EIT HEI Initiative

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Contents

Executive Summary

This deliverable includes the training program prepared within the scope of Task 1.2 of Work Package 1 of the Skills2Scale project. The purpose of the training program is to enhance the capacity of HEIs (Higher Education Institutions) in fostering institutional engagement and change in the field of beyond 5G technology. The material of the program was based on the results of the needs assessment of HEIs conducted in the previous task of this work package to determine their current capacity and needs in fostering institutional engagement and change in the field of beyond 5G technology.

In the tasks that will take place in the following months, HEI administrators, faculty, and staff will be trained. The training will be delivered through webinars and will cover topics such as innovation and entrepreneurship, partnership building, and knowledge sharing. Following the training, mentorship and support will be provided to HEIs on how to implement the practices and tools learned through the training program. The mentorship and support will be provided through b2b (business-to-business) and b2m (business-to-many) follow-up digital sessions.

After completing the courses, the participants are expected to have a better understanding of the relative technologies of 5G and beyond, as well as how they can use this knowledge to realize their unique ideas through innovation and entrepreneurship.

About the EIT HEI Initiative

The EIT HEI Initiative: Innovation Capacity Building for Higher Education has been designed with the aim of increasing the innovation and entrepreneurial capacity in higher education by bringing together HEIs in innovation value chains and ecosystems across Europe. A central philosophy of the EIT is the integration of the EIT Knowledge Triangle Model

into all its activities. HEIs selected to participate in the HEI Initiative will also leverage and use the Knowledge Triangle Model as an enabler, facilitating the creation of systemic, institutional change. Additionally, HEIs selected to participate in the HEI Initiative will contribute to and leverage Smart Specialisation Strategies, the Regional Innovation Impact Assessment (RIIA) Framework, as well as align to the goals of the EIT Regional Innovation Scheme (EIT RIS).

This will strengthen the links between HEIs and their local and regional ecosystems and provide an impetus to leverage additional funding sources beyond the HEI project funding period of the selected HEI projects.

HEIs are encouraged to prepare applications which will support the development and implementation of six Actions in their institutions, cumulatively leading to institutional transformation, an increase in entrepreneurial and innovation capacity, and integration with innovation ecosystems.

1 Introduction

1.1 Purpose of the document

The purpose of this document is to develop a training program to enhance the capacity of Higher Education Institutes (HEIs) in fostering institutional engagement and change in the field of beyond 5G technology. This document is considered a crucial step for the project's development as it serves as the base and syllabus for the upcoming webinars that will take place later in the project. The training program has been carefully designed, incorporating material on both beyond 5G technologies and innovation and entrepreneurship. It takes into consideration the results of Task 1.1, which performed a needs assessment of HEIs to determine their capacity and requirements in fostering institutional engagement and change in the beyond 5G field. Using this information, the program has been tailored to meet the specific needs of HEIs and provide the desired outcomes. Upon completion of the courses, participants are expected to have a better understanding of the relative technologies of 5G and beyond, as well as how they can leverage this knowledge to realize their unique ideas through innovation and entrepreneurship.

1.2 Structure of the document

The deliverable is organized in the following manner:

- Section 1 - Introduction: This section describes the purpose and structure of the deliverable, as well as the target audience.
- Section 2 - Training Program: This section describes the training program that has been developed in the scope of Skills2Scale: Deep Tech Empowerment for Higher Education Institutes project. It includes the training content description and material. The training program consists of two main areas. One related to 5G and beyond technologies and a second related to innovation and entrepreneurship in 5G and beyond.
- Section 3 - Conclusions: A final summary of the training program that also includes next steps of the WP1.

1.3 Target audience

The training program is developed for a diverse audience, including HEI administrators, faculty, staff, and students. Additionally, it addresses a scientific audience with a relative background and technical knowledge, a business-oriented audience with less understanding of technical terms, as well as others interested in the field of beyond 5G. The program has been designed to accommodate the needs and ensure comprehension for all audiences, regardless of their technical background.

2 Training Program

2.1 Course description

With the term "Training Program" in the Skills2Scale project, we refer to the syllabus, comprehensive description and material of the content that will be used for the training in the upcoming tasks. Relative slides with enhanced details, based on the material provided in this training program, will also be developed and used for the training as part of the webinars. By participating in this training course, participants will gain knowledge on 5G and beyond technology and its principles, exploring how 5G can transform the business landscape in combination with innovative ideas. The primary goal of this training course is to strengthen the entrepreneurial capacity of HEIs in the field of Beyond 5G technologies and to improve their quality of innovation and entrepreneurial education. This course can be taken without any prior knowledge of 5G or other wireless technology.

2.2 5G Syllabus

2.2.1 Evolution of Mobile Networks: From 0G to 5G & Beyond 5G

Mobile networks have evolved significantly over the years, progressing through multiple generations from 0G to the current 5G technology:

- 0G: The initial mobile communication systems were analog-based and provided limited voice-only communication. These systems were introduced in the 1940s and 1950s and were primarily used in car-mounted devices known as Mobile Telephone Service (MTS).
- 1G: The first-generation (1G) mobile networks, introduced in the 1980s, marked the transition to digital communication. These networks, based on technologies like Advanced Mobile Phone System (AMPS) and Nordic Mobile Telephone (NMT), offered voice communication with improved sound quality and reduced interference. However, 1G systems had limited capacity and lacked data services.
- 2G: Second-generation (2G) mobile networks, introduced in the 1990s, brought significant advancements. Systems like Global System for Mobile Communications (GSM) and Code Division Multiple Access (CDMA) offered digital voice services and introduced data capabilities, enabling services like text messaging (SMS). 2G networks also supported higher capacity, improved call quality, and the introduction of basic mobile data services.
- 2.5G: Also known as 2.5G or 2.75G, this intermediate phase between 2G and 3G introduced data enhancements to existing 2G networks. Technologies like General Packet Radio Service (GPRS) and Enhanced Data rates for GSM Evolution (EDGE) increased data speeds, enabling basic internet browsing and email on mobile devices.

- 3G: Third-generation (3G) networks, introduced in the early 2000s, marked a significant leap forward in mobile communications. Technologies like Universal Mobile Telecommunications System (UMTS) and CDMA2000 offered higher data rates, improved voice quality, and multimedia capabilities. 3G networks enabled the widespread adoption of mobile internet, video calling, and advanced data services.
- 4G: Fourth-generation (4G) networks, introduced around 2010, represented a major milestone in mobile network evolution. Based on technologies like Long-Term Evolution (LTE) and WiMAX, 4G networks offered significantly faster data speeds, lower latency, and improved capacity. 4G brought forth a revolution in mobile internet, supporting high-quality video streaming, online gaming, and advanced mobile applications.
- 5G: The fifth-generation (5G) networks, launched commercially in recent years, have been designed to address the increasing demands of a hyper-connected society. 5G introduces technologies like 5G New Radio (NR) and Network Function Virtualization (NFV) to deliver ultra-fast data rates, extremely low latency, massive device connectivity, and network slicing capabilities. 5G networks enable transformative applications such as autonomous vehicles, remote surgery, massive IoT deployments, augmented reality (AR), and virtual reality (VR) experiences.

Each generation of mobile networks has brought significant improvements in terms of speed, capacity, data services, and network capabilities. The evolution from 0G to 5G has enabled the proliferation of mobile devices and the transformation of various industries, empowering users with unprecedented connectivity and driving innovation across multiple sectors.

2.2.2 Key Features of 5G

2.2.2.1 Enhanced Mobile Broadband (eMBB)

eMBB stands for enhanced Mobile Broadband. It is one of the key use cases for 5G (fifth-generation) wireless technology. eMBB is designed to provide significantly higher data rates, lower latency, and increased network capacity compared to previous generations of mobile networks.

The main objective of eMBB is to enhance the mobile broadband experience for users by delivering faster download and upload speeds, smoother streaming of high-definition and ultra-high-definition (UHD) content, and improved overall network performance. It aims to enable applications such as virtual reality (VR), augmented reality (AR), 4K/8K video streaming, online gaming, and other bandwidth-intensive services. 5G networks supporting eMBB utilize advanced technologies such as higher-frequency bands (e.g., millimeter wave), massive Multiple Input Multiple Output (MIMO) systems, beamforming, and carrier aggregation. These technologies enable higher data throughput, improved spectral efficiency, and reduced latency, resulting in a better user experience and support for a wider range of applications. eMBB is just one of the use cases of 5G, along with other use cases like massive Machine-Type Communications (mMTC) and ultra-reliable and low-latency communications (URLLC). These different use cases cater to diverse requirements and applications, positioning 5G as a versatile technology capable of supporting a wide array of services across various industries.

Here are some additional details about eMBB and its significance in the context of 5G:

- Higher Data Rates: eMBB aims to deliver significantly higher data rates compared to previous mobile network generations. While 4G LTE networks typically provide download speeds of up to hundreds of megabits per second, 5G eMBB can achieve multi-gigabit per second download speeds, enabling faster downloads, seamless streaming, and quicker access to cloud-based applications and services.
- Reduced Latency: Latency refers to the time it takes for data to travel between devices and the network. 5G eMBB networks are designed to have significantly lower latency compared to 4G networks, with target latency values of a few milliseconds. This low latency is crucial for applications that require real-time responsiveness, such as autonomous vehicles, remote surgery, industrial automation, and gaming.
- Increased Network Capacity: eMBB is expected to address the growing demand for data-intensive applications and services. With higher frequency bands and advanced antenna technologies, 5G networks can support a larger number of devices simultaneously, increasing the network capacity and reducing congestion in densely populated areas or crowded events. This enables a smoother and more consistent user experience, even in high-traffic scenarios.
- Enhanced User Experience: The combination of higher data rates, reduced latency, and increased network capacity significantly improves the user experience. With eMBB, users can enjoy seamless streaming of high-resolution videos, immersive virtual and augmented reality experiences, and faster downloads and uploads. It also opens up possibilities for emerging applications and services that rely on high-speed, low-latency connectivity.
- Impact on Industries: eMBB has the potential to revolutionize various industries by enabling new services and applications. For example, in healthcare, 5G eMBB can facilitate remote patient monitoring, telemedicine, and real-time data exchange between healthcare professionals. In transportation, it can support connected vehicles, intelligent transportation systems, and smart infrastructure. In entertainment and media, eMBB can enable immersive media experiences, interactive gaming, and personalized content delivery.

Overall, eMBB is a key use case for 5G technology, delivering faster speeds, lower latency, and increased network capacity. It paves the way for innovative applications and services, transforming industries and enhancing the way we connect, communicate, and experience the digital world.

2.2.2.2 Ultra-Reliable Low-Latency Communications (URLLC)

URLLC stands for Ultra-Reliable and Low-Latency Communication and is designed to provide highly reliable and ultra-low latency communication capabilities, meeting the requirements of critical applications and services that demand near-instantaneous responsiveness and guaranteed reliability.
The key characteristics of URLLC are:

- Ultra-Reliable Communication: URLLC aims to provide exceptionally reliable communication links with extremely low failure rates. This is crucial for applications that require uninterrupted and error-free data transmission, such as industrial automation, mission-critical systems, autonomous vehicles, and remote surgery. URLLC enables reliable and deterministic connectivity, ensuring that critical data is delivered with utmost reliability.
- Low Latency: Latency refers to the delay or time delay between a data transmission and its reception. URLLC focuses on achieving extremely low latency, often in the sub-millisecond range. It ensures near real-time communication, enabling applications that require instantaneous responsiveness. Examples include industrial control systems, real-time monitoring and control, tactile internet applications, and virtual reality applications where any delay can significantly impact the user experience.
- Diverse Industry Applications: URLLC has far-reaching implications across various industries. In manufacturing, it can enable real-time monitoring and control of production lines, leading to improved efficiency and automation. In transportation, URLLC can support advanced driver assistance systems, vehicle-to-vehicle communication, and cooperative collision avoidance. In public safety and emergency services, it can facilitate instant communication and coordination during critical situations.

