A Marketplace Solution for Distributed Network Management and Orchestration of Slices

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***Abstract*—The H2020 Distributed management of Network Slices in beyond 5G (MonB5G) project aims to provide zero-touch management and orchestration to support network slicing at scale to reduce the management burden on mobile operators by leveraging distribution of operations along with advanced data-driven Artificial Intelligence (AI)-based mechanisms. However, while this approach shows promise and large companies with abundant data and ML expertise are developing powerful ML-driven services, a critical aspect that remains to be analyzed is its business case. The vast majority of potentially valuable ML services, such as predictive maintenance, Quality of Service (QoS) optimization, network security enhancements, remain stuck at the idea or prototype stage. This paper delves into an analysis of how the MonB5G solutions in particular the tuples (Monitoring System (MS), Analytics Engine (AE), Decision Engine (DE) and Actuator (ACT) could be applied within the network management and orchestration market while investigating various business models and value chains. Numerical results based on experimental data have also been performed to evaluate the OpEX (Operational Expenditure) benefits associated with different network management techniques, for centralized and distributed systems.**

***Keywords*—business models, network slicing, network management, closed loop.**

I. Introduction

The advent of data-driven decision making, powered by Artificial Intelligence (AI) algorithms, is revolutionizing society and business and having profound positive impacts on our daily lives. At the same time, around the world, mobile network operators face significant challenges as managing large scale network services become more complex. The true value of management of network data lies in its contextualization and integration with other data sources, opening up possibilities for new services and products for network management and orchestration space. To fully realise the potential of network management data for society and the economy, it must be combined with AI and business management capabilities. Despite its tremendous potential and initial growth, the marketplace solution for network management is still in its early stages, leading to an uncertain future and some existential challenges. This is mainly because the necessary combination of data, data manipulation skills, and viable business models rarely exist within the same organization. These challenges span a wide range of technical issues from various disciplines in telecommunications, including communication theory, machine learning, distributed systems, security, and privacy. In this paper, we explore a network management marketplace solution in which various actors such as service providers/controllers and intermediaries, often in the form of management data marketplaces or network management systems, facilitate the control and monetization of management data or services by mobile operators.

Web 3.0 has the potential to change the way companies buy and sell their products. Hence, several business models have been explored in many aspects [1] mostly focusing on non-networking applications. 5G-PPP has recently published a whitepaper describing the blueprint of a marketplace for network applications [2]. TM Forum has introduced the Open Digital Architecture (ODA) [3] which presents scenarios for Business and Infrastructure Functions. These functions are implemented using technology-neutral "flavours," allowing for flexible and versatile implementations. Several marketplaces for network applications are present. EVOLVED-5G Marketplace[1] offers a wide range of tools to create, manage and connect to network applications for various vertical

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[1]Online: https://marketplace.evolved-5g.eu/, Available: July 2023.

use cases. 5GASP marketplace[2] functions similarly to the stores for mobile applications and offers a variety of network applications from different industries. Key advances in business models for 5G networks, and Mobile Network Operators (MNOs) in particular, from the perspectives of industry, use cases, and the research community, are explored in [4]. Various business models and scenarios, including value chains between new players specifically for 5G offloading scenarios, are presented in [5]. The whitepaper in [6] discusses the opportunities for novel, sustainable, and open ecosystem business models for the future 6G systems. Four scenario themes and a total of 16 alternative future scenarios for the business of 6G are proposed in [7]. A blockchain enabled 6G business is proposed in [8] for scalability, replicability and sustainability.

However, most of the previous studies have focused on analyzing typical network application scenarios without considering the potential business models and scenarios for offering AI-driven solution tuples in the management layer for network management services, taking into account the benefits for mobile operators. This paper aims to fill this gap by presenting a framework that explores the business models, marketplace solutions, involvement of actors, new technologies (e.g., AI techniques and Blockchain Networks (BCNs)) when implementing the MonB5G platform for network management within a mobile operator's business ecosystem. The structure of this paper is as follows: Section II introduces the general marketplace solution for distributed network management and orchestration of slices. Section III presents list of stakeholders and various business case analyses with network management Application Programming Interfaces (APIs). Section IV calculates energy and cost expenditure for an example Virtual Reality (VR) streaming application in the context of network management and orchestration. Finally, Section VI provides the concluding remarks.

