

WHITE PAPER

5G-as-a-Service (5GaaS)

A Decentralised Marketplace for Telcos



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5GaaS

INTRODUCTION



The fifth generation of mobile communications promises to transform several sectors of the economy, commonly referred to as “verticals” like Industry, Energy, Transport, Health and others. However, the first vertical where 5G will have a more immediate and meaningful impact is the telecom ecosystem itself.

With the price per gigabyte of mobile traffic steadily declining, Mobile Network Operators (MNOs) are facing tighter margins in what can be considered a “race to the bottom” in offering the same mobile broadband services at a cheaper cost. Although still feasible, the value proposition of 5G to the Business-to-Consumer (B2C) segment is not as clear as it was with previous Radio Access Technologies and MNOs are looking at opportunities in the Business-to-Business (B2B) segment to diversify their revenue streams.

Currently MNOs have little service differentiation, focusing on the “pipes” that carry all different traffic types. The rationale is straight forward: the better these pipes are performing, the better all the services/traffic flowing through them perform as well. This is not enough if MNOs seek to provide more differentiated offers, such as connectivity for critical services, tailored for the enterprise customers from the different verticals. Following the initial Non-Standalone (NSA) deployment, which represented additional capacity to current mobile networks, with 5G anchored on a 4G core and base stations, MNOs are starting to migrate towards 5G Standalone (SA) architecture. This challenging step is crucial to unlock the benefits and differentiating factors that 5G can offer, such as slicing capabilities, predictable low latency, edge services and others.

Public or Private Networks? It is important to mention these two distinct deployment paradigms where one re-uses a pre-existing (public) infrastructure, whilst the other offers a complete on-premise (private) solution that can have different levels of integration or be completely isolated from other public networks. For MNOs the public option is very relevant, although significant transformations need to happen at the very core of the network, transitioning from 5G NSA to 5G SA. With the introduction of 5G SA to their toolkit, Network Slicing can do for MNOs what Virtual Machines did for Cloud Providers, meaning MNOs will be able to create several virtual networks with different Quality of Service requirements, on top of the same physical infrastructure. A big question mark is if customers will pay any extra cost for a

premium service that can better serve their needs. To explore this new service paradigm and go beyond the traditional revenue model, MNOs need to find new ways/models of collaboration with a wider and more diverse range of partners, fostering a healthy development ecosystem on top of their biggest asset, the services offered by their network.

5GaaS proposes a new way for MNOs and Service Providers to offer more differentiated services to Verticals, through Network Slicing and by launching a new product in the form of a decentralised marketplace for the telecom ecosystem, with the objective of helping MNOs to address the B2B opportunity of 5G. This new solution serves as a nexus between MNOs/CSPs and Enterprises of the different verticals who seek more tailored connectivity services. This innovative platform is enabled by a decentralised and trustable multi-stakeholder marketplace allowing flexible and transparent business interactions through Distributed Ledger Technology (DLT).

The level of transparency achieved through DLT can create a strong value proposition for neutral hosts such as Municipalities, who typically face a higher level of scrutiny when compared with private entities and can use 5GaaS to lease public infrastructure and the respective tenant management in an open and secure way. Ultimately, this innovative vision: (i) allows reducing the environmental impact in terms of over-densified physical infrastructure and spectrum by leveraging massively scalable digital urban furniture (lampposts, street cabinets, etc.); and (ii) enables capital and operation cost savings by allowing network operators, and potentially disruptive new-entrant Communication Service Providers (CSPs), to rely on advanced neutral hosting and sharing techniques at different levels for faster and more efficient provisioning and operation of 5G services.

In this White Paper, the main functionalities and building blocks of 5GaaS are described.

¹ Estimated average price of cellular data per gigabyte in the United States from 2018 to 2023

² Tighter margins, more grief this year for telcos—report

³ Unlocking the value of 5G in the B2C marketplace

⁴ Why is 5G SA taking so long?