To achieve URLLC, 5G networks employ advanced technologies such as network slicing, edge computing, prioritized traffic management, and advanced error correction mechanisms. These technologies help optimize network performance, reduce latency, and ensure high reliability for critical communications. Overall, URLLC is a vital use case of 5G technology, enabling reliable and low-latency connectivity for critical applications. It has the potential to transform industries by unlocking new possibilities in automation, remote control, real-time monitoring, and safety-critical systems.

2.2.2.3 Massive Machine-Type Communications (mMTC)

mMTC stands for massive Machine-Type Communications and focuses on supporting massive connectivity for a large number of devices, particularly for Internet of Things (IoT) applications that involve massive deployment of sensors, actuators, and other connected devices.
The main characteristics of mMTC are:

- Massive Connectivity: mMTC is designed to handle a massive number of connected devices simultaneously. It aims to support tens of billions of IoT devices, enabling applications such as smart cities, industrial automation, agriculture monitoring, and logistics. These devices typically require low data rates but require long battery life and efficient use of network resources.
- Low Power Consumption: Many IoT devices are battery-powered and expected to operate for extended periods without frequent battery replacement or recharging. To address this requirement, mMTC focuses on optimizing power consumption by implementing power-saving techniques and efficient transmission protocols. This enables devices to have long battery life while staying connected to the network.

- Scalability: mMTC needs to be scalable to accommodate the exponential growth of connected devices. It involves designing network architectures and protocols that can handle the increasing number of devices efficiently without sacrificing performance or quality of service.
- Low Cost: IoT deployments often involve a large number of devices, and cost considerations play a significant role. mMTC aims to provide cost-effective solutions, both in terms of hardware and network infrastructure, to enable widespread adoption of IoT technologies across various industries.

To support mMTC, 5G networks employ technologies such as narrowband IoT (NB-IoT) and Cat-M1 (LTE-M), which are specifically designed to optimize IoT device connectivity. These technologies enable devices to connect to the network with low power consumption, extended coverage, and enhanced indoor penetration. Overall, mMTC is a crucial use case of 5G technology, focusing on enabling massive connectivity for IoT devices. It unlocks the potential for innovative applications and services in areas such as smart cities, industrial automation, healthcare monitoring, agriculture, and logistics, driving the growth of the IoT ecosystem.

2.2.3 5G Enabling Technologies

2.2.3.1 Network Functions Virtualization (NFV)

The goal of 5G is to cost-effectively deliver eMBB, URLLC, and mMTC. To meet the requirements for scale, throughput, latency, and reliability, 5G architecture has adopted Network Function Virtualization (NFV) and cloud implementation to streamline network and service deployment, operations, and management. It is a technology concept that is not specific to 5G but is often associated with it. NFV is an architectural approach that aims to virtualize and consolidate network functions traditionally performed by dedicated hardware appliances into software-based implementations running on standard servers or cloud infrastructure.

NFV allows network operators to manage and expand their network capabilities on demand using virtual, software based applications where physical boxes once stood in the network architecture. This makes it easier to load-balance, scale up and down, and move functions across distributed hardware resources. With continual updates, operators can keep things running on the latest software without interruption to their customers. This part of the training program will discuss NFV motivation and problem statement, general architecture, vision & approach, benefits & promises, as well as requirements and challenges.

In the context of 5G, NFV plays a significant role in enabling the flexibility, scalability, and efficient management of network resources. It allows network operators to deploy and manage network functions as virtualized software instances rather than relying on dedicated hardware devices for each function. This shift from hardware-based to software-based network functions brings several benefits, including:

- Agility and Scalability: NFV enables rapid deployment and scaling of network functions based on the dynamic demands of the network. Virtualized network functions (VNFs) can be instantiated, migrated, and scaled up or down more easily and quickly compared to traditional hardware-based solutions. VNFs can be, in principle, VM-based and container-based. In this document, cloud native /container-based will be referred to as CNFs and as VNFs when referred to VM-based. This flexibility allows network operators to respond to changing traffic patterns and service requirements more efficiently.

- Cost Reduction: By virtualizing network functions, NFV helps reduce capital and operational expenditures. It eliminates the need for specialized hardware appliances for each network function, leading to cost savings in equipment, maintenance, and power consumption. Additionally, NFV allows for better resource utilization and sharing, optimizing infrastructure efficiency and reducing the overall network footprint.
- Service Innovation: NFV enables the introduction and deployment of new services more rapidly. With the decoupling of network functions from dedicated hardware, network operators can introduce and test new services and applications more easily through software-based VNFs. This promotes service innovation and accelerates time-to-market for new offerings.
- Simplified Management and Orchestration: NFV provides a centralized management and orchestration framework for virtualized network functions. This allows operators to automate resource allocation, scaling, and network service chaining, improving operational efficiency and reducing manual configuration tasks. It also facilitates dynamic service chaining, enabling the creation of customized service chains based on specific application requirements.

Here are the key components and steps involved in the functioning of NFV:

- Virtualized Network Functions (VNFs): Network functions such as firewalls, routers, load balancers, and intrusion detection systems are virtualized and implemented as software-based instances. Each network function becomes a VNF that can run on general-purpose servers or cloud platforms.
- NFV Infrastructure (NFVI): NFVI provides the underlying hardware and software resources to support the deployment and execution of VNFs. It typically consists of servers, storage, networking infrastructure, and virtualization technologies such as hypervisors or containers.
- Virtualization Technologies: NFV leverages virtualization technologies, such as hypervisors or containers, to create virtual instances of servers and network resources. These virtualization technologies allow multiple VNFs to run concurrently on shared hardware resources, providing isolation and resource management.
- Management and Orchestration (MANO): MANO is a key component of NFV that provides management and orchestration functions for VNFs and NFVI. It includes three main elements: a) Virtualized Infrastructure Manager (VIM): VIM manages the underlying NFVI resources, including server and network virtualization, resource allocation, and monitoring. b) VNF Manager (VNFM): VNFM is responsible for managing the lifecycle of VNFs. It handles tasks such as VNF instantiation, scaling, monitoring, and termination. c) NFV Orchestrator (NFVO): NFVO orchestrates and manages the overall NFV infrastructure. It coordinates the allocation and chaining of VNFs, automates service deployment, and handles service-level policies and optimization.
- Service Chaining: NFV enables flexible service chaining, where multiple VNFs are interconnected to create a service path for network traffic. Service chaining allows the customization and configuration of specific network service paths based on application requirements.

- Automation and Orchestration: NFV automates various network management tasks, including service deployment, scaling, and configuration changes. Orchestration systems leverage policy-driven automation to dynamically allocate and manage network resources based on real-time demands.

By implementing NFV, network operators can achieve greater agility, scalability, and cost efficiency. They can deploy and manage network functions as software instances, reducing the reliance on dedicated hardware and enabling rapid service deployment and customization. NFV brings benefits such as improved resource utilization, simplified management, and faster innovation in delivering network services. Overall, NFV in 5G enables a more flexible, scalable, and cost-effective network infrastructure. It helps network operators adapt to the evolving demands of 5G services and applications by virtualizing network functions, leading to improved agility, reduced costs, and faster service innovation.

2.2.3.2 Software-Defined Networking (SDN)

In the context of 5G, SDN stands for Software-Defined Networking. SDN is an architectural approach that separates the control plane and data plane in a network, allowing for centralized control and programmability of the network infrastructure. It enables the dynamic management and configuration of network resources to meet the requirements of 5G networks. In 5G, SDN plays a crucial role in providing network flexibility, scalability, and efficiency. It allows network operators to manage and control the 5G network infrastructure in a more agile and automated manner. Some key benefits of SDN in 5G include:

- Network Programmability: SDN allows operators to programmatically control and configure the network, enabling the creation of customized network services and policies tailored to specific requirements.
- Dynamic Resource Allocation: SDN enables dynamic allocation of network resources based on the demand and traffic conditions. This flexibility is essential for handling the diverse requirements of 5G applications, such as ultra-low latency for autonomous vehicles or massive connectivity for IoT devices.
- Network Slicing: SDN facilitates network slicing, which involves dividing a physical network infrastructure into multiple virtual networks. Each network slice can be customized to meet the specific needs of different applications or user groups, ensuring efficient resource utilization and isolation between services.
- Centralized Management: SDN provides a centralized control plane, allowing network operators to manage and monitor the entire network from a single point. This centralized management simplifies network operations, enhances visibility, and enables faster troubleshooting and configuration changes.
- Service Orchestration: SDN enables the orchestration of network services and resources, allowing for the automated deployment and provisioning of services in a 5G network. This automation reduces manual configuration efforts, accelerates service delivery, and improves overall operational efficiency.

SDN enables on-demand resource allocation, self-service provisioning, and truly virtualized networking and secures cloud services. Thus, the static network can evolve into an extensible provider-independent service delivery platform capable of quickly responding to changing business, end-user, and market needs, greatly simplifying the net's design and operation.

In this part we discuss basics of SDN as well as OpenFlow, a standard SDN communication protocol that allows the SDN controller to directly interact with the forwarding plane of network devices such as switches and routers, both physical and virtual, so it can better adapt to changing business requirements. It defines the communication between the control plane and the forwarding plane in an SDN-enabled network. OpenFlow allows for the centralized control and programmability of network switches and routers, providing a standardized interface for managing and directing network traffic. With OpenFlow, network switches and routers are designed to have a separation between the data plane (where packets are forwarded) and the control plane (where decisions about packet forwarding are made). The control plane resides in an SDN controller, which acts as a centralized intelligence for the network. The OpenFlow protocol is used to communicate between the controller and the switches, allowing the controller to manage and control the forwarding behavior of the switches.

When an OpenFlow-enabled switch receives a packet for which it has no specific forwarding instructions, it sends the packet to the SDN controller. The controller can then analyze the packet, determine the appropriate forwarding actions, and send instructions back to the switch through the OpenFlow protocol. These instructions can include forwarding the packet to a specific port, modifying the packet header, or applying specific traffic management policies. OpenFlow provides several benefits, including:

- Programmability: OpenFlow allows network administrators or applications to define and modify the behavior of network switches dynamically. It enables the implementation of custom network policies and protocols without requiring changes to individual network devices.
- Centralized Control: OpenFlow enables a centralized control plane, where network-wide decisions can be made and implemented uniformly across the network. This centralized control simplifies network management, configuration, and troubleshooting.
- Network Visibility: OpenFlow provides detailed visibility into network traffic by allowing the controller to monitor packet flows and collect statistics from the switches. This visibility facilitates network monitoring, traffic analysis, and optimization.
- Innovation and Experimentation: OpenFlow's programmability and openness encourage innovation and experimentation in networking. It enables the development and deployment of new network services, protocols, and applications in a flexible and controlled manner.

OpenFlow has been instrumental in advancing the concepts of SDN and has gained significant traction in both research and industry communities. It has been widely adopted as a standard protocol for implementing SDN and has opened up new possibilities for network management, control, and innovation.

2.2.3.3 5G KPIs and performance evolution

In this chapter, the important aspects of 5G Key Performance Indicators (KPIs) are presented. These metrics represent the dynamic capabilities of 5G networks and show their performance evolution. 5G technology is driven by eight specification requirements:

- Availability 99.999%.

- Coverage 100%.
- Reduction in network energy usage of 90%.
- Up to 10-year battery life for low power IoT devices.
- Up to 100x number of connected devices per unit area (compared with 4G LTE).
- 1000x bandwidth per unit area.
- Latency of 1 millisecond.
- Up to 10Gbps data rate. Equal to 10 to 100x improvement over 4G and 4.5G networks.

Examining the 5G KPIs and how they have evolved from previous generation networks, it can be derived that there are enhanced data speeds, lower latency, wider coverage, and bigger capabilities for connected devices. These advancements play a major role in the communication performed every day, as well as in the applications and services that can be developed in the future.

