O-RAN SMO Extension for enhanced RIC Use-Cases

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***Abstract*—Network management systems for beyond 5G (B5G) and 6G networks today require efficient approaches for handling increased heterogeneity, network-function dis-aggregation, performance requirements, and optimizing networks to support highly diverse use cases. While the Open-Radio Access Network (O-RAN) Service Management and Orchestration (SMO) frameworks efficiently manage RAN and cloud infrastructure, the fragmentation of management platforms across RAN, Core Network (CN), and Transport Network (TN) introduces operational inefficiencies, particularly in Non-Public Networks (NPNs) deployments. This paper proposes a novel extension to the O-RAN SMO architecture, integrating CN and TN management functionalities into a unified control framework. By exploiting AI/ML-driven x/rApps and a converged data analytics pipeline, the proposed architecture enhances SMO's fault management, resource optimization, and service continuity capabilities. Our implementation validates the feasibility of the proposed SMO extension, demonstrating subscriber-specific QoS assurance through O-RAN-based mobility management mechanisms. The proposed approach successfully shows how RAN-/Core-converged SMOs enable significant enhancements to O-RAN's x/rApps, allowing for subscriber-specific as well as application-specific differentiated QoS assurance.**

***Index Terms*—SMO, 6G, O-RAN, RIC, OAM**

I. Introduction

Amongst an ever-increasing demand for higher network performances, the trajectory of 6G mobile broadband telecommunication networks is driven by the emergence of highly customized and specialized Non-Public Networks (NPNs) and the proliferation of dis-aggregated and highly programmable Radio Access Networks (RANs), such as Open-Radio Access Network (O-RAN). O-RAN-based NPN trials have already shown significant potential by leveraging RAN Intelligent Controllers (RICs) and Artificial Intelligence/Machine Learning (AI/ML)-based x/rApps for Quality of Service (QoS)-, resource-, energy-, mobility-management, and optimization. However, the O-RAN Service Management and Orchestration (SMO) architecture is currently limited to the management of RAN and Cloud infrastructure. This results in a need for implementing, deploying, and managing separate management platforms for RAN, Core Network (CN), and Transport Network (TN). Public telecommunication networks today utilize diverse and concurrent management systems to perform Fault, Configuration, Billing/Accounting, Performance, and Security (FCAPS) service and network management activities across different network infrastructure domains. In addition, each of these infrastructure domains can introduce multiple levels of vendor-specific hierarchical control (e.g. the Telecom Infra Project (TIP)'s Mandatory Use Case Requirements for SDN for Transport (MUST) architecture for optical networks). Beyond the challenges of orchestration and synchronization across multiple domains, such hierarchical control within each domain adds further layers of complexity in terms of implementation, deployment, and maintenance, as analyzed in our previous work [1]. While these complex network management systems are still typical for large-scale, public telecommunication networks, they prove to be exceedingly intricate and inefficient for smaller NPNs. NPNs are typically designed for a unique range of applications such as smart manufacturing, logistics, healthcare, and education, which typically demand unique end-to-end connectivity, security, and performance requirements. Furthermore, amalgamating management and monitoring data from different network domains, and allowing AI/ML mechanisms to exploit this data, offer significant potential for enhancing operational efficiency, enabling proactive fault detection, optimizing resource allocation, and improving overall network performance. Thus, the integration, unification, and harmonization of these management platforms is essential for streamlining operations and enhancing efficiency for NPNs. Drawing on the O-RAN SMO architecture, this study proposes an expanded approach towards an integrated SMO architecture, aiming for a unified management of RAN, CN, TN, and cloud infrastructure. The implemented and evaluated QoS assurance use case successfully proves how RAN-/Core-converged, unified SMOs are able to significantly enhance O-RAN-based NPN optimization mechanisms.

The remainder of the paper is structured as follows. An overview of relevant background and related work is provided in Section II. Section III details the key requirements for such an extension while Section IV elaborates the extension proposals by outlining the components and interfaces. As a synthesis, the fully extended, converged SMO architecture is summarized in Section V. In addition, it provides a brief overview of the challenges and scope of our future research. Section VI presents a prototype of a converged RAN- and Core-SMO. A QoS assurance use case harnessing the converged SMO's enhanced capabilities is presented and evaluated, highlighting the feasibility as well the advantages of such an extended and integrated SMO architecture. Finally, Section VII concludes our paper.

II. Background and Related Work

A. Background

As Network Functions Virtualization (NFV) extended the Software-defined Networks (SDNs) concept to virtualize Network Functions (NFs) such as routing, firewalling, 5G introduced virtualized RAN (vRAN) and utilized NFV in the radio domain. The 3rd Generation Partnership Project (3GPP) released technical specifications for 5G which introduced the New Radio (NR) interface and 5G Core network [2] enabling applications from enhanced mobile broadband to ultra-reliable low-latency and massive machine-type communications. Termed "Open RAN", 3GPP defined functional split options between Centralized Unit (CU), Distributed Unit (DU), and Radio Unit (RU), disaggregating formerly monolithic eNodeBs (in Long Term Evolution (LTE)) and gNodeBs (in 5G) [3]. To foster an open, interoperable ecosystem, the O-RAN ALLIANCE developed an architecture for virtualized and dis-aggregated RAN on open hardware and cloud platforms, complementing 3GPP standards. O-RAN enhances interoperability by standardizing RAN elements and interconnection standards for Commercial Off-The-Shelf (COTS) hardware and open-source software from various vendors.