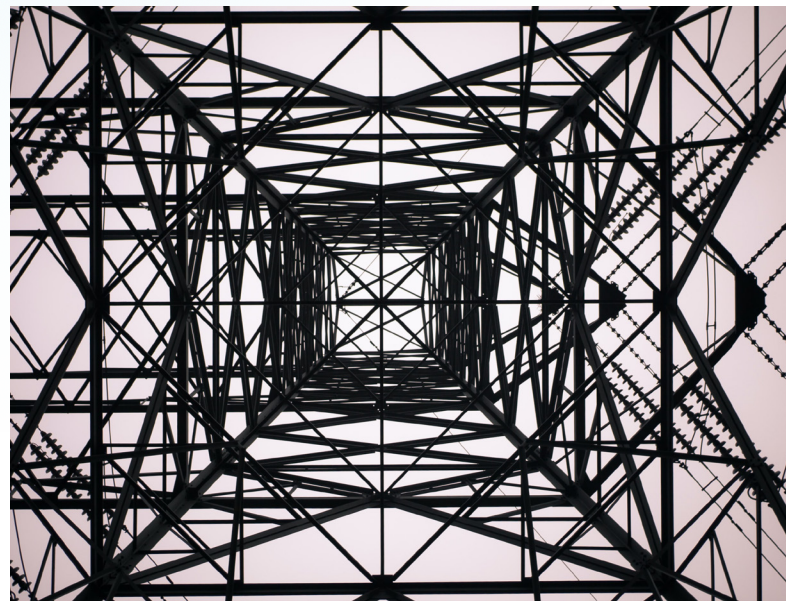
WHAT IS THE 5GAAS MARKETPLACE



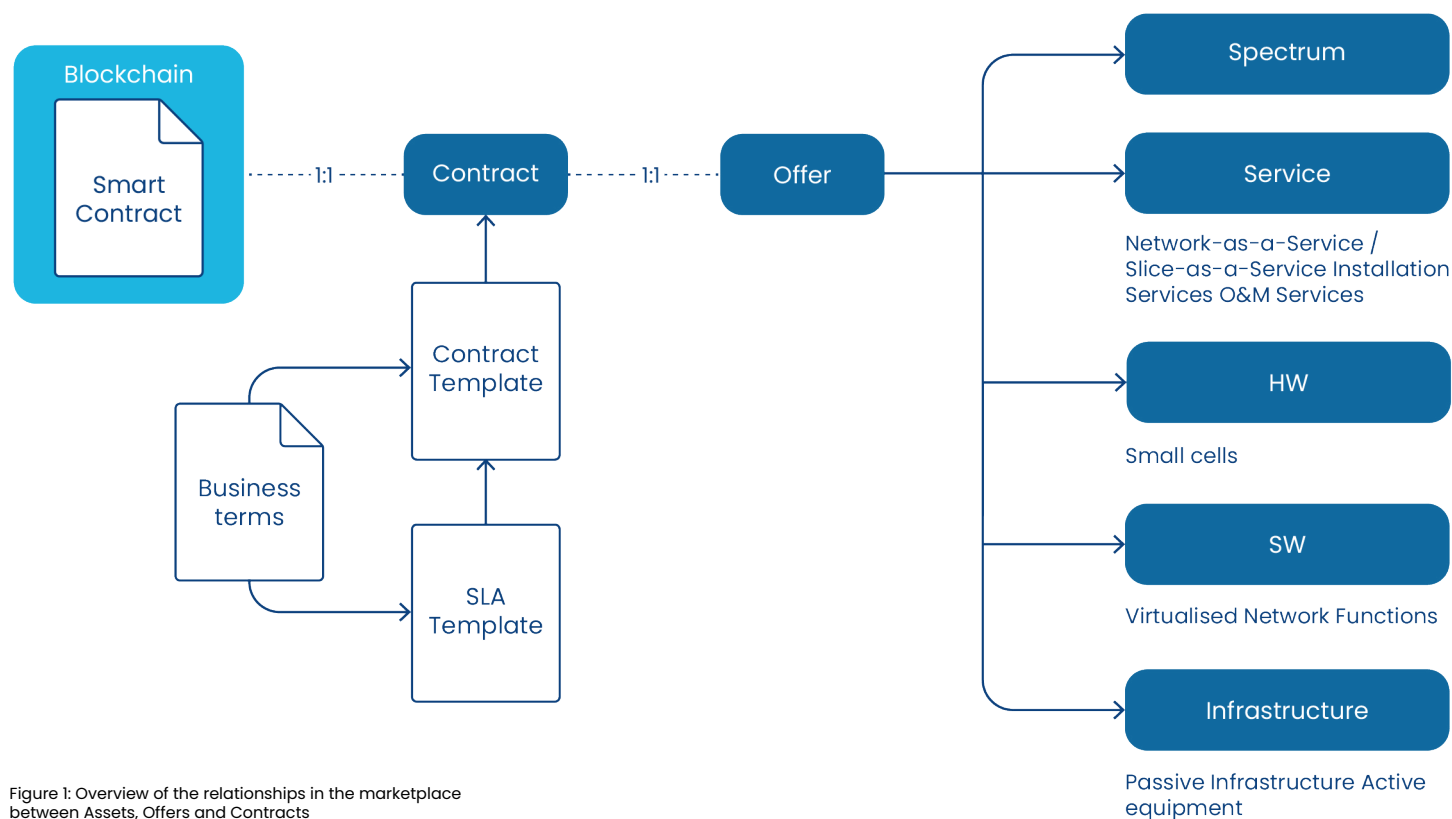
The 5GaaS marketplace connects supply and demand in a single digital marketplace, simplifying the processing of transacting assets and services using the programmability of smart contracts. The stakeholders in the telecom sector such as, MNOs, Communication Service Providers (CSPs), Neutral Hosts and Landlords, can conduct business under transparent multilateral business agreements, using a simple and attractive User Interface (UI). Underneath the 5GaaS UI, all the complex integration with the DLT is encapsulated, allowing 5GaaS Marketplace users to focus on their core business activities while still reaping the benefits of using a smart contracts system.

Although this paper focuses on the value proposition of 5GaaS to connectivity providers, the full vision of what can be transacted is presented here:

- ▶ **Spectrum**, i.e., the frequency bands that are needed to wireless connectivity, via sub-leasing of licences from MNOs and CSPs to vertical enterprises who seek to build their own cellular networks.
- ▶ **Services** that span from tailored connectivity services in the form of network slices, to the entire network lifecycle management that goes from installation and the deployment of the on-prem solutions (private networks), to the operation and management of private networks.
- ▶ **Software**, with the increasing softwarization of networks and specialised Virtual Network Functions (VNFs) that are optimised for certain types of traffic profiles and applications.
- ▶ **Hardware** such as antennas, radios, user equipment and other physical objects that are present in the network.
- ▶ **Infrastructure** like SmartLampPosts and other smart urban furniture solutions that can play a relevant role in the rollout of small cells that will enable a higher level of granularity to 5G that needs to be closer to the end user.



One of the goals of the 5GaaS marketplace is for its users to provide certainty while purchasing a service. This is achieved by inserting conditions in the smart contracts regarding service quality and what happens (actions) that will be taken should a service disruption or degradation occur. This is possible by deploying smart contracts on top of Distributed Ledger Technology. Figure 1 provides a high level overview on the relations between services, offers and contracts in the marketplace.



As highlighted in Figure 1, it is envisioned for the marketplace to support several assets. The consortium will focus on the 5G Network Slices that will be showcased in the pilot or a Slice-as-a-Service, highlighting the added value that 5GaaS platform can bring to MNO's and CSP's, with the service orchestration, automated billing, SLA monitoring, service discovery and lifecycle management functionalities of the platform.