2.2.3.4 Network Slicing

Network slicing is a key feature of 5G networks that enables the creation of multiple virtual networks on a shared physical infrastructure. It allows network operators to partition the network resources into independent, isolated slices, each tailored to meet specific requirements of different use cases, services, or customer groups. Each network slice in 5G represents a logically separate network with its own dedicated and optimized set of resources, including radio access, core network, and transport network resources. These slices can be dynamically allocated and configured to adapt to the specific needs of different applications, industries, or user groups. Here are some key aspects and benefits of network slicing in 5G:

- Customized Service Capabilities: Network slicing enables the creation of dedicated slices with specific capabilities to meet the diverse requirements of different use cases. For example, a network slice can be optimized for low-latency applications like autonomous vehicles, while another slice can be tailored for massive machine-type communications (mMTC) for IoT devices.
- Resource Efficiency: Network slicing allows efficient resource utilization by allocating resources on-demand and dynamically scaling them based on the requirements of each slice. This flexibility ensures that network resources are efficiently allocated to meet the needs of different applications, avoiding overprovisioning or underutilization.
- Isolation and Security: Each network slice is isolated from other slices, providing enhanced security and privacy. This isolation prevents interference and ensures that resources allocated to one slice do not affect the performance or security of other slices.
- Service Differentiation: Network slicing enables service providers to offer differentiated services to their customers. They can customize and optimize slices based on the specific requirements of industries or user groups, providing tailored services with unique characteristics, such as bandwidth, latency, or quality of service (QoS).

- Faster Service Deployment: Network slicing facilitates rapid service deployment by allowing service providers to quickly create and provision new slices as needed. This flexibility and agility enable faster time-to-market for new applications and services.
- Network Efficiency: Network slicing improves overall network efficiency by allowing different slices to share the same physical infrastructure. By leveraging the same underlying resources, such as radio spectrum or network equipment, network operators can maximize resource utilization and reduce operational costs.

Network slicing is a fundamental concept in 5G that unlocks the potential for customized services, efficient resource allocation, and improved network performance. It plays a crucial role in enabling the diverse range of applications and use cases that 5G networks are designed to support.

2.2.3.5 5G NR

5G New Radio (NR) is the wireless air interface technology developed for 5G mobile networks. It defines the specifications and standards for the radio access technology in 5G networks. 5G NR is designed to deliver significantly faster speeds, lower latency, improved capacity, and better overall performance compared to previous generations of wireless technologies. 5G NR works by utilizing advanced technologies and techniques to deliver high-speed, low-latency, and reliable wireless communication. Here is a simplified overview of how 5G NR works:

- Radio Access Network (RAN): The 5G NR system includes the Radio Access Network, which consists of base stations (gNodeBs) deployed in the network. The gNodeBs communicate wirelessly with user equipment (UE) such as smartphones, tablets, or IoT devices.
- Multiple Access Techniques: 5G NR employs multiple access techniques to enable simultaneous communication with multiple devices. Orthogonal Frequency Division Multiple Access (OFDMA) is used for downlink transmission (from the gNodeB to UEs), allowing multiple UEs to share the same frequency and time resources. Similarly, Uplink transmission (from UEs to the gNodeB) utilizes Single Carrier Frequency Division Multiple Access (SC-FDMA) to ensure efficient resource utilization.
- Frequency Bands: 5G NR operates in both sub-6 GHz frequency bands and high-frequency mmWave bands. The sub-6 GHz bands provide broader coverage and better penetration, while mmWave bands offer higher capacity and faster data rates. The selection of frequency bands depends on factors such as coverage requirements, available spectrum, and use case considerations.
- Massive MIMO: 5G NR employs advanced antenna technologies, such as Massive Multiple-Input Multiple-Output (MIMO), to improve capacity, coverage, and spectral efficiency. Massive MIMO utilizes a large number of antennas at the gNodeB to serve multiple UEs simultaneously, increasing overall system capacity and enhancing signal quality.
- Beamforming: Beamforming is a technique used in 5G NR to focus the radio signal in specific directions, improving signal strength and quality. By steering the transmission beam towards the intended UE, beamforming enhances coverage, increases throughput, and reduces interference.

- Subcarrier and Frame Structure: 5G NR divides the available frequency spectrum into subcarriers, which are used as individual channels for transmitting data. Each subcarrier has a specific frequency and carries data in the form of symbols. These subcarriers are organized into time frames, with each frame consisting of multiple slots. The subcarrier and frame structure of 5G NR is designed to support flexible and efficient transmission of data.
- Dynamic Spectrum Sharing: 5G NR supports dynamic spectrum sharing (DSS), which allows for the simultaneous operation of 4G LTE and 5G NR in the same frequency band. DSS enables a smooth transition from 4G to 5G by dynamically allocating spectrum resources between the two technologies based on demand. This helps to maximize spectrum utilization and ensures backward compatibility with existing networks.
- Dual Connectivity: 5G NR introduces the concept of dual connectivity, which allows a UE to simultaneously connect to multiple gNodeBs. In dual connectivity, a UE maintains a primary connection with one gNodeB while establishing a secondary connection with another gNodeB. This enables the UE to benefit from the combined resources and capacities of both gNodeBs, resulting in improved data rates and coverage.
- Control and User Plane Separation: Similar to SDN principles, 5G NR separates the control plane and user plane functionalities. The control plane handles tasks such as network management, signaling, and policy control, while the user plane is responsible for the actual data transmission. This separation enhances network flexibility, scalability, and enables more efficient resource allocation.
- Quality of Service (QoS) Differentiation: 5G NR provides enhanced QoS differentiation, allowing operators to prioritize certain types of traffic over others. This enables the provision of different service levels based on the specific requirements of applications or users. For example, critical services like emergency communications or autonomous vehicles can be given higher priority in terms of network resources and latency guarantees.

2.2.3.6 Cloud Native

Cloud native paradigm has recently arrived to 5G, affecting to the way in which infrastructure is managed and applications are developed. This section presents this paradigm, which the Cloud Native Computing Foundation (CNCF) defines it as a set of state-of-the-art technologies that "empower organizations to build and run scalable applications in modern, dynamic environments such as public, private, and hybrid clouds. Containers, service meshes, microservices, immutable infrastructure, and declarative APIs exemplify this approach. These techniques enable loosely coupled systems that are resilient, manageable, and observable. Combined with robust automation, they allow engineers to make high-impact changes frequently and predictably with minimal toil" [1]. This paradigm was adopted by cloud and IT vendors before starting to being embraced by the 5G industry, requiring the adaptation of different areas such as [2]:

- Application design and development.

- Technology and infrastructure.
- Management and orchestration.
- Processes and ways of working.

Regarding applications, the cloud native paradigm is based on microservices, an architectural style that structures applications as a set of loosely-coupled services, that can be maintained and deployed independently. Applications, like those from the 5G Core network or related to network tasks (VNFs such as firewalls, virus scanners, intrusion detection systems, etc.) are expected to be delivered as containers, although compatibility with virtual machine-based services and legacy network hardware (specialized devices) needs to be maintained [3], as not all VNFs can be transformed to be cloud native. Examples of cloud native 5G Core can be seen, from commercial (e.g., Nokia [4], Ericsson [5]) to open-source solutions (e.g., open5gs [6], OAI-5G CN [7]).

This change in the way of designing and deploying applications forces a change in the infrastructure and supporting technologies. Platforms based on Kubernetes (K8s) are the de facto standard for managing containers, making effective use of the underlying hardware resources. It brings several benefits such as reduction of vendor lock-in, enhanced scalability and faster application deployment and upgrading times with respect to previous paradigms. K8s provides a baseline platform for managing containers that needs to be enhanced and tailored with supporting cloud native technologies, extending its monitoring (e.g., Prometheus), service mesh (e.g., Istio), network plugins (e.g., Calico), storage (e.g., OpenEBS) or service discovery (e.g., CoreDNS) features, among others. Also, as Kubernetes is not designed with 5G in mind, a dedicated Management and Orchestration is needed on top. That is the role of ETSI MANO, which defines the specifications related to NFV orchestration and management, which extends from Mobile Edge Environments (MEC) to cloud infrastructure, the provision of network slices and the lifecycle orchestration of VNFs deployed on top. Recently, the embracement of the cloud native paradigm forced updating the specifications, and state-of-the-art MANO solutions are already supporting the coexistence between VNFs and CNFs, deployed on top of OpenStack and Kubernetes-based solutions, respectively. It is expected that the evolution of this framework is Kubernetes-centric [8], in which legacy VNFs can be supported with dedicated K8s plugins, not only as proof of concepts but as standards (see Figure 1). Applications development, integrations and deployment in infrastructure can be boosted in this paradigm by implementing DevOps methodologies and CI/CD methods, supported with dedicated tools. Being more agile in the way of deploying and updating applications and services is key in the sector, as technology evolves faster and faster.

The course will include introductory content to cloud native, containers, Docker, Kubernetes and related technologies, open-source 5G Core and MANO solutions; as well as best practices for designing, developing and implementing applications (considering microservices patterns and DevOps methodologies).

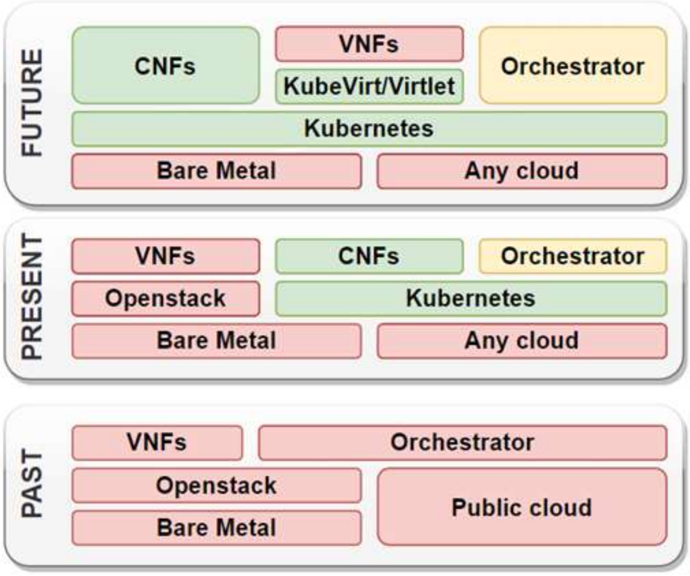

Figure 1. Past, current and expected evolution of MANO

2.2.4 5G SBA

Prior to LTE, cellular core networks needed specialized telecom hardware and specialized telecom protocols. The initial steps toward virtualization were taken using LTE vEPC. The 5G System has embraced Service-Based Architecture (SBA), a development of this strategy.

5G Service Based Architecture (SBA) is a next-generation architectural framework that aims to enhance the flexibility, scalability, and agility of 5G networks. It introduces a service-oriented approach, shifting from traditional network-centric models to a more open and modular architecture. With 5G SBA, network functions are decomposed into smaller, independent services, allowing for easier customization, deployment, and integration of new applications and services. The adoption of SBA brings several advantages to 5G networks. It enhances agility and innovation by enabling faster deployment of new services and functionalities. The service-oriented approach also promotes scalability and efficiency, as operators can scale specific services independently without affecting the entire network. Additionally, SBA facilitates openness and interaction with the network by allowing third-party developers to integrate their applications and services into the network ecosystem through the utilisation of standardized Application Programming Interfaces (APIs).