The European Telecommunications Standards Institute (ETSI) significantly pioneered NFV standards by extensively exploring network virtualization addressing Virtual Network Function (VNF) management and orchestration, performance, reliability, and security. ETSI's ongoing initiatives include Multi-access Edge (MEC) for edge cloud computing, Experiential Networked Intelligence (ENI) for AI-driven network operations, and Zero-touch Network and Service Management (ZSM) for automated management in multi-vendor environments [4]. However, application management falls outside ETSI NFV's scope and is typically handled by RAN groups like 3GPP Stand-Alone Serving Mobile Location Center (SMLC) (SAS). The O-RAN SMO addresses this gap by defining interfaces for application configuration on O-RAN-managed elements and managing the lifecycle of NFs on the O-Cloud. The O-RAN SMO facilitates Operations, Maintenance, and Administration (OAM) in an O-RAN. Key components such as the non-real-time Radio Intelligent Controller (NonRT-RIC) execute non-real-time control loops or tasks (>=1s) including policy management, service lifecycle management, network orchestration, resource optimization while supporting third-party applications, called rApps, to provide value-added services to these tasks. The near-real-time (NearRT) tasks of dynamic network adjustments and metric collection of the NearRT-RIC are influenced by the SMO via the A1 interface. The SMO is further capable of configuring all O-RAN components, including the NearRT-RIC, and supporting lifecycle management of O-RAN nodes, such as startup, configuration, fault-tolerance, performance assurance, trace collection, and software management, via the O1 interface. In a cloudified environment, where the O-RAN network elements are implemented as VNFs, the SMO uses the O2 interface for managing and provisioning these NFs [5].

B. Related Work

An important aspect of the SMO architecture of the O-RAN is its exclusive focus on the management of RAN and Cloud. This limitation complicates end-to-end network management for small and private campus networks, as it requires multiple management systems or SMOs to handle all aspects of the network, including the TN and the CN. Furthermore, it underscores the need for synchronization and communication among different SMOs, which falls outside the current scope of the O-RAN SMO architecture, thus challenging interoperability between SMOs. In [6], the authors highlighted a similar challenge of interoperability of SMOs. They proposed to enhance the O-RAN SMO to incorporate management and orchestration components from 3GPP and ETSI, while unifying interfaces to ensure interoperability among the NonRT-RIC, ETSI-NFV Management and Orchestration (MANO), and 3GPP-Network Slice Management System (NSMS). However, the study did not delve into the role of individual controllers and their management of specific components, such as transport links, within the O-RAN architecture. Therefore, as presented in Figure 1, we propose a unified SMO framework by extending the scope of O-RAN SMO management to TN and CN, eliminating the need for individual SMOs or management functionalities for corresponding network aspects. The study in [7] proposed the convergence of RAN computing and communication capabilities, and while doing so, introduced an SMO extension to include a joint communication and computing service, exposed to external consumers such as Service Providers. This further underpins the common service exposure and communication discussed in the following sections.