Resource Discovery

Among the technical novelties and value propositions achievable through the 5GaaS model and its Digital Marketplace, one key feature is the automatic Resource Discovery. Resource owners such as service providers, federated through the marketplace, will advertise compute and storage, spectrum, software functions, network services and slicing capabilities in an innovative way. This will be done by relying on DLT decentralised and trusted infrastructure that allows for subsequent actions of brokering among alternative offers and selection of best resources. Moreover, the coupling of this feature with the management and orchestration run at the various levels of the virtualized infrastructure will allow to implement highly flexible network reconfigurations which can allow the operator to fast adapt to new demands.

Service Orchestration

The main aim of the 5GaaS platform project is to enable transparent interactions between various orchestrators by relying on multi-tier orchestrators (MTOs). The service provider of 5GaaS is designed to perform highly flexible network reconfigurations between various virtual infrastructure levels, end-to-end slice managers, MEC, NFV, SDN, and cloud-native orchestrators domains; this allows operators to quickly adapt to changes in needs.

In this regard, the slice manager was created to allow for the coordinated creation of slices that include chunks of various layers of the 5G network (RAN, core, transport, edge cloud platform, service orchestration platform, and access network). Within the slice management lifecycle, the slice manager manages and handles network slice instance requests for the deployment of a new virtual application or network service (NS) to perform a certain operation.

To do this, the 5GaaS orchestration provides 5G edge service programming models and a northbound API for access to the various orchestrator and edge service features upon request.

Smart Contracts

The innovative 5GaaS marketplace will integrate DLT to support its stakeholder participation and their contractual binding relations, implementing its integration with the technology layers, enabling automated provisioning and service data collection for contractual KPI governance.

This integration will provide an automated decentralised system based on different smart contracts, that enable the platform users to go through totally decentralised finance and accounting workflows. In addition, the automation of these workflows will reduce the friction and lower the barrier of entry to the platform.

Distributed/Self-sovereign Identity

A key differentiating factor of 5GaaS marketplace is the fact that it does not rely on traditional user/password accessibility, which have been widely used throughout e-commerce platforms. In [1]⁵ and [2]⁶, it is highlighted how impractical this siloed approach is for the users, which require several distinct identities to be maintained for different websites/platforms. It is also explained how federated identity models, popularised by companies such as Google and Facebook, address some of these problems but raise new ones, with the main point being the centralisation of user identity data around a small number of providers, increasing the risk of data leakages and user privacy.



Once a potential user/stakeholder applies to a position in the governance smart contract, the rest of the participants can vote agreeing or not to the onboarding. In case the applicant succeeds access to the whole platform will be granted, including a smart contract automated deployment system. Although not all the Smart Contract System functionalities will be implemented in the scope of 5GaaS, this system also allows the participants to perform crowdfunding campaigns, apply and commit of service and infrastructure consumption over these campaigns and once the appliances and services, finally, account for the billing process of all parties, including agreements and SLAs without manual intervention.

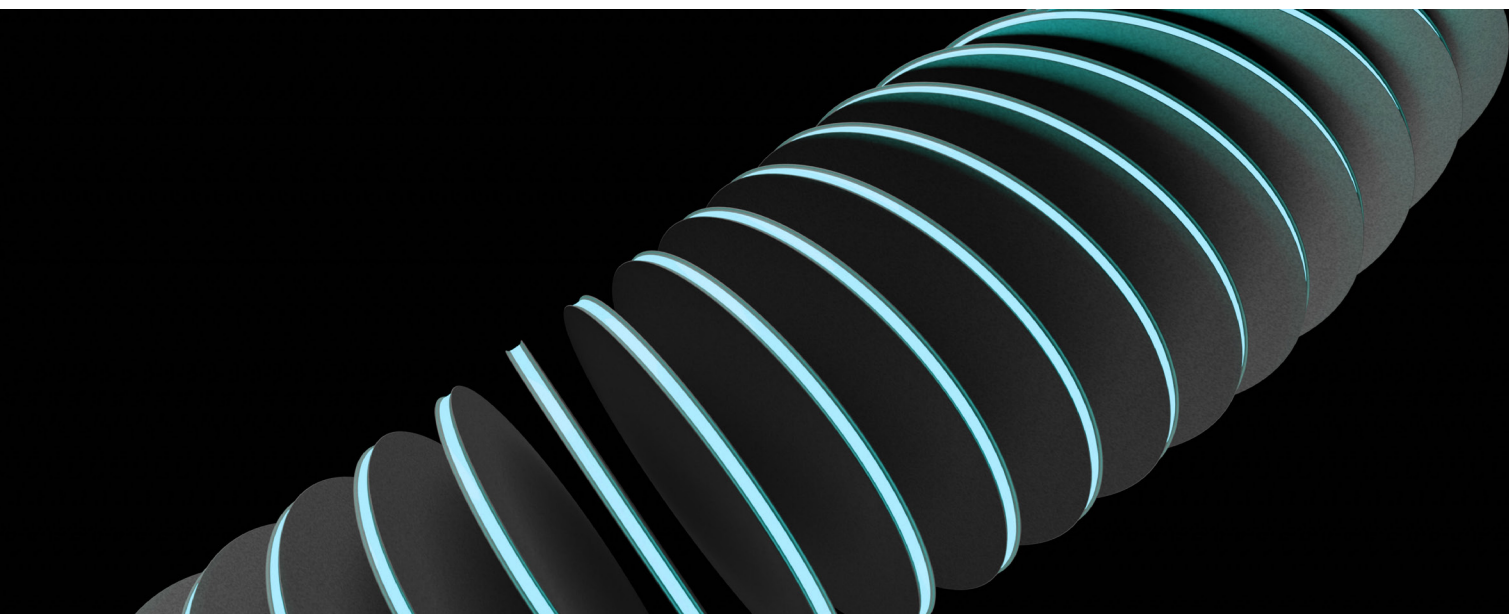
By making use of a self-sovereign identity model in the platform, the consortium's main goal is for its users to have a digital identity that is owned and controlled by them, not a 3rd party entity that could represent a single point of failure. Moreover and according to [2], DLT was the missing piece to enable self-sovereign identity where by creating an infrastructure that resides in an environment of diffused trust, not controlled or owned by a single individual or organisation, such as public blockchains, it enables the tracking of ownership, to share not only identity but also verified attributes regarding people, organisations and things. Distributed identity is a cornerstone of the 5GaaS marketplace, allowing peer-to-peer business interactions and making the respective payment process much more efficient, without recurring to the traditional banking system for money transfers.