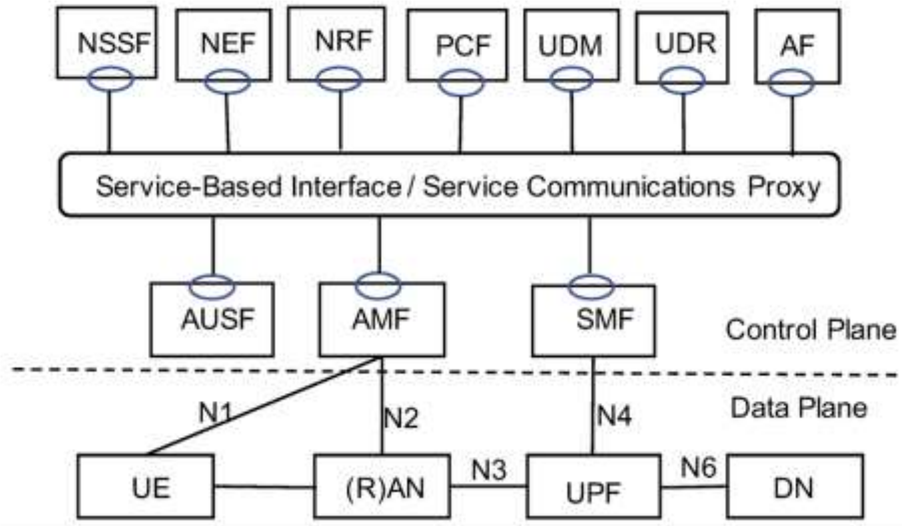

Figure 2. 5G Service-Based Architecture

The software industry has been using service-based architecture to increase the modularity of products. Communication services may be divided up into software products. By using this strategy, the developers will be able to combine services from several suppliers to create a single product. Service-oriented architecture, or SOA, is a method of software design in which services are delivered to other components using a network communication protocol. In order to cut costs and share data among several data centers, 5GC makes use of the cloud computing and virtualization concepts.

A group of Network Functions (NFs) in SBA offer services to other approved NFs. All that these NFs are is software implementations running on commercially available hardware, maybe in the cloud. One or more services may be provided by an NF. Client-server architecture and clearly specified APIs are used to interface NFs. API calls on a logically shared service bus have taken the role of conventional telecom signaling messages.

More specifically:

AMF: The user equipment transmits all control- and session-related data to the 5G core Access and Mobility Management Function. It is in charge of managing responsibilities connected to connections and mobility. It has a N11 interface that connects to the SMF. Many AMF instances can be found in a mobile network, and each one is given a unique identifier via GUAMI (Globally Unique AMF Identifier). It uses integrity protection and NAS (Non-Access Stratum) Ciphering techniques. Lawful intercept, access authentication, and authorization are under its purview. Additionally, it manages the security context.

SMF: It is the essential component of the 5G core network architecture and is in charge of producing, updating, and deleting PDUs (Protocol data units), as well as interfacing with the decoupled data plane. With the help of the user plane function, it controls the session context. SMF carries out a variety of tasks, such as UE IP address management and allocation, interface termination, downlink data notifications, charging data collecting, legal intercept, roaming capabilities, etc.

UPF: It serves as the cornerstone of the 3GPP 5G Core Architecture. It illustrates the control and user plane separation's (CUPS) data plane evolution. UPF performs a variety of tasks for the user plane, such as handling QoS for the user plane, traffic accounting and reporting, packet routing and forwarding, packet inspection, and legal user plane intercept.

AUSF: The user equipment authentication is carried out through an authentication server function. It is in a private network at home. It decides whether to employ UE Authentication for data and keying material authentication, such as 5G AKA and EAP-AKA. It facilitates 5G security objectives.

NSSF: AMF chooses the Network Slice Instances that will service a certain device using NSSF. The Network Slice Instances are chosen after determining the NSSAI, or permitted network slice selection assistance information. In the course of UE registration and PDU formation, it can retrieve NRF, NSI ID, and target AMFs.

NEF: The Network Exposure function makes it simple and secure for developers to access network services. The services and capabilities offered by 3GPP network functions can be safely exposed using this function.

NRF: The network Repository function serves as the operator's network's central repository for all 5G network functions. Using common APIs, NRF enables 5G NFs to register with one other and find one another. It keeps track of the profiles of the NF instances that are accessible and the services they provide in the 5G core network. Enables NF instances to keep track of each other's state.

PCF: It backs up the uniform policy framework that controls how networks behave. It offers guidelines for their enforcement. The subscription data is acquired for this purpose via the Unified data management function. It offers policy guidelines for the control plane's network slicing, roaming, and mobility management operations.

UDM: It is a centralized method of managing network utilization information. It was created with 5G technologies in mind and is cloud-native. UDM performs comparable tasks to HSS (Home Subscriber Service). This function creates the 5G AKA authentication vectors, handles user identification, and keeps the long-term security credentials required in AKA authentication. It keeps records of subscriptions.

AF: AF exposes the Application layer for interacting with 5G network resources. It asks for pricing control and/or dynamic policies. It carries out actions like requesting resources from the Network Exposure Function. It communicates with PCF to control policies, route application traffic, expose services to end users, etc.

DN: The 3GPP 5G Architecture is connected to the data network known as DN. Operator services, internet access, or other services might be included.

The interfaces between network functions and APIs are loosely connected, allowing for independent development and deployment of each NF. It adds scalability since new instances of NFs may be formed or destroyed dynamically in minutes rather than installing physical nodes, which could take some time. Monitoring systems can recognize a failure of an instance or a physical node and spin up additional instances. Network slicing is made possible by SBA's architecture. A single physical network can support several logical networks. In SBA, network operations are made accessible through clearly defined Service based Interfaces. Existing NFs won't be impacted when new ones are introduced. It is implemented as containers orchestrated by Kubernetes, enabling the core to run on infrastructure, letting new software vendors plug-and-play their NFs for the best-of-breed approach, enabling network slicing with dynamic and efficient resource utilization, streamlining operations using Application programming interfaces (APIs), and facilitating the seamless integration of third-party vendors' applications with the core network.

2.2.4.1 Openness of the Network

With the aim to support fragmentation within the network and promote more dynamic 5G services, 3GPP defines an "open" core, in which all core network functions have been virtualized. Openness in the context of 5G networks refers to the principle of providing open interfaces through standardised APIs that enable interoperability and facilitate "collaboration" among different entities within the ecosystem. APIs play a crucial role in the concept of openness by defining a set of rules and protocols that allow different software components, services, and applications to communicate and interact with each other. This endeavor shapes a new and dynamic ecosystem in mobile networks from both the technology and marketing perspectives. External third parties with permission, such as industries, platform owners, and application developers may use those standardised APIs for building network-aware (5G-enabled) applications, which can establish a bi-directional communication with the 5GC.

2.2.4.2 NEF

Introduction

In 5G technology, the Network Exposure Function (NEF) plays a crucial role by providing standard APIs, based on OpenAPI 3.0.0 standard to application developers. By utilizing standardized APIs, developers have the capability to interact with various elements of the 5G ecosystem, including network functions, data services, devices, and network slicing. This opens up the possibility of creating a wide range of applications, including IoT devices, augmented reality (AR) and virtual reality (VR) experiences, autonomous vehicles, and a plethora of other possibilities.

One of the key benefits of NEF's API exposure is that it effectively hides the complexity of the underlying network from developers. By providing standardized interfaces, the NEF simplifies the interaction between applications and the network, allowing developers to focus on building their applications without needing in-depth knowledge of the mobile network's functionalities. As depicted in Figure 3, NEF lays on top of the SBA, providing secure and controlled network access for external applications. It establishes a layer of protection that ensures only authorized applications can access and utilize network resources, enhancing network security. Furthermore, the NEF facilitates the monetization of network capabilities. By exposing specific network APIs required by certain AFs, the NEF enables network operators to create new business opportunities.

The exposure of those specific network functionalities and the definition of interfaces is led by 3GPP standardization body. However, these APIs are not readily suitable for most application developers who lack in-depth knowledge of the telecom network. To bridge this gap, a translation layer has been introduced to convert service APIs into a format that can be exposed to enterprise app developers. To facilitate the development and adoption of these APIs, a rapidly growing industry alliance called CAMARA has been established as an open-source project under the Linux Foundation. CAMARA collaborates with the GSMA Operator Platform Group to align API requirements and publish API definitions and documentation for developers. This collaborative effort aims to make applications globally available. Many leading service providers, vendors, and HCPs (Hosting and Cloud Providers) have already become members of this alliance.

In summary, the NEF in 5G technology empowers developers by providing standardized APIs, simplifying network interaction. Its role in bridging technical network features with business use cases enhances the flexibility, accessibility, and commercial viability of the 5G ecosystem.

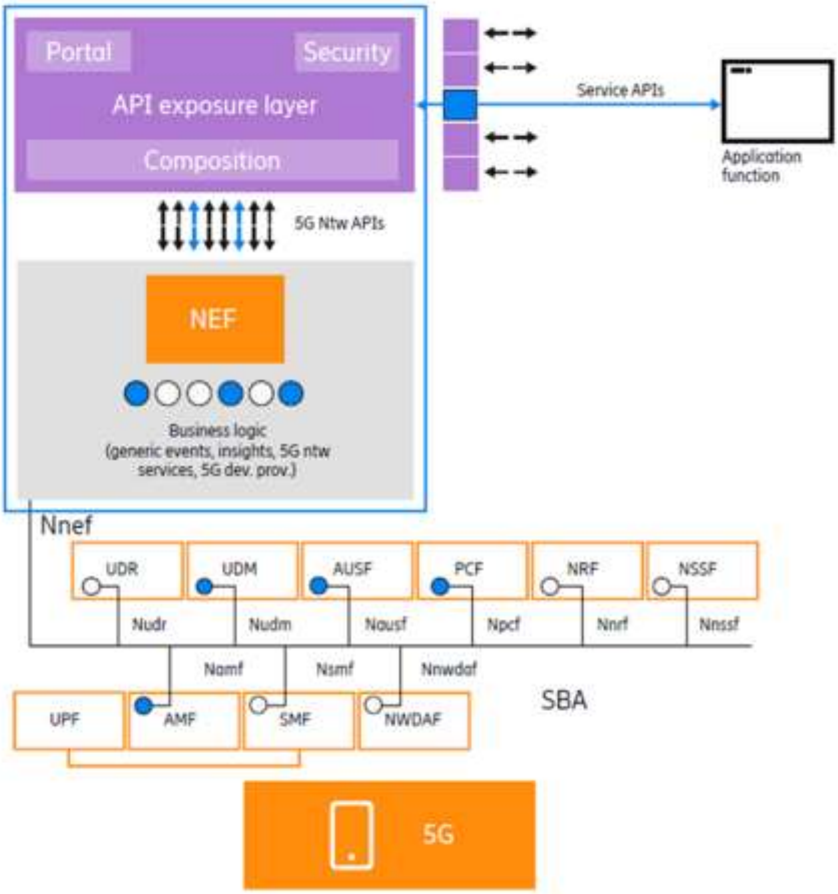

Figure 3. Network Exposure Function in 5G SBA [9]

Services

The NEF consists of various services, including Monitoring services, Policy and Charging services, Application Provisioning services, Analytics services, and IoT specific services. This section provides a description and categorization of these services at the service level. The objective is to establish a connection between the standardized APIs and the corresponding capabilities of the 5G network, as defined by 3GPP, and their potential applications in use cases.
Within the 5G network, a device goes through various stages in terms of connectivity, availability, and location awareness. This type of information can be valuable for external applications that are 5G-enabled. For example, an

application may require knowledge of its users' locations within an industrial zone in order to make authorization decisions for personnel.
The **Monitoring Event API** enables an external application to monitor the lifecycle of UEs within a 5G system. This API covers events such as location reporting, UE reachability, loss of connectivity, and more.
The NEF also exposes services that are related to policy and charging capabilities that the 5GC offers.

Policy Control and Charging (PCC) system is responsible for providing these functionalities within 3GPP. PCC enables mobile operators to ensure better service-aware QoS and charging control. Typically, in wireless networks where the bandwidth and capacity are of major importance, it is essential to utilize the radio resources efficiently. Furthermore, not only the network but different services themselves require divergent QoS levels, which is necessary to transport the data. Additionally, some applications may know the amount of data they need to exchange with a number of devices (UEs) in a geographical area. For example, an IoT agriculture application may need to exchange some weather forecast information with one hundred sensors in the night time. As a result, the IoT application can interact with the network and provide this information, allowing the network to better schedule radio resources.

