BG aims to activate concurrent 5G NSA/SA mode across multiple bands. The 2100 MHz band will be re-farmed from LTE to NR FDD mode with a bandwidth of 20 MHz and will play a vital role in ensuring continuous data transfer. This band is ideal for mobile broadband services due to its balance of coverage and capacity, and it will support both SA and NSA modes soon. The 700 MHz band, operating in NR FDD mode with 10 MHz of bandwidth, is crucial for wide area coverage and strong indoor signal penetration, making it particularly effective in rural and suburban areas. While currently utilized for 5G NSA, A1BG plans to enable concurrent SA/NSA mode and has selected to deploy Option 2 for the Standalone Architecture (SA). In Figure 14 below, Option 1 is the LTE architecture, Option 3(3x) is the Non-Standalone Architecture and Option 2 is the Standalone Architecture. In 5G SA Option 2, New Radio (NR) access network consists of gNBs that are connected to 5G Core (5GC). The user-plane and control- plane of SA Option 2 are pure NR and are completely independent of Long-Term Evolution (LTE). 5G System (5GS), including 5G SA Option 2, is an end-to-end system ranging from devices, radio access network (gNB) and core network (5GC).

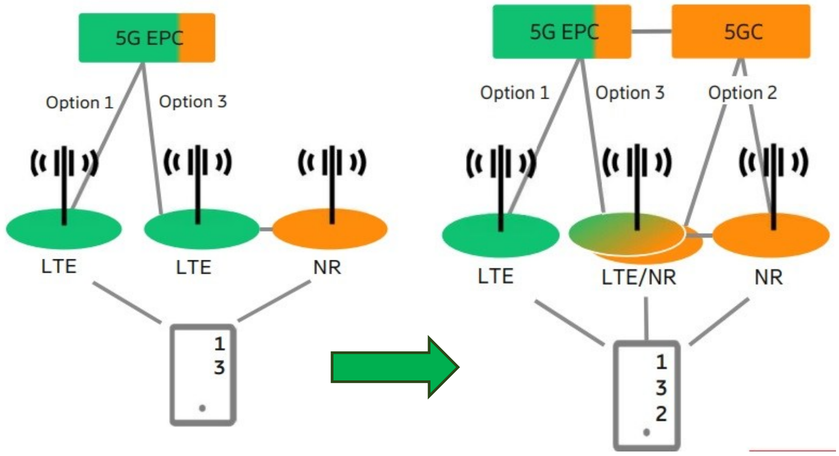

Figure 14: From left to right A1BG NSA option 3x and A1BG SA option 2

In the SA Option 2 architecture, A1BG gNBs connect to 5GC(AMF) via N2(NG-C) and to 5GC(UPF) via N3(NG-U) interface. In addition, A1BG SA gNBs are interconnected via Xn interface and via X2 interface with A1BG eNBs.

A1BG intends to implement 3CC carrier aggregation, combining different frequency bands to enhance network capacity and performance. This deployment strategy reflects A1's commitment to a smooth migration to 5G Standalone (SA), ensuring the network can handle diverse user demands and next-generation applications.

A1BG is currently covering the 5G SAMITEA RAN part with 4G (LTE) radio, using 20 MHz bandwidth on 1800 MHz frequency, 20 MHz bandwidth on 2100 MHz frequency, 20 MHz bandwidth on 2600 MHz frequency and 5MHz baseband bandwidth for 900 MHz frequency. According to A1BG 4G layering strategy, UE near to cell center, has to be connected to high frequency band layers to aggregate max bandwidth. UEs which are in poor radio conditions, such as at the cell edge will be pushed to handover to low frequency band (coverage) layers. All layer's traffic load balancing will be implemented to avoid overload.

For A1BG, 3.6 GHz band is emerging as the primary frequency band for the introduction of 5G by 2020 with availability of 100 MHz channel bandwidth. Additional 20MHz bandwidth is exploited in Carrier Aggregation (CA) combination on 3.6GHz band. A1BG acquisition of spectrum in n28 band (700MHz) will be in place to be exploited as part of the project. According to A1BG 5G layering strategy, at the cell edge 700MHz band will be the serving layer, while 3.6 GHz will stay as secondary supplementary band.

2.3.3 Shared RAN (MOCN) functionality

A network sharing architecture enables a public mobile network operator (MNO) to share the resources of a single public radio station with private mobile network customers according to agreed allocation schemes. The shared network includes a radio access network (RAN). Consequently, the sharing network operator allocates shared resources to the participating mobile private network customers based on their current and future needs and in accordance with service level agreements.