There is the potential for companies, such as public MNOs, who adopt these types of services to protect their consumer data to differentiate themselves from their competitors. Public MNO Dish and Input Output Global (IOG), established a partnership to implement an anti-piracy system, using blockchain technology⁷.

⁵ Sovrin Foundation White Paper: The Inevitable Rise of Self-Sovereign Identity

⁶ Article in International Journal on Advanced Science Engineering and Information Technology: Blockchain Technology the Identity Management and Authentication Service Disruptor: A Survey, September 2018

⁷ Dish Network Uses Blockchain in Anti-Piracy System



Tokens

An essential pillar of the 5GaaS marketplace is using Tokens in the business interactions between its different stakeholders. Tokens can be used across a wide range of applications, such as used in voting systems, to represent real-world assets and company's shares, just to name a few. Tokens can represent works of art, as a Non-fungible token (NFT) or currency, as a fungible token. In the context of the 5GaaS marketplace, tokens can be created and exchanged, usually using smart contracts, used as currency. There are several options to tokenize the 5GaaS platform, described below:

- ▶ **Proof of authority permissioned network**, where a central trusted authority (or a governance contract) can provision the wallets according to an initial conventional on-boarding contract, adding the token funds supported by a fiat collateral.
- ▶ **Use of a public network** such as ethereum and rely on a stable coin ERC-20 contract in order to avoid volatility issues and tokenize the platform. In essence, the tokens used in the marketplace transactions are what is commonly defined as a stable coin, which is still a digital currency but its value is bound to a fiat currency under the governance of a central bank such as USD and EUR.

This option can be particularly interesting for public MNOs, with the possibility of creating a token for customer loyalty programs, replicating what airlines companies have done with air miles. Should MNOs choose to go this route, it is also possible for the platform to support other types of crypto currencies, such as bitcoin (btc) or ethereum (eth), opening an entirely new ecosystem that their customers have the ability to interact with.

THE BUILDING BLOCKS OF 5GAAS



The 5GaaS Marketplace is composed of several components, each with its own distinctive function and scope. Its main components are the Vertical Slicer (VS), Slice Manager (SM) and dRAX (part of the 5G System), which can be described as the clock wheels of the platform. These intertwined blocks come together to close the gap between the consumer's connectivity needs and the tailored service that will meet those requirements, enabling service providers to further differentiate their portfolio in a new business paradigm, where the financial transactions take place in a trustless environment, in a peer-to-peer fashion.

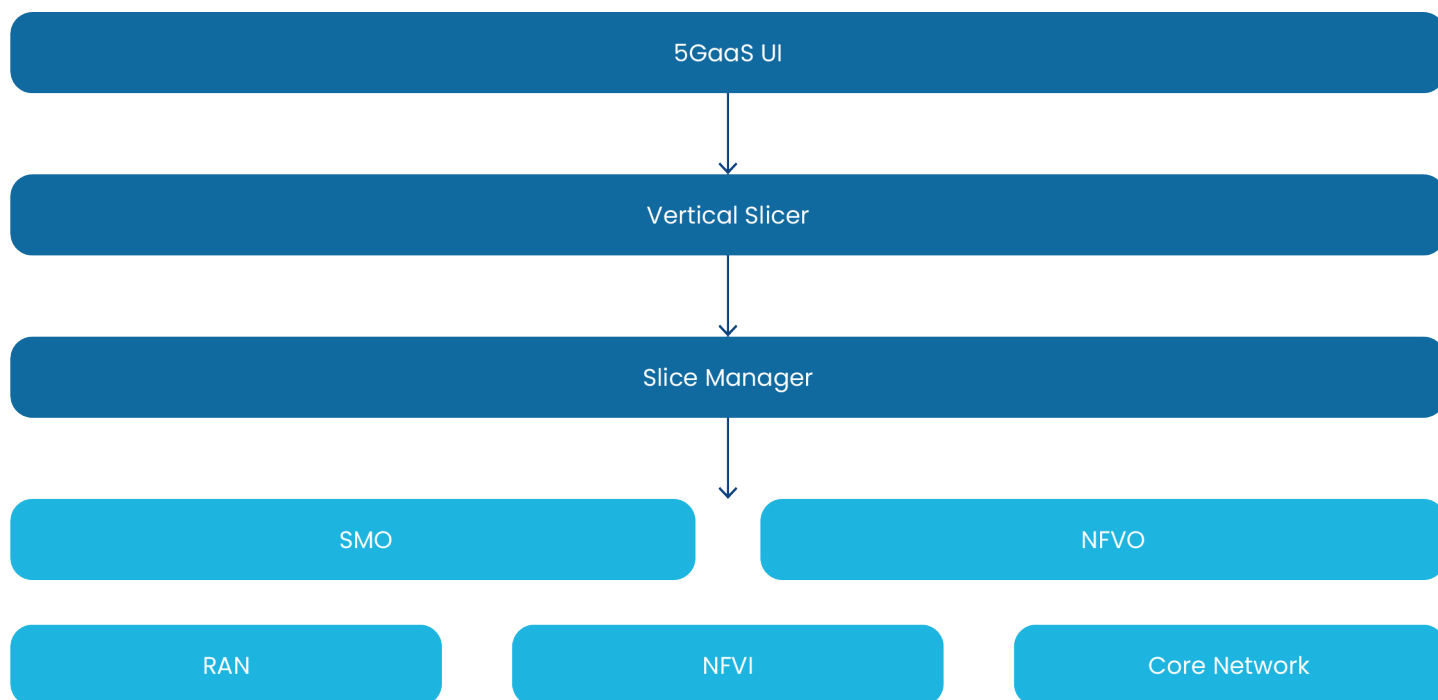


Figure 2: High level architecture of 5GaaS

The main building blocks of the 5GaaS Marketplace are highlighted in Figure 2 and described in more detail in the next section.