IoT applications / Industry 4.0 are often characterized by the fact that they rarely need to receive data but periodically send a heartbeat message to a server to indicate that the device is active and able to receive. Rather than sending heartbeat messages to the server, the UE can listen on a Short Message Service (SMS) Port or Non-IP connection for a short trigger, or wake up message, requesting that the UE application should contact the server. To achieve this type of communication between the UE and the application in the most optimal way, NEF exposes APIs that allow the external application to exchange data with the UE via to different non-IP data delivery methods: SMS and Non-Access Stratum (NAS) based Non-IP Data Delivery (NIDD). This kind of data delivery takes place over the control plane since the data packets to be exchanged are so small that a potential use of the IP protocol would impose an unmanageable overhead. Since SMS messages are stored in the network when the recipient UE is sleeping, SMS triggering is particularly useful for initiating contact with UEs that sleep for long stretches of time. In order to initiate this type of communications, the network needs to reach the sleeping devices through the NEF.
Besides the fact that the 5G network exposes its capabilities through the NEF, applications can also assist the network by providing application-related information. For instance, in V2X communications, a vehicle can provide the destination and path of a moving UE to the 5G network, enabling more efficient handling of handovers. The 3GPP core network offers several services that are particularly useful for applications used by UEs. These APIs allow applications to update parameters already configured in the 5GC, inform the network about maximum acceptable delay and availability requirements, check for the status of Enhanced Coverage Restriction Control, provision UE radio capability information, provide service parameters for proximity-based services, configure a 5G virtual Private Network, choose whether to share location information with external applications, and influence traffic routing in the network.
In the context of industrial automation, communication standards have been defined for future factories, covering various application areas such as motion control, wireless sensor networks, augmented reality, process automation, factory floor connectivity, and inbound logistics for manufacturing. Data analytics plays a crucial role in these use cases by ensuring network availability and enabling predictive maintenance functionalities. Analytics can also

facilitate efficient management of QoS, traffic steering, and mobility. In terms of QoS management, 5G networks introduced the concept of network prediction, where the 5GS can notify an application for autonomous vehicles about potential downgrades in ongoing communication QoS due to anticipated network conditions, radio technology changes, or radio congestion. Consequently, analytics significantly contribute to aligning the 5GC network with applications, enhancing service availability and quality. The Network Data Analytics Function (NWDAF) acts as a network-aware function, gathering events from various 5GC network components for further analysis and the relevant API is the Analytics Exposure API.

2.2.4.2.1 NEF Emulator

The NEF Emulator is an open experimentation framework that implements NEF APIs on top of a simulated environment, to help evaluate the service APIs that are now available. It consists of three layers: the network layer, the exposure layer, and the management layer. In the network layer the emulated environment helps users to create scenarios that replicate the fundamental elements of a 5G network. For example, service consumers (application developers) can achieve user mobility via predefined paths in the simulated environment. The emulator is built using the RESTful APIs across the layers which means most of the simulator's components (e.g., cells, UEs, Monitoring Event API, OAuth2 token etc.) are available as APIs, thus it enables third party applications, proprietary equipment, AI/ML services to interact with the components of each layer. On top of that, NEF emulator's compliance with 3GPP makes it interoperable with other solutions. For example, the functionalities of the management and the exposure layer can be easily integrated with a production-ready 5G Core SBA.

In the exposure layer, the MonitoringEvent API and the AsSessionWithQoS API are the two APIs. They allow network applications to access monitoring information about the UE's lifecycle, and to set up a session with the desired level of quality of service (QoS) for a given IP traffic flow. The MonitoringEvent API supports location reporting and connectivity events, such as the loss of connectivity and reachability events.

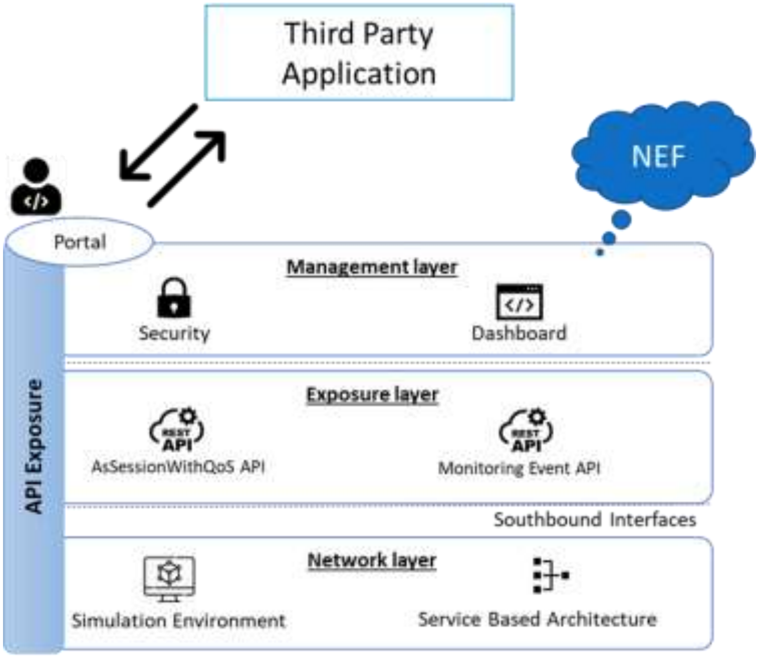

Figure 4. NEF Emulator Architecture

Furthermore, a number of security features are built into the NEF design, such as server-side authentication, integrity, replay and confidentiality protection of the NEF-AF interface (N33) based on TLS protocol. Additionally, API requests from external applications are authorized using OAuth-based authorisation. NEF Emulator can be used as a standalone component or using CAPIF, thus it can operate in a variety of deployment scenarios.

2.2.4.3 CAPIF

The Common API Framework (CAPIF) is a standardized way for managing the utilization of 5G network capabilities (e.g., NEF) in a consistent manner. CAPIF adds an extra layer of protection for the network infrastructure by preventing direct access from untrusted sources. It simplifies service discovery, enables auditing of services, facilitates the onboarding of relevant entities, and ensures the secure delivery of these capabilities.

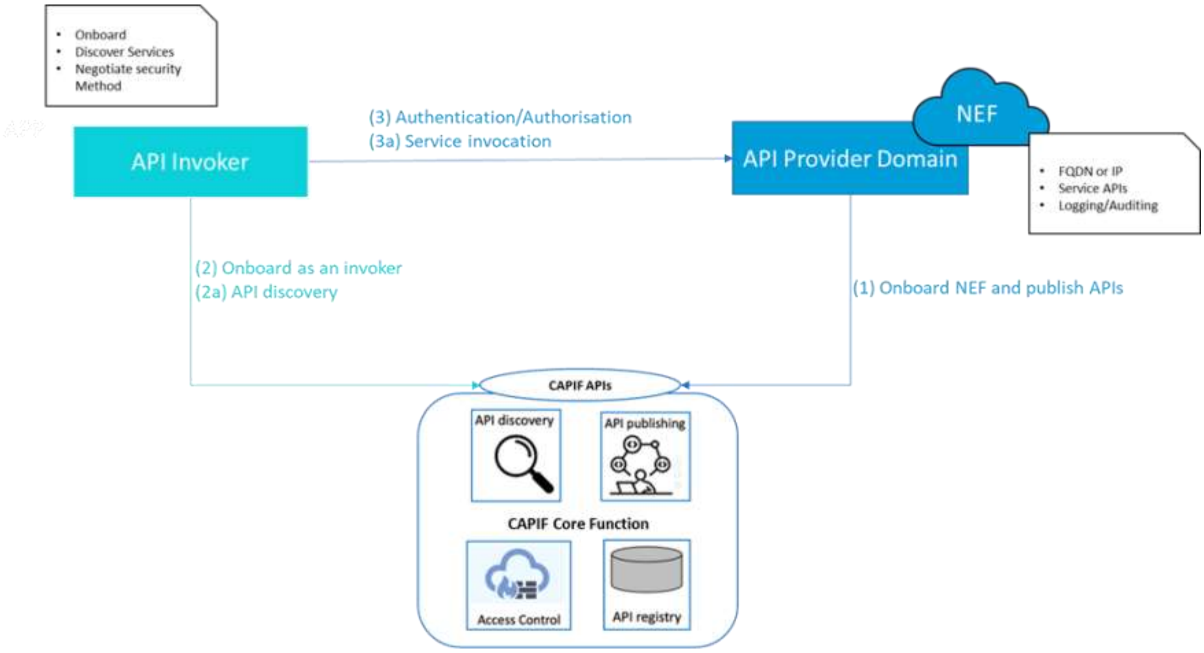

Figure 5. CAPIF Architecture

The CAPIF architecture consists of the following functional entities: CAPIF Core Function (CCF), API Invokers, and the API provider domain, which includes the API Exposing Function (AEF), API Publishing Function (APF), and API Management Function (AMF). The architectural model, adapted from [3GPP TS 23.222], is illustrated in Figure 5. Here is a brief description of each entity:

- CCF: Acts as an orchestrator, managing the interaction between service consumers (external apps) and service providers (e.g., NEF, other network APIs). The CCF is responsible for authenticating API invokers, authorizing their access to available service APIs, and monitoring service API invocations. Additionally, CCF onboards and authenticates the service providers.
- API Invoker: Represents the external app that utilizes CAPIF to consume service APIs. The API Invoker provides necessary authentication information to the CCF, discovers available service APIs, and invokes them.
- AEF: Responsible for exposing the service APIs. After authorizing API invokers, the AEF provides direct communication entry points to the service APIs. It may also authorize API invokers and record invocations in log files that will forward to the CCF..
- APF: Responsible for publishing service APIs to the CCF, enabling API Invokers to discover them.
- AMF: Provides administrative capabilities to the API provider domain. These include auditing service API invocation logs received from the CCF, onboarding/offboarding new API invokers, and monitoring the status of service APIs.

As presented in Figure 5, a simplified workaround for exposing network capabilities to external applications through CAPIF includes the following steps:

- In the API Provider Domain, the NEF authenticates with CCF and after the security negotiation it is onboard in the CCF. As part of the successful onboarding, NEF assumes the role of APF and publishes its APIs to the CCF. Finally, NEF is ready to expose the services to external applications (playing the role of AEF) under CCF's supervision.
- On the other hand, external applications (API Invokers) follow a similar signaling flow to authenticate and eventually onboard into CCF. Upon successful onboarding, API invokers can discover the available APIs.
- Finally, invokers can consume the discovered APIs after successful authorisation with the API Provider (i.e., Invokers send http requests to the domain name or IP of the provider, obtained from step 2).

2.2.4.4 NWDAF

With the rapid expansion of connected devices, increasing traffic volumes, and diverse service requirements, traditional approaches towards the management of the network are no longer sufficient. This necessitates the introduction of a component to address the evolving demands of the 5G and B5G ecosystem, that will be driven by the growing need for efficient data analysis and decision-making processes.

Thus, in the dynamic and at the same time complex ecosystem of 5G technology, the Network Data Analytics Function (NWDAF) emerges as a crucial enabler for network operators and service providers, offering valuable insights derived from data analytics. 3GPP TS 29.520 defines the interfaces from the service-based architecture that NWDAF utilises to collect data by subscription or request model from other network functions as well from operations, administration, and maintenance (OAM) systems deployed at the 5G Core, Cloud, and Edge of the network. By collecting and processing data from multiple sources, it provides a holistic view of the network's performance, users' behaviour, and services' patterns. This holistic view for the aforementioned characteristics empowers the operators to optimize resources' allocation, enhance the efficiency and automation of the network and deliver enhanced user experiences.

Regarding the relation between NWDAF and NFs we can identify two discrete functionalities. As depicted in Figure 6, NWDAF can either provide network analysis data to other NFs, referred to as analytics information, or NFs can request data delivery by subscribing to NWDAF, known as events subscription through the Nnwdaf interface. Nnwdaf represents the service-based interface of NWDAF, while Nnf represents the service-based interface of any NF within the 5G Core network.