The Sofia Airport MPN follows the Multi-Operator Core Network (MOCN) sharing architecture as defined by 3GPP, in which only the RAN is shared in 4G and 5G systems. The RAN MOCN feature for 4G and 5G systems enables the use of more than one PLMN ID (i.e., with different network codes (MNC)) and thus RAN resources within a single cell, eNodeB, or gNodeB is managed by PLMN-IDs. This approach ensures efficient utilization of network resources while maintaining distinct identities for public and private networks. To accommodate this need, A1BG has reserved PLMN-ID 284-02 exclusively for all Private Networks. This reservation allows for seamless integration and management of private networks alongside the public network.

The RAN site serving the Airport Mobile Private Network will simultaneously broadcast two PLMN-IDs, enabling parallel operation of both the A1BG public and Airport private network domains: PLMN-ID 284-01 for the A1BG Public Network and PLMN-ID 284-02 for the Airport Private Network. This dual broadcast ensures that both networks can operate simultaneously and efficiently, providing robust connectivity for both public and private users.

2.4 Transport Network Architecture and Design

5G SAMITEA project will reuse the current A1BG Core and Aggregation Transport Network architecture and design. New links and connections will be deployed and required technological upgrades will be implemented to address the needs of the new sites, as well as the additional capacity requirements that 5G SAMITEA project needs.

2.4.3 Backhaul Transport Network

The access layer covers the edge part of the transport of the IP/MPLS network. The devices building the layer are Nokia 7250 IXR-e [6] with capacity to provide the current needs, with a combination of large number of 10G access ports to the gNodeBs and an option of 100G uplinks, in case future traffic needs. The devices from Access layer are responsible for the delivery of the synchronization from the sync sources to the gNodeBs, as well. The Access layer provides two types of physical topologies:

- Ring topology - with termination of two aggregation sites.
- Start topology - termination of multiple access devices to at least two aggregation sites and devices.

The gNodeBs are either local or interconnected to the IP/MPLS network with Dark Fibers (DFs).

2.4.4 IP Aggregation Network

A1BG IP Aggregation network is deployed with Nokia devices – Nokia 7750 SR7/SR1/a4/ [6]. All the major IP Aggregation sites have two redundant devices. They are protected by uplinks to two separate sites via independent optical paths. The functions of the devices of this layer are to:

- terminate the links from the small access sites or access rings
- terminate gNodeB in the vicinity of the local site
- transfer the traffic from the Access to the Core layer and from there to Mobile Core sites.

2.4.5 IP Core Network

The overall topology of the IP/MPLS network is presented in Figure 15. It depicts end-to-end transport path from the RAN/gNodeBs to the Mobile Packet Core and IMS.