II. Marketplace for Network Management

Designing a marketplace solution for distributed network management and orchestration of slices requires careful consideration of various aspects, including architecture, systems, and protocols. By carefully considering these design elements, an efficient, flexible, and secure environment for managing and orchestrating network

[2]Online: https://portal.5gasp.eu/services/services_marketplace, Available: July 2023.

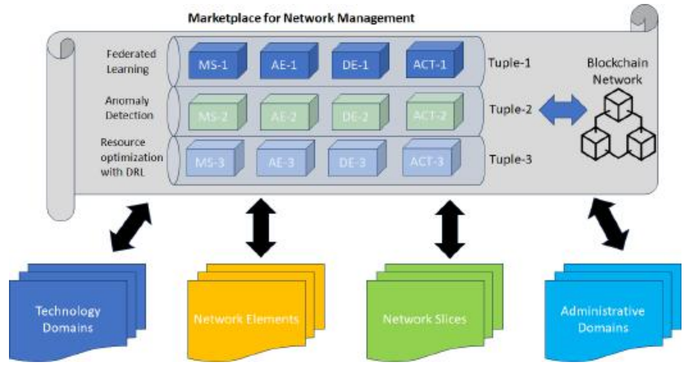

Fig. 1: Marketplace for Network Management and Monb5G solutions as tuples.

resources in a distributed and collaborative manner can be provided. Fig. 1 shows an illustration of a marketplace solution for network management with MonB5G specific tuples, i.e. Monitoring System (MS), Analytical Engine (AE), Decision Engine (DE) and Actuator (ACT) are proposed as separate solutions for different network slices in network management, e.g., a slice designed with Federated Learning (FL) for predicting resource consumption, a slice designed for Anomaly Detection (AD) for VR streaming video application or another slice designed for bandwidth optimization with (federated) Deep Reinforcement Learning (DRL) for better resource usage and low energy consumption. Several other similar tuples for network security enhancements, quality-of-service (QoS) enhancement and predictive maintenance can also be put into marketplace. The marketplace solutions can be for different technology domains of a MNO, network elements, network slices or administrative domains (i.e. multiple MNOs). Additionally, BCN can enhance the marketplace's functionalities such as security, transparency, and automation advantages, enhancing its overall efficiency and reliability. By offering a diverse range of network management solutions through the marketplace, network operators can access cutting-edge technologies and services tailored to their specific needs. This collaborative ecosystem fosters innovation, cooperation, and cost-efficiency, ultimately driving the advancement of network management and orchestration in 6G era.

III. Stakeholders and Business Models

A. List of stakeholders

Fig. 2 shows MonB5G's Slice lifecycle business model. Roles of stakeholders in the MonB5G ecosystem are as follows: (i) The infrastructure provider owns and manages the physical network infrastructure, including cellular, backhaul, data centers, etc. It is responsible for provisioning and maintaining the network, but does not interact directly with end users. (ii) Network Slice Provider creates and prepares logical partitions of communication networks (slices) and offers them to tenants. It also allocates and manages resources based on tenant requirements, ensuring isolation between slices. (iii) The Network Slice Management Provider manages the entire lifecycle of network slices, from development to instantiation to closed-loop operation. It oversees autonomous management processes, policy enforcement, and technical rules. (iv) The slice tenant is the customer/operator of the slice. It submits slice provisioning requests to the slice provider and agrees to Service Level Agreements (SLAs) for specific Key Performance Indicators (KPIs). (v) The service/content provider uses the network infrastructure of a mobile network operator based on predefined SLAs . It requires interaction with infrastructure providers for network resources and SLA negotiations. (vi) The end user uses services/content or slices provided by other actors.

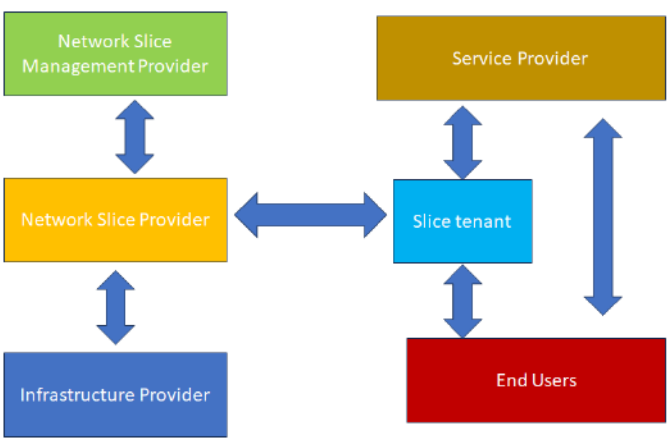

Fig. 2: MonB5G's slice lifecycle value chain.