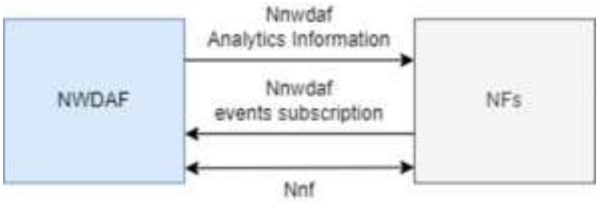

Figure 6. Data collection and network data analytics exposure architecture

When specific analytics can be performed independently by a 5G Core NF, a dedicated NWDAF can be co-located within that NF. In such cases, the data used by the NF for analytics must be accessible to enable centralized deployment of the NWDAF. 5GS NFs and OAM framework decide then on how to use the data analytics supplied by NWDAF so as to improve the performance of the network, as illustrated in Figure 7. As an outcome a NF can make the data analytics available to any consumer NF via a service-based interface.

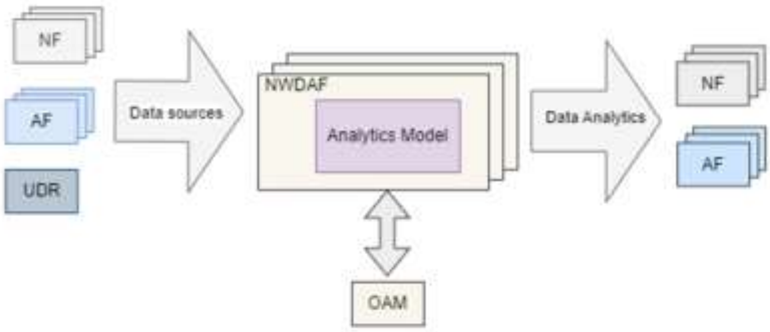

Figure 7. General Architecture of Network Data Analytics Function

In the context of 5G evolution, Release 18 [10] has placed significant emphasis on enhancing the capabilities of the NWDAF. These enhancements include decomposing the NWDAF logic into two distinct components: the Model Training Logical Function (MTLF) and the Analytics Logical Function (ANLF).

- ANLF is a logical function in NWDAF, which performs inference, derives analytics information (i.e., derives statistics and/or predictions based on Analytics Consumer re- quest) and exposes analytics service.
- MTLF is a logical function in NWDAF, which trains Machine Learning (ML) models and exposes new training services (e.g., providing trained ML model).

As illustrated in Figure 8 the Nnwdaf interface is used by an NWDAF containing AnLF to request and subscribe to trained ML model provisioning services.

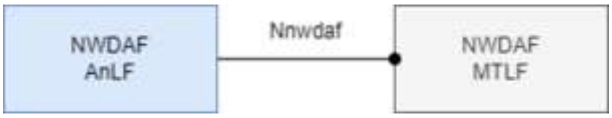

Figure 8. Trained ML Model Provisioning architecture

2.2.4.5 Network Application

5G and B5G system is envisioned to increasingly embrace new capabilities towards programmability, openness and interoperability in a multivendor environment. As a result, vertical industries will be able to develop applications assembling new services by leveraging 3GPP APIs as well as other telecom assets.
Towards this direction, 3GPP has introduced the concept of Vertical Application Enablers (VAEs) in Rel. 16 [11], enabling the efficient use and deployment of vertical apps over 3GPP systems (3GPP, 2019). The specifications and the architecture are based on the notion of the VAE layer that interfaces with one or more vertical applications (vApps). VAEs communicate via network-based interfaces that are well defined and version-controlled. The main focus of VAEs is to provide key capabilities, such as message distribution, service continuity, application resource management, dynamic group management and vertical application server APIs utilising the 5G system

Although the APIs are well defined by the standardization bodies, there is a major gap that needs to be bridged so as to realise the full potentials that 5G and B5G networks provide. The lack of deep expertise about the network's internal operating mode from the industrial service providers is an inhibitory factor that hinders the utilization of its full potential. Given the diversity of verticals, an important question is whether each vertical intends to develop specific solutions for all of their required services.
Therefore, the introduction of an intermediate layer so as to interact with the control plane of a mobile network by consuming the exposed 3rd Generation Partnership Project (3GPP) APIs, called Network Application (Network App), is deemed necessary for allowing the proper development of 5G and B5G enabled applications that take full advantage of the capabilities that the new generation of cellular networks offers.
In the light of the above the Network App is a software component designed to interact with the control plane of a mobile network by consuming exposed APIs (e.g., Northbound APIs) in a standardized and trusted way in order to compose services for the vertical industries.
The main two characteristics identified for Network Apps by 5GPPP [12] are: a) the exposure of APIs for other service consumers, which should be delivered in an Open API model and follow the 3GPP recommended APIs, and b) that they may interact with the 5G/B5G system by consuming its APIs (i.e., the NEF), provided that relevant 3GPP standards are supported.
In this context, Network Apps can offer services to a vertical system in two ways: as an integrated component of the vertical Applications (vApps) or by exposing business APIs to interface with vApps. The latter approach, known as business APIs, enables the reusability of the Network App across multiple relevant vApps. Therefore, depending on how the services are provided to the vertical applications, two modes can be identified: Stand-alone and Non-Standalone, as illustrated in Figure 9.

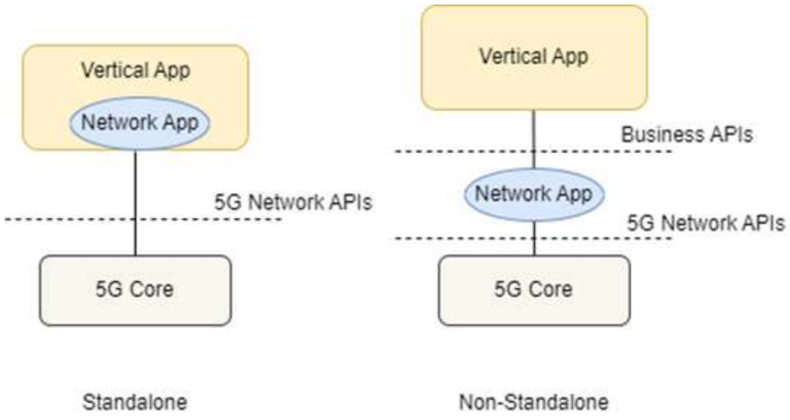

Figure 9. Standalone and Non-Standalone modes of Network Apps

Standalone: A standalone Network App provides complete services to one or more vertical industries, either directly or through its integration to a vApp. A Network App that is integrated into a vApp, enhances the functionality of the application by adding network management and monitoring capabilities exposed by the 5G network.

Non Standalone: As per the second mode, the Network App operates as a wrapper of Northbound APIs to expose services through Business APIs. It is a supplementary software piece that becomes functional when its business APIs are consumed by an application. In that sense, a Non Standalone Network App enables the development and up grading of vApps without altering the integral parts of their software. This is achieved by consuming the Business APIs, which are consumed from the vApp and obtain the requested data provided by the 3GPP APIs.

Implementation principles

In a nutshell, the expected workflow and intercommunication between vAPPs and Network Apps would be as follows:

The process starts with the vApp making a request to the NetApp exposed interfaces. Consecutively, the NetApp interprets the request and in turn makes one or more requests to the 5G API Core. The NetApp then gets a reply with all the data that were requested and proceeds with the data modification and its designed functionality, while finally sending the reply to the vApp.

It's important to note that in the above workflow, there could potentially be one extra flow, depending on the 5G API call needed. Some of the 5G APIs could make a further call with updated information on a particular request. This aspect will be considered while developing a Network App by making accommodations to the interfaces provided as well as in the vApp side. Based on the above-mentioned workflow three main implementation principles for Network Apps can be extracted. These principles are cloud native approaches and can be used in order to facilitate the development of Network Apps and the entire Network App life cycle via an efficient and beneficial implementation:

- Function as a Service (FaaS) Deployment
- Container-based Deployment with a Message BUS

- Container-based REST API Deployment

2.2.5 Future Trends and Beyond 5G

This section depicts some future trends related to 5G and beyond technologies. The higher KPIs expected to be achieved with B5G will facilitate the design and implementation of more advanced applications. More resilient and reliable connections (especially in emergency or natural disaster scenarios), higher peak rates, shorter latencies, greater mobility (speeds supported), power optimization, enhanced coverage in remote areas, among others. Among others, the following trends are topics in evolution that will be part of the next cellular evolution, and will be introduced in the training material:

- With respect to technological evolution:
    - Novel wireless communication technologies. Research will focus on systems should cope with higher KPIs (terabytes-per-second throughput, sub-milliseconds latency, extremely high reliability, massive mMTC and cm-level accuracy localization).
    - Openness. Apart from openness related to the B5G core and NetApps penetration (see Section x), RAN openness is of interest so that it can be shared among providers/vendors, helping at reducing/sharing costs, moving beyond OpenRAN. Innovative methods are required to facilitate multi-vendor interoperability, and flexible service introduction.
    - True cloud native infrastructure. As stated in Section x, there is still effort to be made to evolve to a truly cloud native adoption. And, extended to edge native, in which B5G applications can be tailored to edge environments (not just related to MEC infrastructure, but constrained devices).
    - Energy-efficient network technologies. From signal processing techniques to protocols, ultra-massive MIMO and end-devices.
    - AI support. The 5G SBA and MANO architectures must evolve to include several supporting tools aiming at enhancing different aspects such as energy consumption, applications scheduling and orchestration, security, privacy, reliability and resiliency.
    - Security, privacy and trust. These three properties are crucial for allowing an effective market penetration of multi-tenant and multi-stakeholder environments. One trend in research will be related to data governance models supported by dedicated AI techniques.
- With respect to applications and business opportunities:
    - Non-public networks. Industry, especially in manufacturing and logistics, will increasingly improve their operations installing and using low-latency and private 5G networks, as a preferred option over network slicing.
    - Mission critical control. The combination of ultra-low latency with extremely high availability, reliability and security, tactile internet applications will unlock the penetration of true tactile internet applications, of particular interest in the healthcare sector [13] and AR-supported

applications, so that highly-skilled surgeons/employees can execute remote tasks reliably (e.g., addressing skills shortage or hard access).

- Enhanced customer experiences. Immersive experiences and large-scale adoption of XR technology solutions (metaverse, VR training, remote control) will open several businesses opportunities.

Although some applications belonging to the former applications could be already supported by current 5G technology, they are not yet spread in the society for different reasons, such as costs, regulation, availability, coverage, security, reliability, resiliency or trust, among others.

2.3 Innovation and Entrepreneurship in 5G Syllabus

- Description: This section provides an overview of the role of innovation and entrepreneurship in the context of 5G and Beyond technologies. Participants will gain insights into the transformative power of 5G and the importance of integrating an entrepreneurial mindset in leveraging its capabilities.
- Objective: By the end of this section, participants will be able to understand the significance of innovation and entrepreneurship in driving the development and adoption of 5G technologies, and recognize the potential impact of an entrepreneurial approach in the 5G ecosystem.

2.3.1 Introduction to Innovation and Entrepreneurship in 5G

In this section, we will explore the role of innovation and entrepreneurship in the context of Beyond 5G technologies. The rapid advancement of 5G has opened up new opportunities for innovators and entrepreneurs to shape the future of various industries. This introduction sets the stage for understanding the significance of integrating an entrepreneurial and innovative approach into 5G technologies.

2.3.1.1 Role of Innovation and Entrepreneurship in Technology Development

Innovation and entrepreneurship are pivotal drivers of technology development, and their significance in the context of 5G technologies cannot be overstated. As 5G networks continue to expand, it is crucial to understand how innovation and entrepreneurial mindsets can shape the evolution and adoption of these technologies.

Innovation lies at the heart of technological progress. It involves generating novel ideas, concepts, and approaches that push the boundaries of what is possible. In the realm of Beyond 5G, innovation encompasses developing disruptive applications, services, and solutions that leverage the unique capabilities of 5G and Beyond networks, such as high-speed data transfer, ultra-low latency, and massive device connectivity.

Entrepreneurs play a vital role in translating these innovative ideas into tangible outcomes. They possess the vision, capacity, ambition, drive, and resourcefulness to identify opportunities in the 5G landscape and transform them into successful ventures. By combining technical knowledge with business acumen, entrepreneurs can create sustainable business models that deliver value to customers while capitalising on the transformative potential of 5G technologies.