5GaaS User Interface

The UI is the “face” of the platform and it is designed to provide a simple and intuitive user experience, both for supplier and consumer. In the 5GaaS UI, the service providers can make use of the pre-configured Network Slices (NS) to easily create

several service offerings with distinct Quality of Services (QoS) characteristics, as exhibited in Figure 3, pricing and declared upfront Service Level Agreements (SLAs) will be directly tied to the offer.

Figure 3: Steps to create an offer in the 5GaaS Marketplace

The consumer will be able to browse the existing offers from the providers, compare the service QoS parameters, price and respective SLAs from the different service providers, choosing the one that fits best to the business requirements, as highlighted in Figure 4.

These conditions will be stored in the Distributed Ledger, giving assurance that each party will fulfil their contract obligations. The provider will only activate the service once a payment has been made, and should the service provided be inadequate or with poor performance, the consumer is covered via the contract clauses inserted in the contract (SLAs).

name	description	sla type	version
nova 5b6308c258f568073093f70e	brief sla description and what it contains (KPIs, metrics, service levels, management and availability, exceptions)	service-based, customer-based or multi-level	20.12.2022
nova2 5b6308c258f568073093f70f	brief sla description and what it contains (KPIs, metrics, service levels, management and availability, exceptions)	service-based, customer-based or multi-level	20.12.2022

Figure 4: Service Level Agreements (SLAs) in the 5GaaS Marketplace

Vertical Slicer

The network services and slices which originate from the transactions in the 5GaaS marketplace are managed and orchestrated by specific MANO (Management and Orchestration) components of the 5GaaS Platform. These MANO components implement the various design and lifecycle management tasks required to define 5G network slices and their related network services in the underlying virtualization infrastructure. Examples of supported services may include eMBB services, like HD video streaming, remote video production, and remote video surveillance, or uRLLC services, like low-latency applications for remote control of industrial robots or tele-operated driving for the automotive sector.

Starting from the top level, i.e. the one exposing a Northbound interface to the Marketplace and the one closer to the Vertical/Operator application for 5G network management, the Vertical Slicer (VS) is the main functional module which can support the abstract definition and subsequent provisioning and lifecycle management of vertical services across network slices.

The Vertical Slicer is the component of the 5GaaS architecture which mediates the platform access for customers like vertical industries and service providers, offering a rich set of features to customise the desired vertical services and facilitate their deployment in the target 5G infrastructures. In particular, the Vertical Slicer provides a simplified and service-oriented interface to the verticals for browsing and selecting service offers, designing new services and requesting their instantiation following a language and an information model easy to understand for application developers and service providers without deep know-how on 5G technologies.

This approach helps in filling the gap between the verticals' interest and expertise, mostly focused on service-level and business-level requirements, and the complexity of the 5G network configuration that the network operators need to enforce to guarantee the desired QoS. The interface exposed by the Vertical Slicer can be accessed in a programmable manner via REST APIs to facilitate the integration with existing BSS/OSS platforms available on the customers' side. Alternatively, the 5GaaS Graphical User Interface (GUI) offers a graphical representation of the various steps to follow for selecting, configuring and deploying the 5G-enabled services, guiding the user through the settings of the various parameters.