B. Various business models with network management APIs

APIs facilitate communication between software systems and enable the exchange of data and functions. Network management with AI-driven closed control loops API monetization is about generating revenue by offering APIs to vertical industries, Service Providers (SPs), MNOs and vendors. As APIs become critical in modern technology ecosystems, especially in network management, finding effective ways to monetize them has become essential. Selecting the right monetization strategy depends on factors like the target market, competition, value proposition, and customer needs. A combination of different methods may be used to maximize revenue and cater to different customer segments. A business canvas model for network management marketplace solution is provided in Fig. 3.

To monetize the network management with AI-driven closed control loops, several business models can be followed: (i) API providers may offer different levels of API access to MonB5G tuples via subscription plans with fixed recurring fees. Each level may offer different MonB5G features (e.g., anomaly detection, FL), support, or usage restrictions. (ii) Network management API providers can provide customization and consulting services to help industries, SPs integrate MonB5G specific network management with AI-driven closed control loops APIs into specific, customized projects. (iii) Network management API providers may offer a free basic version of the API and charge for advanced features or higher usage limits. (iv) Network management API providers can monetize APIs by licensing access to network management specific datasets used for network analysis, testbed activities, or integration with other systems. (v) Network management API providers can charge industries or MNOs based on API usage using pricing models (such as pay-as-you-go, tiered pricing, or metered billing). (vi) Network management API providers may offer additional tools, plugins or network services that can be monetized through fees or royalties. (vii) Network management API providers can provide APIs to the industry for free and take a percentage of industry revenue from network management applications built on the API.

IV. Cost Expenditure for Network Management

This section relies on energy computation and energy comparisons between the Centralized SLA Constrained deep Learning (CCL) [9] and the Statistical Federated Learning (StFL) [10], [11] algorithm previously studied in [12]. In CCL, training is done in a central location considering SLA constraints during model training. In StFL, the FL local task is designed to effectively capture the intricate long-term statistical patterns of the desired KPIs while considering SLAs. This is especially important considering that the learning process takes place using historical data sets, which leads to the inclusion of data-dependent constraints. StFL or distributed learning algorithms (e.g., federated DRL as another example in a slice) can be used in a network management marketplace

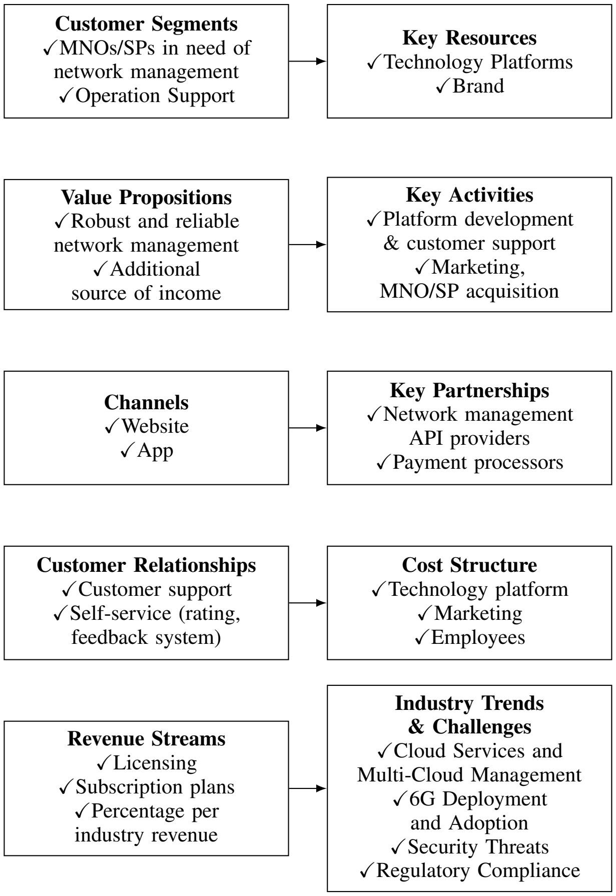

Fig. 3: Business Model Canvas for Network Management Marketplace Solution

solution to enable efficient and privacy-preserving data processing and model training across distributed network nodes and to leverage the collective intelligence of the distributed network nodes without compromising data security. They can be used to enable collaborative model training, network anomaly detection, traffic prediction, resource optimization, and other advanced network management tasks at various network slices.