To illustrate the role of innovation and entrepreneurship in 5G technology development, let's consider a hypothetical example. Imagine a team of aspiring entrepreneurs identifies a gap in the market for seamless, real-time communication between healthcare providers and patients. Leveraging the capabilities of 5G networks, they develop a telemedicine platform that enables remote consultations, remote patient monitoring, and quick access to medical records. This innovative solution improves healthcare accessibility, reduces costs, and enhances patient outcomes.

This example highlights how innovation in 5G technologies can lead to the creation of disruptive solutions that address societal challenges and drive economic growth. It underscores the crucial role of entrepreneurs in identifying opportunities, developing innovative products or services, and navigating the complex ecosystem to bring their ideas to fruition. Overall, technological advancement has value when it is capitalised and commercialised in ways that improve the quality of life, overcome everyday difficulties and have impact in our lives. This is why entrepreneurship must be directly linked with technological development by structural departments that are directly connected with HEIs.

2.3.1.2 Overview of Opportunities in 5G for Innovators and Entrepreneurs

The advance of 5G technologies has unleashed a world of opportunities for innovators and entrepreneurs. The exceptional speed, ultra-low latency, massive device connectivity, and network slicing capabilities of 5G and Beyond networks open up new horizons for technological advancements and business innovation.

In the realm of 5G, innovators and entrepreneurs have the potential to revolutionise industries, reimagine business models, and create transformative experiences. Let's explore some of the exciting opportunities that await them:

- Smart Cities: 5G facilitates the creation of smart cities, where interconnected devices, sensors, and infrastructure communicate seamlessly, enabling efficient resource management, intelligent transportation systems, and improved urban living.
- Industrial Automation and IoT: 5G empowers the Industrial Internet of Things (IIoT), enabling real-time data exchange, machine-to-machine communication, and advanced automation in manufacturing, logistics, and supply chain management.
- Augmented Reality (AR) and Virtual Reality (VR): With 5G's ultra-low latency and high bandwidth, AR and VR experiences can reach new heights, revolutionising fields like gaming, entertainment, education, and remote collaboration.
- Autonomous Vehicles: 5G networks provide the reliability, low latency, and high-speed connectivity required for safe and efficient autonomous transportation systems, enabling intelligent vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2X) communication.
- E-Health and Remote Monitoring: 5G facilitates remote healthcare services, remote patient monitoring, and telemedicine, enhancing access to healthcare, reducing costs, and improving patient outcomes.

- Precision Agriculture: 5G enables real-time data collection, remote monitoring, and precision control in agriculture operations, leading to improved crop yields, optimised resource utilisation, and sustainable farming practices.
- Emerging Technologies Integration: 5G serves as a catalyst for the convergence of emerging technologies like AI, IoT, blockchain, and edge computing. By integrating these technologies with 5G, innovators can create groundbreaking solutions with enhanced capabilities and transformative potential.

It is essential for aspiring innovators and entrepreneurs to recognize these opportunities and develop a deep understanding of the specific industry landscapes in which they operate. By leveraging the power of 5G, they can create disruptive solutions, drive economic growth, and shape a future that provides opportunities and solutions to today's problems.

2.3.2 Strategies and Opportunities for 5G Innovation

- Description: This section of the training program will elaborate on various methods, strategies, paths and reasoning processes that are connected with Innovation and Entrepreneurship in the 5G and Beyond sections.
- Objective: By the end of this section, participants will be able to understand different frameworks for innovation strategy, such as design thinking, lean startup, and open innovation. They will gain insights into how these frameworks can be applied in the development and implementation of 5G-related innovations, remarkable case studies and ways that will help them to effectively drive innovation within their organisations or entrepreneurial ventures.

2.3.2.1 Frameworks for Innovation Strategy

Innovation frameworks provide structured approaches to generate and implement innovative ideas. By exploring these frameworks, participants will gain a deeper understanding of the methodologies, concepts, and best practices that can guide their approach to innovation in the 5G ecosystem.

- Design Thinking: Design thinking is a human-centered approach that emphasizes empathy, creativity, and collaboration. Participants will learn how to identify and understand user needs, generate creative solutions, prototype ideas, and iterate based on user feedback. This approach can be particularly valuable in developing user-centric 5G applications and services that effectively address customer pain points.
- Design-Driven Innovation: Combining Design Thinking and Strategic Innovation. In addition to Design Thinking, another approach that complements and enhances innovation within the 5G context is Design-Driven Innovation. Design-Driven Innovation goes beyond addressing user needs and extends to strategic innovation that disrupts markets and creates new value propositions. Design-Driven Innovation recognizes that successful innovations require a deep understanding of user needs, market dynamics, and technological possibilities. It combines Design Thinking principles with strategic insights to identify unmet needs and develop breakthrough solutions that have a transformative impact. By integrating Design

Thinking with strategic innovation, participants can easily identify market white spaces and create disruptive 5G solutions that not only meet user needs but also redefine industries and business models.

- Lean Startup: The lean startup methodology focuses on building minimum viable products (MVPs) and rapidly testing them in the market to validate assumptions and gather customer feedback. Participants will learn how to embrace a "build-measure-learn" feedback loop, iterate their product or service offerings, and pivot based on market insights. This iterative approach can be applied to developing 5G-related solutions, allowing entrepreneurs to quickly adapt and refine their ideas.
- Open Innovation: Open innovation involves collaborating with external partners, including customers, suppliers, and industry experts, to co-create and develop innovative solutions. Participants will explore the benefits of open innovation ecosystems, such as access to diverse expertise, resources, and market insights. They will learn strategies to effectively engage with external stakeholders and leverage their knowledge and capabilities to drive 5G innovation.

These frameworks are just some examples of how a concrete, structured methodology can help someone to visualise and give shape to an idea/concept. This is the first step for the commercialisation of a breakthrough that will have uses and impact to the quality of human life.

2.3.2.2 Case Studies of Disruptive 5G Innovations

- Fivecomm: Fivecomm is a clear example of a 5G start-up with a B2B model that has multilevel impact. This company is also stemming from the UPV, a partner in the Skills2Scale project, with the participation of professors and an investor. Fivecomm accelerates the digitalization of the Industry using the most advanced communication technologies, creating real and cost-efficient Internet of Things applications from the devices to the Edge. Its activities have upgraded Valencia's port and Valencia in general to one of the smartest cities in Europe, while also being active in various other fields, such as media, 4.0 industry, mobility, energy and healthcare. Fivecomm is a great example of how a company can provide 5G based solutions to multiple societal challenges.
- Bosch-Nokia Positioning: The 2 giants develop a 5G-based system for real-time video analysis and management of parking spaces. The solution seeks to optimise the utilisation of parking areas, reduce congestion, and improve the overall efficiency of urban transportation. The system utilises high-resolution cameras installed in parking areas to monitor and capture real-time video footage. The captured video data is processed using AI algorithms and data analytics techniques. Based on the analysis of the video data, the system provides real-time parking guidance to drivers, directing them to available parking spaces. The 5G network enables the transmission of this video data with low latency and high reliability. The Bosch-Nokia collaboration demonstrates how 5G technology can be harnessed to develop innovative solutions for smart parking and urban mobility challenges.
- LiveEO: LiveEO is a startup that leverages satellite imagery and data analytics for infrastructure monitoring and management. They utilise 5G technology to transmit and process large amounts of geospatial data in real-time, providing insights for industries such as utilities, transportation, and agriculture. LiveEO's solutions enable the monitoring of various types of infrastructure, including power transmission lines,

pipelines, railways, and vegetation. The satellite imagery is regularly updated, allowing for near-real-time monitoring and detection of potential risks or anomalies. By analysing the satellite imagery, LiveEO can identify potential risks and detect early warning signs of infrastructure issues. This proactive approach enables organisations to take preventive measures, schedule maintenance activities, and mitigate potential disruptions. LiveEO leverages 5G technology for efficient and real-time transmission of geospatial data. The high-speed and low-latency capabilities of 5G networks enable LiveEO to transmit large amounts of data quickly, facilitating rapid analysis and decision-making.

- Airspan Networks: Airspan Networks is a startup that focuses on providing wireless access solutions for various industries and applications. They specialise in developing and deploying advanced wireless technologies, including 5G, to enhance network capacity, coverage, and performance. Airspan Networks offers a range of 5G infrastructure solutions, including small cells and macrocells. These solutions are designed to enable high-speed and low-latency connectivity, catering to the increasing demand for data-intensive applications and supporting the deployment of 5G networks. Airspan's solutions cater to various vertical applications, including smart cities, industrial automation, transportation, and public safety. Their 5G infrastructure enables reliable and efficient connectivity, supporting emerging technologies like autonomous vehicles, smart grids, and IoT deployments. Overall, Airspan Networks focuses on providing wireless access solutions, including 5G infrastructure, to enable high-speed, reliable, and scalable connectivity. Their solutions cater to various industries and use cases, supporting the growing demand for advanced wireless technologies, high speed data transmit and their applications.

2.3.2.3 Identifying Opportunities for Start-ups in 5G

This section focuses on helping participants identify opportunities for start-ups within the 5G ecosystem. It provides guidance on conducting market analysis, identifying unmet needs, and spotting gaps where 5G technologies can be leveraged to create innovative solutions and business models.

To identify opportunities for start-ups in the 5G industry, it is crucial to conduct thorough market analysis. This includes understanding the current state of the 5G market, assessing market trends and growth potential, and analyzing the competitive landscape. Participants will learn how to identify specific industry sectors where 5G technologies can have a transformative impact, such as smart cities, healthcare, logistics, or entertainment.

Moreover, participants will explore how to identify unmet needs within these sectors. By conducting market research, engaging with potential customers, and understanding their pain points and challenges, entrepreneurs can uncover opportunities where 5G can address these needs and provide innovative solutions. For example, identifying the need for real-time monitoring and predictive maintenance in industrial settings or recognizing the demand for immersive and interactive experiences in the entertainment industry.

Participants will also learn to spot gaps in the market where 5G technologies can disrupt existing business models or create entirely new markets. By exploring emerging technologies and trends, participants can identify areas where 5G integration can drive innovation and open up new possibilities. For instance, combining 5G with AI, IoT, or edge computing to develop advanced applications in sectors like autonomous vehicles, precision agriculture, or remote asset management.

By mastering the skill of identifying opportunities for start-ups within the 5G ecosystem, participants will be equipped to envision and develop innovative business ideas that leverage the transformative power of 5G technologies. Especially in fields such as 5G and Beyond technology, a field that is futuristic from its nature and that has to create solutions that bridge the future with today's problems, it is essential that the pioneers in this field are able to spot opportunities and exploit them.

2.3.2.4 Developing a 5G Business Model

This section focuses on the process of developing a business model that aligns with the unique characteristics and opportunities presented by 5G and Beyond technologies. Participants will learn about the key components of a business model canvas and how to adapt it to create a robust and sustainable business model that incorporates the direct, or indirect, commercialization of 5G and Beyond technologies..

A successful 5G business model requires careful consideration of various elements. Participants will learn to define their value proposition, understanding how their products or services uniquely leverage the capabilities of 5G to solve specific customer problems or fulfil unmet needs. They will explore different customer segments within the 5G ecosystem and develop a deep understanding of their customers' preferences, behaviours, and pain points.

It is very important to clarify whether the company "sells" the 5G technology or a potentiality that is achieved through this technology.

Revenue streams play a crucial role in a 5G business model. Participants will explore different monetization strategies, such as subscription-based models, licensing, data monetization, or revenue-sharing partnerships. They will also gain insights into the cost structure and resource allocation required to support their business model, including considerations such as infrastructure costs, technology investments, and talent acquisition.

In addition to these core elements, participants will also learn to analyse and address key aspects such as distribution channels, customer relationships, and key partnerships within the 5G ecosystem. They will understand the importance of building strong relationships with stakeholders, adapting to evolving market dynamics, and fostering innovation within their organisations or start-ups. Network, especially in fields that are narrow, such as 5G technology, is crucial.