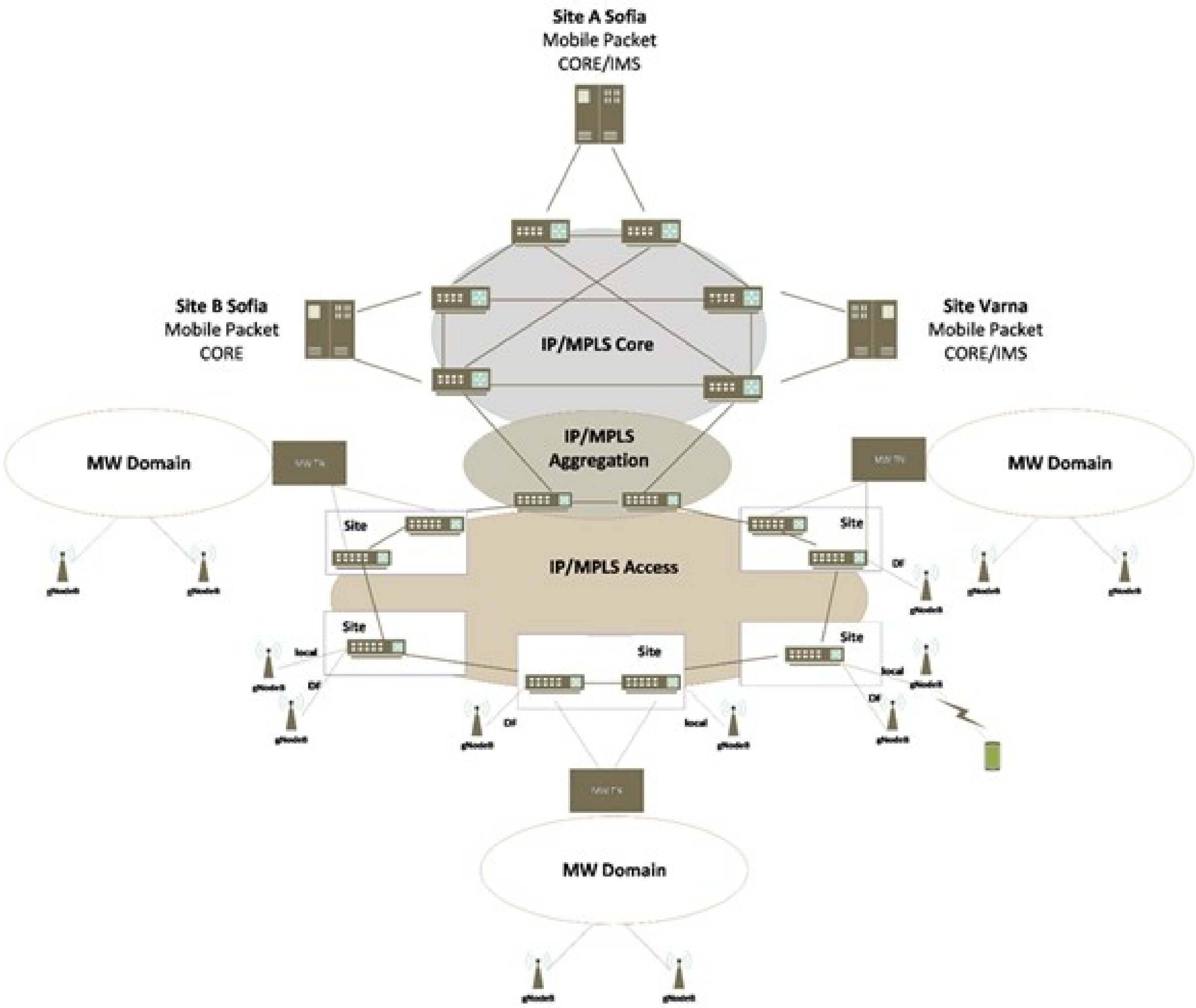

Figure 15: A1BG Overall topology of the IP/MPLS network

The IP/MPLS Core transport network is based on Nokia 7750 SR12 and and SR7s chassis [7], which provide highly redundant and resilient transport of the mobile service of A1 BG. The devices are equipped with 100G modules, while in Sofia sites they are interconnected with 400G links. The combination of high-capacity links and redundant devices is leading design principle of the transport network of A1BG. The physical topology and the provisioned capacities are depicted below:

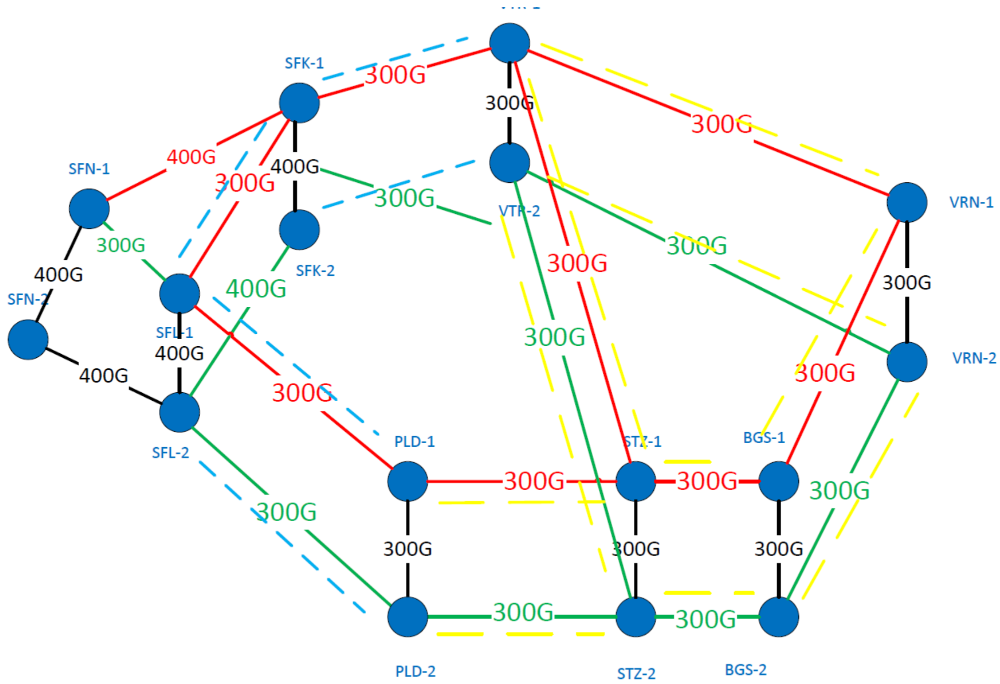

Figure 16: A1BG Tier 1 Transport Sites

The physical interconnects between A1BG sites are implemented mainly with Nokia DWDM equipment through independent optical paths, which guarantees no isolation of part of the network in case of a fiber cut. The only exception to the DWDM connectivity is Sofia, where there are several DF links, which are again following the logic of a physical path with no single point of failure.

On Figure 16 are displayed A1BG Tier 1 transport sites - each Tier 1 site has two core nodes for node redundancy and all nodes are connected through with Ring 1 and Ring 2 for link redundancy and load-balancing.