To convert the energy consumption of the decentralized and centralized algorithms into Operational Expenditure (OpEX), we used additional information regarding the cost of power per unit (e.g., cost per Watt) and the time period for which the power is consumed (e.g., cost per hour). Later, the OpEX savings is obtained by multiplying the power consumption at each data point of the method by the corresponding cost per unit and time period. The formula in (1) represents the cost calculation in Euros for a given energy consumption in millijoules (mJ) based on the price per kilowatt-hour (kWh). The formula calculates the cost of energy consumption by converting the energy consumption from millijoules to kilowatt-hours. To do this, first it converts millijoules to joules by dividing the millijoules by 1000 to get joules. Then, it convert joules to kilowatt-hours by dividing the joules by 3,600,000 (the number of joules in a kilowatt-hour).

$$Cost(Euro) = \frac{X}{1000 * 3,600,000} * price[Euros/kWh] \tag{1}$$

where Cost (Euro) is the cost in Euros spent for network management task (training in particular). X represents the energy consumption in millijoules. Millijoules is a unit of energy, and used in the formula to represent the amount of energy consumed. Price (Euros/kWh) is the price per kilowatt-hour (kWh) of energy consumption and indicates the cost in Euros to consume one kilowatt-hour of energy. A kilowatt hour of electricity (kWh) cost in Spain is provided based on the daily electricity market or pool for PVPC and indexed rates[3].

Fig. 4 represents the "Total Training Cost" in cents for two different components, denoted as "CCL" and "StFL," over a 24-hour period. Energy cost calculations are scaled for 52 GB of training data, with the original sample data size of 52 KB [13] from VR streaming traffic [12]. The figure shows the cost of each component at different times of the day. The average cost for StFL is 0.46 Euros, while for CCL it is 5.2 Euros over the 24-hour period. The peak hour (time when the maximum value is reached) is at 10 pm and the trough hour (time when the minimum value is reached) is at 3 pm. Note that the total training cost is lower in the StFL approach compared to CCL, showing the advantages of the distributed training approach. Note also that training costs are higher for larger datasets, further increasing the benefits of distributed learning for network management and orchestration.

V. Discussions and Future Work

A. NFTs, Blockchains, Smart Contracts and their role in network management marketplace solution

Non-Fungible Tokens (NFTs), BCNs and smart contracts play an important role in a network management marketplace solution and offer unique advantages in terms of security, transparency and trust. They can

[3]Online: https://tarifaluzhora.es/info/precio-kwh, Available: August 2023.

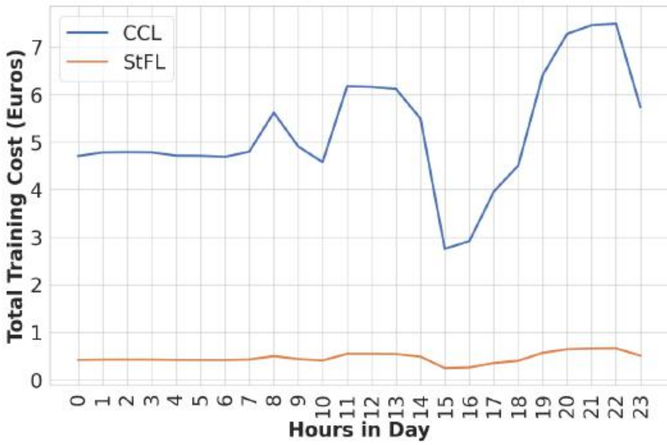

Fig. 4: Total cost in Euros training in management plane for StFL and CCL.

establish a secure, transparent, and decentralized ecosystem where participants can efficiently trade and manage network services and resources. These technologies can also contribute to the overall reliability and efficiency of the marketplace, while promoting a trustful environment for all stakeholders involved.

NFTs are unique digital tokens that represent ownership or proof of authenticity of digital assets. In the context of a network management marketplace solution, they can be used in various ways: (i) to verify the identity of network nodes, SPs, and users within the marketplace where each participant can have a unique NFT associated with their digital identity, providing a secure and tamper-resistant way to grant access and permissions. (ii) to represent ownership of network slices, services, or resources where tokenization of these assets allows them to be traded, transferred, or leased in the marketplace, enabling a decentralized and transparent marketplace for network services. (iii) to serve as proof of compliance with network regulations or policies. For instance, SPs can mint NFTs to demonstrate that they adhere to specific QoS requirements or security standards.