By the end of this section, participants will have the tools and knowledge to develop a comprehensive business model for their 5G-related venture. They will be able to create a roadmap for commercial success by aligning their value proposition, customer segments, revenue streams, and cost structure with the unique opportunities and challenges presented by the 5G industry.

2.3.3 Entrepreneurship in 5G

- Description: This section explores the critical aspects of entrepreneurship in the context of 5G technologies. Participants will gain insights into the process of starting and scaling a 5G business, securing funding and investment opportunities, crafting an effective pitch for a 5G business idea, and implementing business strategies for success in the rapidly evolving 5G industry.
- Objective: By the end of this section, participants will have a deep understanding of the entrepreneurial landscape in the 5G industry. They will be equipped with the knowledge and skills to effectively start and

scale a 5G business, navigate the funding ecosystem, craft compelling pitches, and implement business strategies tailored to the unique challenges and opportunities presented by 5G technologies.

2.3.3.1 Starting and Scaling a 5G Business

In this section, participants will explore the intricacies of starting and scaling a 5G business. They will gain insights into the key considerations and strategies required for successful entrepreneurship in the 5G industry.
Participants, in section 2.3.2.5 explored how to identify market opportunities and gaps. In this section, they will elaborate further to validate market opportunities within the 5G landscape, understanding customer needs, based on market research and needs.. They will explore the importance of understanding the regulatory environments and compliance requirements specific to 5G, ensuring that their business adheres to legal and industry standards.
Building a strong team is essential for 5G start-ups, and participants will learn about the necessary technical and business expertise required. They will understand the importance of assembling a team that possesses the technical and demanding skills to develop and execute on 5G-related projects, such as network engineering, software development, and business development.
Developing a compelling value proposition aligned with 5G capabilities will be a key focus. Participants will learn to articulate the unique value their product or service brings to the market by leveraging the transformative potential of 5G technologies. They will also explore strategies for formulating sustainable growth strategies, including market expansion, partnerships, and customer acquisition.
Case studies of successful 5G start-ups will be presented again, if it is considered necessary, to provide real-world examples and practical insights into the challenges and strategies involved in starting and scaling a 5G business. These case studies can showcase different approaches to market entry, growth strategies, and scalability, highlighting the successes and lessons learned by these companies.

2.3.3.2 Funding and Investment Opportunities for 5G Start-ups

This section focuses on the funding and investment landscape specific to 5G start-ups. Participants will explore various sources of funding available for 5G ventures and learn about investment opportunities in the 5G ecosystem.
Participants will gain an understanding of different funding sources, such as venture capital, angel investors, and government grants. They will explore the criteria that investors typically look for when evaluating 5G start-ups, including market potential, technology differentiation, scalability, and the strength of the management team.
Some examples of investing opportunities, such as accelerators, incubators, awards and competitions will be presented in order to showcase potential solutions to startuppers that seek funding and support.
Case studies of successful 5G start-ups from a fund-securing perspective will be analysed to provide practical insights into different funding strategies and their impact on business growth. These case studies can showcase different approaches to securing funding, such as successful pitch presentations, strategic partnerships, and government grants.

2.3.3.3 Crafting an Effective Pitch for a 5G Business Idea

Crafting an effective pitch is crucial for attracting support and resources for a 5G business idea. In this section, participants will learn the process of developing an impactful pitch.
Strong pitches with weaker products can, very often, beat a strong product with a weaker pitch deck.
Linked with the previous section, participants will gain an understanding of the target audience and the importance of tailoring the pitch to their needs and interests. They will learn how to clearly communicate the value proposition of their 5G business idea, highlighting the unique benefits and advantages it offers. Participants will explore techniques for showcasing the market potential and competitive advantage of the proposed solution, leveraging market research and customer insights to support their claims.
Addressing potential challenges and risks while presenting mitigation strategies will be emphasised. Participants will learn to anticipate potential concerns that investors or stakeholders may have and demonstrate their preparedness to overcome these challenges.
Through practical exercises and interactive sessions, participants can refine their pitch presentations and enhance their presentation and communication skills. They can receive feedback and guidance on aspects such as storytelling, slide design, and effective delivery techniques.
The participants will receive a pitch deck workshop from experts and will learn how to improve their self-projecting skills.. By analysing successful pitches from different industries and sectors, participants can extract valuable insights and apply them to their own pitch development.

2.3.3.4 Business strategies for success in the 5G industry

This section explores specific business strategies required for success in the 5G industry. Participants will delve into considerations such as competitive positioning, go-to-market strategies, partnership and collaboration opportunities, and customer acquisition and retention.
Developing a business strategy that is realistic and ambitious, at the same time, is crucial. A business strategy must have a short, mid and long-term vision and goal.
Analysing the competitive landscape will be a key focus. Participants will learn how to identify their unique value propositions and differentiate themselves from competitors in the 5G market. They will explore strategies for developing go-to-market plans that effectively target and reach their intended customer segments in the 5G industry.
Participants will gain insights into leveraging partnerships and collaborations to enhance their product/service offerings and expand their market reach. They will explore different types of partnerships, such as technology integrations, channel partnerships, and strategic alliances, and understand the potential benefits and challenges associated with each.
Implementing effective customer acquisition and retention strategies tailored to the 5G ecosystem will be emphasised. Participants will learn how to identify and attract their target customers, develop customer-centric approaches, and implement strategies for building long-term relationships and customer loyalty.

2.3.4 Regulation Framework of 5G

Since the advent of 5G one of the primary focuses of the European Union (EU) is to shape a robust regulation framework and policies to support the rapid deployment and advancement of 5G technology across its member states, and this framework is regularly updated. At the core of this regulatory approach is the EU's commitment to fostering a connected and competitive digital landscape that can leverage the transformative potential of 5G networks. One of the key elements of the EU's strategy is spectrum harmonization, ensuring that radio spectrum allocation for 5G services is coordinated and standardized throughout the region. This harmonization facilitates seamless cross-border connectivity and efficient use of 5G networks. The 5G Action Plan, initiated in 2016, serves as the initial roadmap for expediting 5G deployment and addresses critical challenges related to spectrum management, infrastructure development, and investments.

Moreover, net neutrality regulations within the EU guarantee equal treatment of all internet traffic, including 5G data, promoting an open and nondiscriminatory digital ecosystem. Complementing these efforts, the European Electronic Communications Code (EECC), established in 2018, modernizes and harmonizes rules for electronic communications, providing a favorable environment for investment and innovation in 5G networks and services.

The EU's Digital Single Market (DSM) Strategy plays a crucial role in creating a unified digital market, thus supporting the seamless deployment of 5G services and encouraging digital innovation. Additionally, the EU focuses on cybersecurity and data privacy measures to ensure the protection of communications and user data in the context of 5G networks, building trust and confidence in the technology.

Through several research and funding initiatives (Horizon Europe), the EU invests in cutting-edge projects and collaborations to drive 5G technology advancements and novel use cases. Towards this direction 5GPPP (Public-private partnerships) further enhance the acceleration of 5G deployment, facilitating collaboration between industry players, research institutions, and the EU.

Moreover, the International Telecommunication Union (ITU) and the 3rd Generation Partnership Project (3GPP) are pivotal players in shaping the regulations and standards for the global telecommunications industry. 3GPP has been responsible for developing the technical specifications, radio access network standards, core network architecture, and other essential elements that form the foundation of 5G and B5G (Beyond 5G) networks. These standards ensure that 5G systems across the world can operate seamlessly, allowing for a global and interconnected 5G ecosystem. On the other hand ITU takes charge of setting international standards and guidelines for telecommunication technologies, encompassing spectrum allocation and harmonization to ensure seamless global interoperability.

The regulations governing 5G technology in the EU are continuously evolving to keep pace with technological advancements and changing market needs. As 5G technology continues to develop and as we move B5G technologies, policymakers regularly review and update the regulatory framework to address emerging challenges and seize new opportunities. This dynamic approach ensures that the EU remains at the forefront of harnessing the transformative potential of 5G and creates a regulatory environment that encourages innovation, investment, and the combination of technologies.

2.3.5 The Future of 5G Innovation and Entrepreneurship

- Description: This section explores the future of 5G innovations and entrepreneurship, focusing on anticipating market trends and opportunities in the 5G landscape and understanding the impact of emerging technologies such as AI, IoT, and blockchain on 5G. Participants will gain insights into the potential directions of the 5G industry and how entrepreneurs can leverage emerging technologies to create transformative solutions.
- Objective: By the end of this section, participants will have a deep understanding of the future trends and opportunities in the 5G industry. They will be able not only to anticipate market shifts, identify emerging technologies that can drive innovation in the 5G context, but also to leverage these insights to develop entrepreneurial strategies that capitalise on the transformative potential of 5G.

2.3.5.1 Anticipating Future Market Trends and Opportunities in 5G

In this section, participants will explore the process of anticipating future market trends and identifying opportunities in the 5G landscape. They will learn how to analyse industry reports, market research, and technological advancements to gain insights into the potential directions of the 5G industry.

Already the technology is getting over 5G and reaching 6G. The dynamic of these technologies is getting bigger and bigger, allowing new opportunities to emerge every day. Due to this dynamic, researchers and workers in this field should not see 5G technology as a possession, that once you get it your work is completed, rather than as a continuous task that needs to be updated and improved constantly.

Participants will delve into topics such as market segmentation, industry forecasts, and emerging use cases for 5G and Beyond technologies. They will explore the potential impact of 5G across various sectors, including healthcare, manufacturing, transportation, and entertainment. By understanding the evolving needs and demands of these sectors, participants can identify potential market gaps and develop innovative solutions to address them.

5G and similar technologies were firstly used in telecommunications. Gradually, new uses were discovered in transportation, healthcare, smart cities etc. There are potential cases that 5G and Beyond technologies can be useful and provide innovative solutions that are not yet discovered. As it is mentioned a lot of times, 5G is a breakthrough, and no borders should be placed on it.

2.3.5.2 Impact of Emerging Technologies on 5G (AI, IoT, Blockchain)

This section focuses on understanding the impact of emerging technologies such as AI, IoT, and blockchain on 5G innovations and entrepreneurship. Participants will explore how these technologies can enhance and shape the future of 5G applications and services.

Participants will gain insights into the potential synergies between 5G and AI, such as leveraging AI-powered analytics and machine learning algorithms to enable intelligent automation, predictive maintenance, and personalised user experiences in the 5G ecosystem. They will also explore the intersection of IoT and 5G, understanding how the massive connectivity and low latency of 5G networks can enable the seamless integration and scalability of IoT devices and applications.

Furthermore, participants will delve into the potential of blockchain in the 5G context, exploring its applications in areas such as secure and decentralised identity management, trusted data sharing, and transparent and auditable transactions.

Last, it should not be omitted that the exploitation of these technologies together can be the key for new breakthroughs.

By gaining insights into the impact of emerging technologies on 5G, participants will be better equipped to identify potential areas for innovation, understand the transformative capabilities of these technologies, and develop entrepreneurial strategies that leverage their synergies with 5G.

3 Conclusions

In this deliverable, a training program was developed with the goal of enhancing the capacity of HEIs in fostering institutional engagement and change in the field of beyond 5G technology.

The training program consists of two sections: one related to 5G technology and the other related to innovation and entrepreneurship. In the 5G section, topics such as the evolution of mobile networks, key features of 5G, enabling technologies, 5G SBA, and openness, as well as future trends and beyond 5G, are covered. In the second section, topics include innovation and entrepreneurship in 5G, strategies and opportunities for innovation, as well as the regulatory framework for 5G.

This training material will be used to train HEI administrators, faculty, and staff. The training will be delivered through webinars and will cover topics such as innovation and entrepreneurship, partnership building, and knowledge sharing. Upon completion of the courses, participants are expected to have a better understanding of the relative technologies of 5G and beyond, as well as how they can use this knowledge to realize their unique ideas through innovation and entrepreneurship.

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