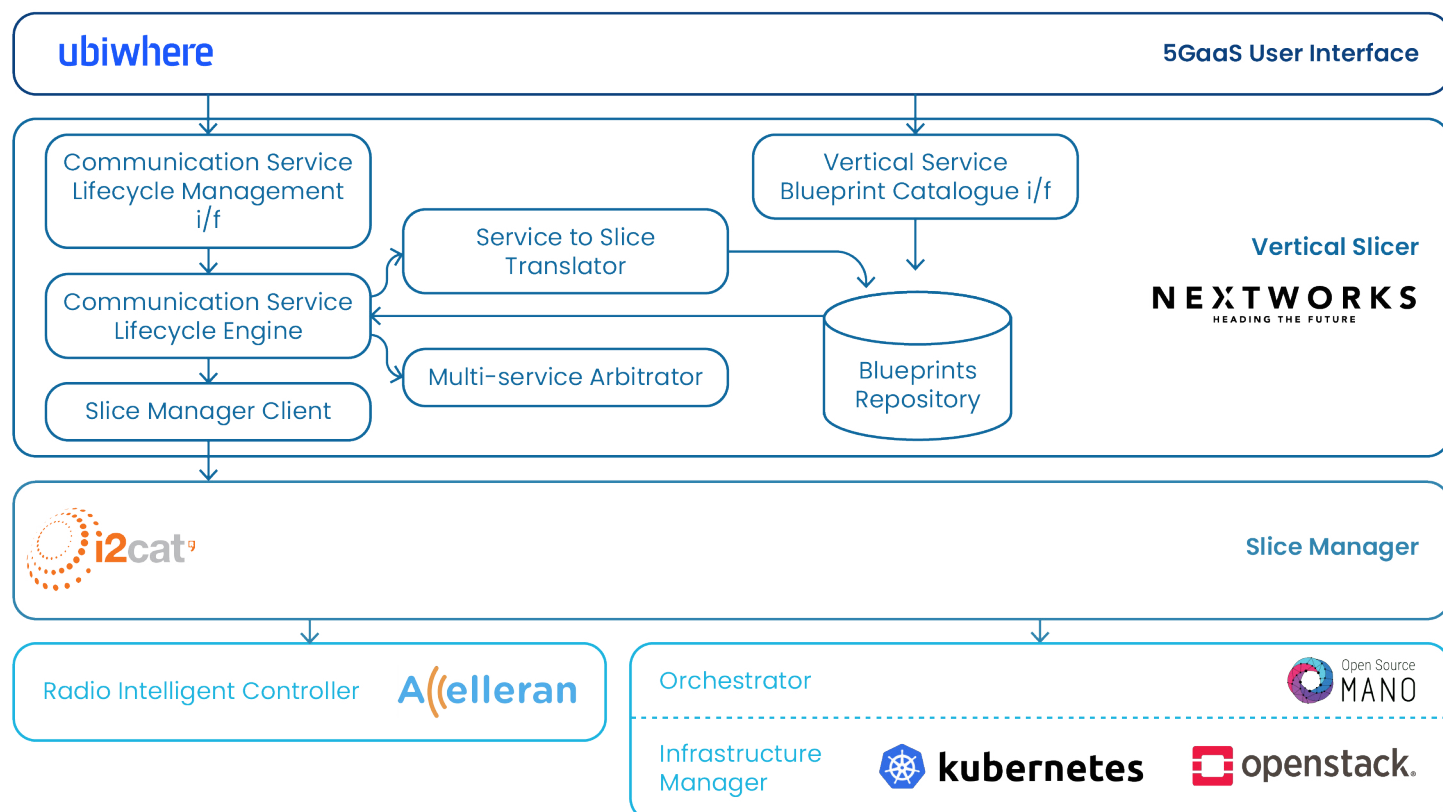


Figure 5: Vertical Slicer internal design and its interaction with the other components of 5GaaS architecture

Internally, the Vertical Slicer (see Figure 5) provides a rule-based logic to translate between the service-level and business-level requirements defined with the high-level service intent from the verticals and the concrete characteristics of the mobile connectivity to be offered by the operators.

The connectivity is automatically tailored to the vertical service requirements, deriving the composition and configuration of the end-to-end network slices to be established on the 5G infrastructure.



Moreover, the Vertical Slicer is able to arbitrate among concurrent services, potentially belonging to different tenants, based on their priority, the SLAs established with the customers, and the level of isolation required by each service. The service arbitration algorithms, combined with the resource allocation logic, optimise the overall network configuration on the basis of the current or the forecasted service demands. Finally, the Vertical Slicer implements the procedures to automate the lifecycle management of the communication services, coordinating their provisioning, runtime modifications and termination interacting with the 5GaaS Slice Manager, responsible for the management of the network slices at the 5G infrastructure level.

In the overall workflow, the VS receives as inputs abstract network slice intent definition, which describes the intended services in application requirement terms, and translates these network slice definitions into specific requests towards the underlying Slice Manager (SM). The SM provides the functionalities for the provisioning and the lifecycle management of the network slices within the virtualization infrastructure. To implement this, the SM interfaces with the NFV Orchestrator (NFVO) which covers provisioning and lifecycle management of the Network Services in the edge/core parts of the virtualization infrastructure, and RAN Service Management and Orchestrator (SMO), which implements configuration and dynamic control of the 5G radio network.

Slice Manager

Network slicing is a design of virtual network architecture utilising the similar basics behind software-defined networking (SDN) and network functions virtualization (NFV) to ensure that “actions in one slice do not negatively affect other slices” [6]. Depending on the use case and application, network slicing is used for a single physical infrastructure, allowing functionality to be placed where and when needed. The network slicing engine, which was initially developed in the 5GCity Neutral Hosting platform and is now used in the 5GaaS Marketplace. It enables the flexibility and modularity of virtualized and non-virtualized network elements on-demand and functions to be easily logically segmented, configured, and isolated into virtual networks on a single shared physical network infrastructure to meet the requirements of a particular use case, i.e., latency, capacity, processing, and resiliency, coupled with a business purpose.

At a more technical level, Figure 6 demonstrates the functional blocks by integration between the platform’s Slice Manager and the smart contract brokers. The slice manager is responsible for the functional management of the virtualization of the various infrastructure requirements and the deployment of network services. An asynchronous message queue based on Apache Kafka is needed to communicate with the various smart contract brokers handled and managed by different stakeholders. This message queue may propagate various events, which are then listened to by each broker plugged into the 5GaaS platform. Depending on the different accounting schematics specified in Solidity Smart Contracts, the final interactions with the DLT/Blockchain infrastructure will be handled by these brokers.