Integrating BCNs into a network management marketplace solution brings several advantages including (i) All transactions based on execution of AI-based algorithms and changes to network configurations based on the logic of MonB5G tuples (MS, AE, DE and ACT) are recorded on the BCN, providing transparency and traceability to all market participants. (ii) Once transaction data is recorded on the BCN, it cannot be modified or deleted, ensuring the integrity and immutability of important network information. (iii) BCNs operate in a decentralized manner and enable consensus among multiple nodes, reducing the need for central authority in managing the network. Smart contracts can play an important role in automating and enforcing rules within a network management marketplace solution in several ways: (i) They can enable automatic execution of predefined actions based on certain conditions. For example, when a user requests a network slice, a smart contract can automatically check resource availability, make the payment, and allocate the slice. (ii) Because smart contracts run on the blockchain, they offer a high level of trust and security, as their execution is transparent and tamper-proof. (iii) Smart contracts can be used as a decentralized escrow service that ensures that payments are only released when certain conditions are met, which strengthens trust between the parties.

B. *Cryptographic Approaches*

Cryptographic approaches, including Fully Homomorphic Encryption (FHE), Secure Multi-Party Computation (SMPC), and Differential Privacy (DP), play important roles in enhancing the security and privacy of data and computations within a network management marketplace solution. They can be deployed to protect sensitive data by encrypting data and performing computations without decryption using FHE ensures sensitive information remains confidential. SMPC can facilitate joint computations among multiple network nodes while preserving data privacy. DP can enable the release of aggregated network statistics without revealing individual user data. However, the adoption of cryptographic approaches in a network management marketplace solution requires careful consideration of the following trade-offs: (i) Cryptographic techniques can introduce significant computational costs, potentially affecting the system's overall performance and responsiveness. (ii) Secure collaboration and privacy-preserving computations can lead to increased communication overhead among network nodes. (iii) Applying privacy-preserving techniques like DP may impact data accuracy, necessitating a balance between privacy guarantees and data utility.

C. *Standards and protocols*

Standards and protocols in a network management marketplace solution are essential to enable seamless communication and collaboration among different stakeholders, services, and network domains within the marketplace ecosystem. These standards and protocols ensure that various components can work together cohesively, promoting interoperability and scalability , and the ability to deploy diverse services and applications while ensuring a cohesive and interoperable ecosystem in a network management marketplace solution. Some common standards and protocols that can be used in the context of federation and network management are: *NGNM-F (Next-Generation Network Management - Federation):* a framework that defines the principles and architectural guidelines for federating network management systems. It aims to enable cooperation between independently managed network domains, facilitating cross-domain management and resource coordination. *TOSCA (Topology and Orchestration Specification for Cloud Applications):* is an OASIS standard that defines a language for describing cloud application topologies and their management processes. It enables the definition of service templates and orchestration plans, promoting interoperability between different cloud platforms and management systems. *YANG (Yet Another Next Generation)* is a data modeling language used to describe the configuration and state data of network elements. It is commonly used in conjunction with NETCONF (Network Configuration Protocol) and RESTCONF (RESTful Network Configuration Protocol) to enable standardized communication and configuration of network devices. *REST APIs (Representational State Transfer Application Programming Interfaces)* provide a standardized way for different services and systems to interact and exchange information over HTTP. They promote interoperability by defining uniform communication interfaces and data formats. *IPFIX (Internet Protocol Flow Information Export)* a standard protocol for exporting flow information from network devices, facilitating the collection and analysis of network traffic data. It promotes interoperability between different flow analyzers and collectors. *OAuth (Open Authorization)* is a protocol that allows secure authorization and delegation of access rights between services, enabling smooth integration and authentication between different components in a network management marketplace solution.

VI. CONCLUSIONS

Innovation in network management and AI has the potential to bridge the gap between cutting-edge technology and its monetization, and ultimately contribute to the evolution of network management and orchestration practices in the dynamic landscape of 5G networks. In this paper, AI-driven network management solutions that come in the form of tuples (MS, AE, DE and ACT specific to each network management problem are offered as a marketplace. This marketplace allows developers of network services to engage with potential users (e.g., MNOs and vertical SPs), streamlining the commercialization process and simplifying access to such services for commercialization. These components can work together in many intelligent systems, including network management systems, to enable efficient and automated decision-making and control.

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