There are three main Mobile Core sites in the network of A1 BG – Sofia Lift, Sofia Kukush and Varna. The Mobile Packet Core is deployed on all three sites, the IMS is only on sites Sofia Lift and Varna. The design includes redundant local links to two dedicated Mobile IP/MPLS devices with 100G interconnects and using static routing or BGP dynamic routing with BFD protocol activated. The used scheme includes automatic rerouting either locally through the second link to the mobile elements or to any of the other mobile core sites in case of total site outage – IP/MPLS device or Mobile element of the Packet Core or the IMS system.

2.5 Airport MPN Monitoring and Performance Management

In the rapidly evolving landscape of mobile communications, the performance of a Mobile Private Network (MPN) like Sofia Airport MPN is paramount to ensuring seamless connectivity, optimal resource utilization, and high-quality user experiences. Performance management in Sofia Airport MPN will involve a systematic approach to monitoring, analyzing, and optimizing various network parameters to meet the specific needs of the organization it serves.

Airport MPN operates independently of public A1BG cellular network, supporting mission-critical applications, and given its critical role, performance management becomes an essential function to maintain network reliability, efficiency, and security.

Performance management will encompasse a range of activities, including:

- **Monitoring:** Continuous tracking of network performance metrics of Sofia Airport MPN such as bandwidth utilization, latency, packet loss, and signal strength. This real-time data collection is crucial for identifying potential issues before they impact network performance. The End-to-End (E2E) Monitoring of Airport MPN involves comprehensive surveillance and observation of all events within the MPN system and service. This approach provides a holistic view of the system's performance, ensuring that every component and interaction functions as expected.
- **Analysis:** Detailed examination of the collected data from Airport MPN to uncover trends, patterns, and anomalies. This analysis helps in understanding the underlying factors affecting network performance and in making informed decisions.
- **Optimization:** Implementing strategies and adjustments to enhance network performance in Airport MPN. This could involve fine-tuning network configurations, upgrade hardware, or deploying advanced technologies like network slicing and edge computing.
- **Reporting:** Generating comprehensive reports that provide insights into network performance over time in Airport MPN. These reports are valuable for stakeholders to assess the effectiveness of the network and to plan future upgrades and expansions.
- **Troubleshooting:** Rapid identification and resolution of performance-related issues. Effective troubleshooting ensures minimal downtime and maintains the integrity of the network services in Airport MPN

The goal of performance management in Sofia Airport MPN is to deliver a robust, scalable, and efficient network that meets the stringent requirements of its users. By leveraging advanced monitoring tools, analytics, and proactive management practices, SofConnect can ensure its MPN operates at peak performance, supporting their business objectives and delivering exceptional value.

3 Conclusions

The 5G SAMITEA project is founded upon a dual-layered approach. On one hand, it encompasses the deployment and utilization of a new, high-quality 5G network in Sofia Airport, addressing both the current lack of coverage and the absence of advanced functional capabilities required to enable the envisaged services, such as low latency communication and prioritization mechanisms in emergency and critical situations along with the targeted use cases related with passengers' flow monitoring, airport security monitoring and safe evacuation. On the other hand, it builds upon the existing A1BG 5G RAN, Core and transport commercial mobile network domains, extending them with additional functionalities and features where necessary to ensure that the project's key objectives are achieved in accordance with the high-quality standards defined for network planning, design, and optimization.

The deployment targets full compliance with 3GPP Release 16 standards and introduces a beyond State-of-the-Art (SoTA) 5G implementation through new and upgraded infrastructure across both the Sofia Airport MPN and the A1BG commercial network. The design follows a both conceptual strategy: in the initial phase will be utilized a Non-Standalone (NSA) architecture leveraging the existing EPC core, while the subsequent phase will introduce a full 5G SA architecture, achieving a beyond–State-of-the-Art (SoTA) implementation in alignment with project performance and reliability objectives. This architecture ensures scalability, resilience, and service continuity across both private and public domains while aligning with the project's technical and operational objectives.

The 5G SAMITEA end-to-end architecture, with particular focus on 5G mobile networks, builds upon the underlying theoretical analysis and fundamentals, as well as practical design considerations. Having set the conceptual architecture and impact analysis on the Use Cases implementation, the document deep dives in Sofia Airport MPN architecture and updates of A1BG commersial mobile network, illustrating infrastructure and topology specific solutions. These sections provide description of the improvements and refinements for each architectural domain for both private and public networks.

Finally, this document D2.2 is the second technical deliverable provided by the 5G SAMITEA consortium and is produced as part of WP2 ""Requirements, Architecture and Scope of Work"," and Task 2.2 "Task 2.2: 5G End-2-End Architecture and Specifications". It marks the completion of the project's milestone MS3 "E2E architecture and technology specifications". The detailed design following the D2.2 work will be reflected and further developed in D3.1 where E2E Low Level Network Design and Planning will be described.

4 References

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