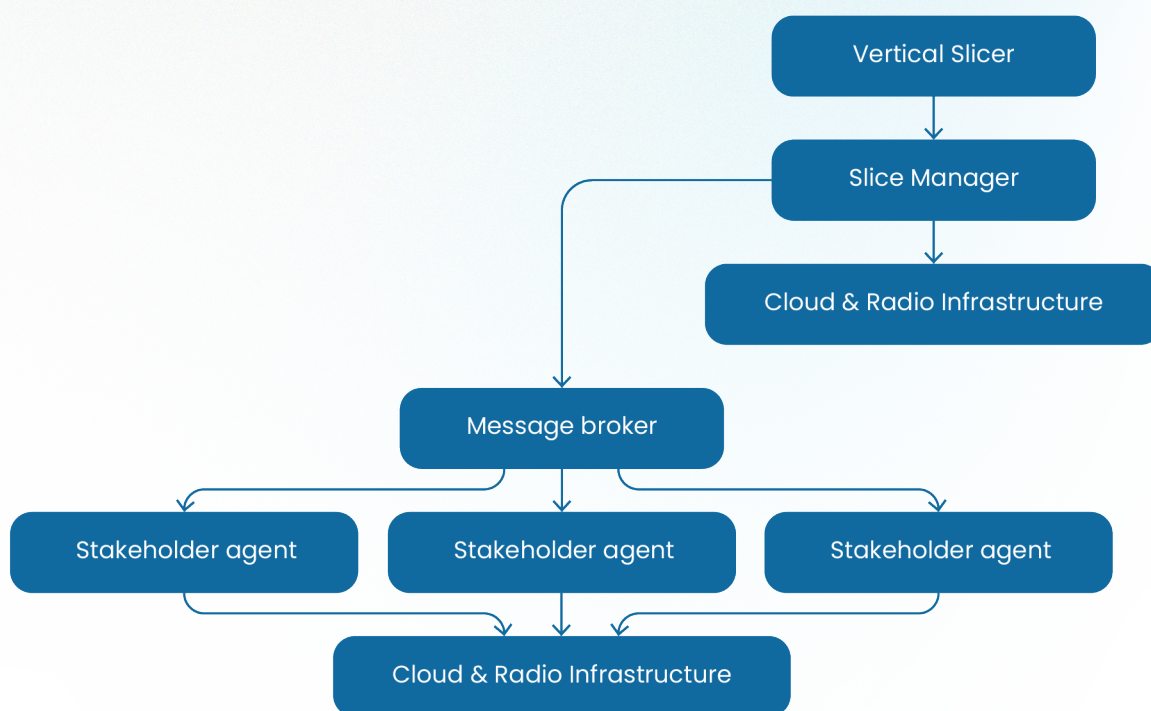


Figure 6: Integration between the platform's slice manager and the smart contract brokers

The demand for marketplaces to be more flexible and agile, with no cost to scale, is increasing. For this purpose, it is anticipated to be able to support on-demand agile businesses. In the network slice module, any network request of the 5GaaS platform is served by integrating available virtual network functions combined as a network service over network slices. The Slice Manager plays a crucial role in the 5GaaS platform, and it comprises the end-to-end service provisioning, operation, management, and termination operations per slice. In the Slice Manager module, a set of components is designed to be integrated using external and internal application programming interfaces (APIs).

The Slice Manager is responsible for interacting with the Virtual Infrastructure Manager (VIM) to control and manage resource tenants (compute and networking resources) between the physical and virtual infrastructures, as well as with the SMO to manage Radio Access Network (RAN) resources. There are three types of resource chunks considered: computing, network, and access network domain chunks, which allow operators to control, manage, and orchestrate services for various verticals. Each service offered has a particular compute and network resource chunk that is customised to its features and requirements. The main goal is to automate the managing of resources for various vertical businesses by creating multiple end-to-end logical networks via a shared virtualized infrastructure.

The Slice Manager is connected to the external features of the 5GaaS orchestration platform via an external API, while the internal APIs are utilised by the various entities composing the Slice Manager. The Slice Manager module is used to manage the infrastructure's available computing, networking, and radio resources by constructing and aggregating resource partitions/chunks to build End-to-End (E2E) slices.

The slice manager is used to enable neutral host capabilities and facilitate lease and share resources among diverse operators, tenants, and verticals. Each slice is assigned a specific SLA, which represents the relationship between slice/service users and slice/service providers as defined by various Mobile Network Operators (MNOs) to ensure and maintain an acceptable QoS policy, cloud resource management, security functions, and routing functions, among other things. The principal function of the slice manager structure is to:

- ▶ Dynamically provision and instantiate end-to-end network slices that contain computational and networking resources.
- ▶ At the network level, automated processes offer seamless and dynamic service provisioning within the resources available for the particular slice.
- ▶ The platform also enables interaction with various edge VIM technologies to improve support for multi-tenancy and multi-tier infrastructures.

RAN virtualization

5GaaS' RAN is aligned with the O-RAN architecture, moving intelligence to the Edge and splitting RAN elements connected by interoperable interfaces. Accelleran's dRAX solution includes near-RT RIC, CU-CP, CU-UP and xApp framework components, while i2CAT's Service Management and Orchestrator (SMO) is able to manage Accelleran's 5G RAN slices according to the requests from the Slice Manager.

↳ dRax

5G radio and antenna solutions were chosen to meet end-user use-case and applications.

5GaaS will initially provide FR1 5G-NR radios primarily in the mid-range (n78 3.3-3.8GHz and n77u 3.7-4.2GHz) TDD C-band. Radio units will be provided for both outdoor (with external antenna) and indoor (with integrated antenna) use with 4x4 Multiple-Input-Multiple-Output (MIMO) capabilities and typical Picocell (24dBm indoor, 37dBm outdoor per Tx port) power profiles.

The indoor RU supports IEEE 1588v2 PTP time & SyncE frequency sync whereas the outdoor RU also supports GNSS sync.

In the 5GaaS architecture, the SMO mainly provides Operation and Maintenance (OAM) and RAN Network Slice Subnet Management Function (NSSMF) functionalities, managing the lifecycle of RAN slices through the configuration and orchestration of the CU instances available in dRAX. This allows the platform to provision customised RAN slices tailored to specific services.

The selection of external commercial off the shelf antennas will be either omnidirectional or sectorized panel antennas, supporting the frequency range & power profiles. The sectorized panels (to increase gain) are typically in 65°, 90° or 120° designs.

The need to share RAN infrastructure is key to 5GaaS and will drive value addressing:

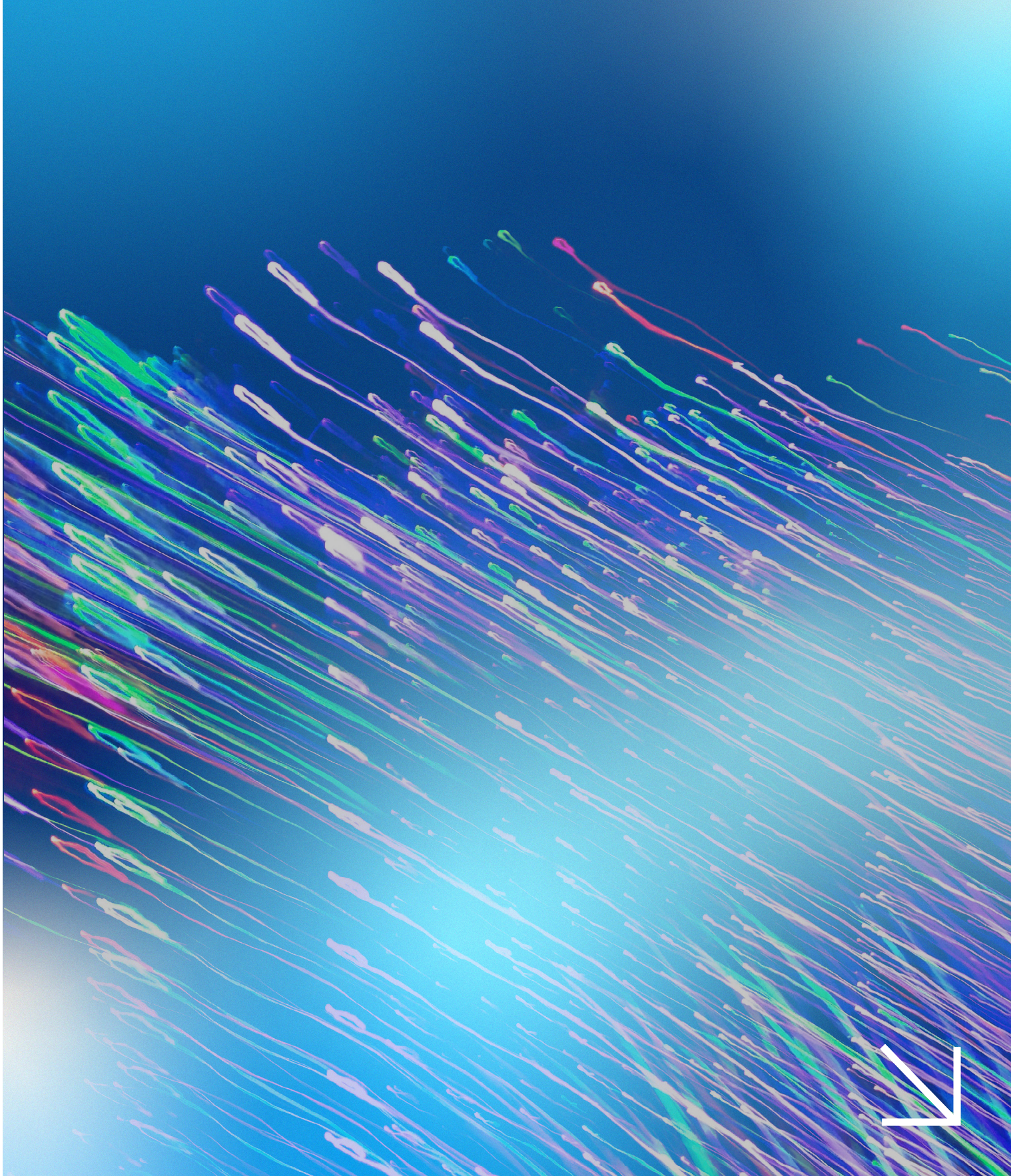
- ▶ Capital expenditures (CAPEX) and OPEX management for new network rollouts and service area expansion;
- ▶ Mitigation of planning & regulatory aspects of cell placement and backhaul provision;
- ▶ Business opportunities for infrastructure owners (like towerco's, utility providers, smart city 'urban furniture' owners) to provide outsourcing to existing.



Through Accelleran's 5G RAN network slicing solution, 5GaaS is able to establish a NG-RAN, namely with one CU-UP (and E1) instance per PLMN/SNPN (MOCN/MORAN neutral host tenant). Within these PLMN/SNPN, multiple network slices can be created which the 5GC associates to specific SMF+UPF instances (via AMF) which may be deployed at the appropriate locations (e.g., for URLLC Edge DN).

Independent of the above CU orchestration, the NG-RAN supports multiple DUs per CU (1..p) and RUs per DU (1..q). The supported cardinality will be constrained by capabilities of the hardware (including hardware acceleration), the aggregate throughput of the transport network and RU bandwidth and MIMO capabilities.

CONCLUSION



A marketplace platform is key in enabling enterprises to conduct business in a more agile way and under a service based paradigm. In order to accomplish that, 5GaaS marketplace foresees two different types of users, asset consumers and asset providers, who will interact via the platform and engage in business activities such as the purchase and sale of assets, either in the form of physical or digital products and services.

The platform's innovative building blocks enable commercial interactions in a distributed and automated manner, through smart contracts and DLT. MNOs and CSPs can offer their connectivity services in the form of network slices, making use of the platform's feature of translating specific application requirements, such as latency, reliability and expected data rate, into network requirements. With 5GaaS, the service creation (slice flavour) is tailored to the vertical customer needs, while managing the complete lifecycle management for each slice/service.

The 5GaaS Marketplace relies on an innovative way, using distributed ledgers, for the advertisement of offers in the platform. This enables subsequent actions of brokering among alternative offers and selection of best resources. Additionally, combining this feature with the management and orchestration run at the various levels of the virtualized infrastructure will allow the implementation of highly flexible network reconfigurations, making it possible for MNO's and CSP's to quickly adapt to new demands. Described below, the main benefits that MNO's and CSP's have in using the 5GaaS platform:

- ▶ One stop shop for consumers, such as verticals, and suppliers of 5G related services (MNOs and CSPs).
- ▶ The platform provides a friendly UI that allows the collection of the service requirements from the verticals.
- ▶ With these inputs, the platform automatically translates them to network requirements, based on predefined rules, and allocates the needed resources, "slicing" the network, while managing the service life-cycle.
- ▶ The platform also provides an automated payment system, via Smart Contracts and Tokens, where SLA conditions can be included.
- ▶ By deploying the smart contract into a Distributed Ledger, both provider and consumer can be assured that the contract terms will not change, interacting in a trustless environment.
- ▶ The project will demonstrate this Network Slicing capability, with preliminary BSS/OSS capabilities as above, in the context of the energy vertical and its requirements for a low latency and high reliability service.
- ▶ The market platform should be understood as a provisioning and possible technical and commercial accounting functional block, to be tailored into the MNO OSS/BSS environment;

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