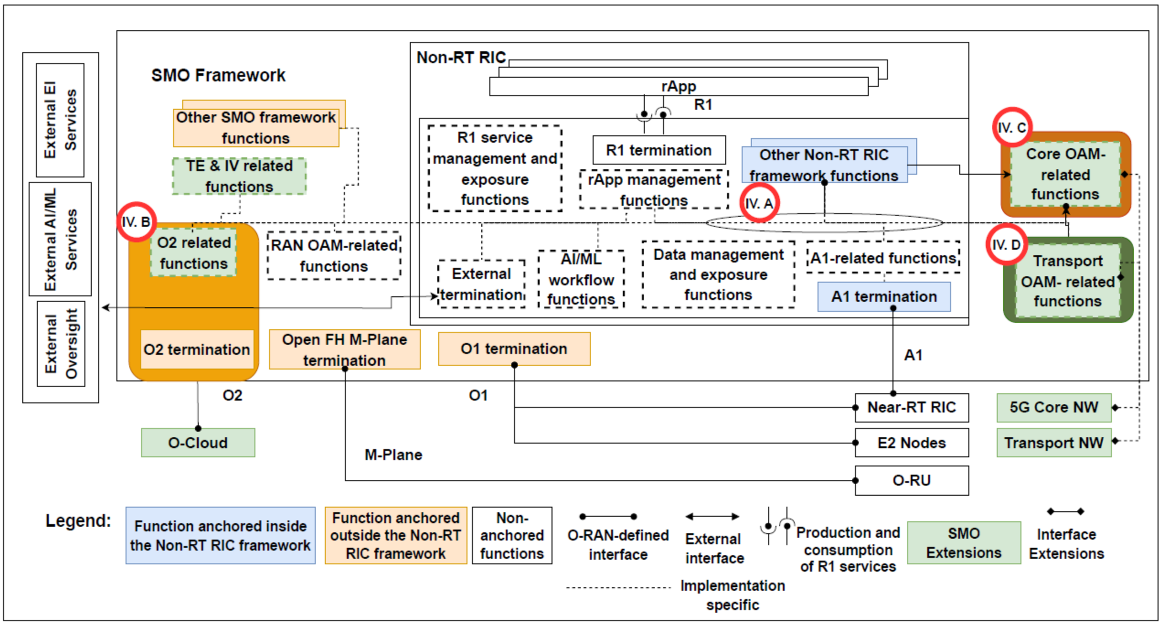

Fig. 1: O-RAN SMO Extensions for Core and Transport Network Management, based on [8]

III. SMO Extension Requirements

Designing the O-RAN SMO towards a unified network management framework involves creating a modular, scalable, and secure platform with unified and interoperable interfaces for comprehensive control and secure cross-domain data exchange. Therefore, we identify the following requirements to guide such SMO extensions.

1) **Modular and Flexible Architecture:** A modular and flexible architecture is vital for the scalability and adaptability of the SMO platform. Componentization allows the system to evolve and scale without major disruptions.
2) **Data Synchronization and Consistency:** Real-time data synchronization across network domains is crucial for consistency. Mechanisms for conflict detection and resolution during data synchronization are critical to ensure data integrity.
3) **Standardized Data Models:** Utilizing standardized interfaces, Application Programming Interfaces (APIs), and data models such as YANG for configuration, TOSCA for orchestration, and OpenAPI for RESTful interfaces ensures a common framework for representing network elements and their relationships, facilitating interoperability and consistency.
4) **Data Exchange Protocols:** Modern data exchange protocols such as Google Remote Procedural Call (gRPC) for real-time communication, Kafka for event streaming, and REST for API interactions, lightweight messaging protocols like Message Queuing Telemetry Transport (MQTT) and Advanced Message Queuing Protocol (AMQP) for Internet of Things (IoT) data transfer are recommended.
5) **Automation and Orchestration:** Zero-touch provisioning and automated lifecycle management are key to reducing operational complexity and human intervention. Closed-loop automation allows for continuous monitoring and automatic corrective actions, enhancing the overall reliability and efficiency of the network
6) **Unified Monitoring and Control:** Unified and integrated network monitoring and control of RAN, CN, and TN are essential for control loops that require actions/configurations across the network. Extended r/xApps should be capable of aggregating data and executing control commands across all network elements.

IV. Extension Analysis of SMO

The core design principle of the unified SMO is to leverage and integrate existing architectural components, principles, functions, and interfaces of current standards. As highlighted in Figure 1, this section details the following four extensions:

A. Extension of Service Communication and Harmonization of Data Exchange

The O-RAN SMO covers functions specific to the RAN domain as well as generic functions that integrate across other domains and networks. To improve the interoperability and cross-domain integration of the SMO, the O-RAN ALLIANCE identifies the strong need to decouple the SMO Functions (SMOFs) and the related SMO Services

(SMOSs). As defined in [9], SMOS are the standardized cohesive set of management, orchestration, and automation capabilities offered by the SMO entities or functions, known as SMOFs. Based on the SMO capabilities in the July 2022 O-RAN specifications, the O-RAN ALLIANCE presented a decoupled SMO architecture in Figure 2 that envisions the SMO to expose all existing capabilities related to the NonRT-RIC including rApps, O-Cloud, and RAN NF OAM among all SMO entities. It is to be emphasized that this service-oriented, decoupled SMO is inspired by the 3GPP's Management Data Analytics (MDA) framework [10]. This MDA framework offers management services, known as MDA Managed Network Service (MDAS), produced or consumed by functions called Management Data Analytics Function (MDAF). MDAF leverages current and historical data from the network including RAN, CN, TN, OAM systems, and even extends to external entities including non-3GPP management systems (e.g., MANO, Verticals). Based on a publish-subscribe (pubsub) model, the framework allows the design of various business logic to produce and consume both standardized and vendor-proprietary analytics and inputs as MDA MDA Network Services (MnSs). While the MDA framework extends MnS to TN, CN, and even non-3GPP systems, O-RAN applies this design to define the SMOSs exclusively for the RAN domain. Leveraging the O-RAN's existing decoupled SMO architecture and 3GPP's MDA framework to encompass the management of TN and CN, thus, simplifies the integration of TN and CN functions as SMOFs.

The communication mechanism highlighted in Figure 2 represents this SMOS Communication, exposing all SMOSs among SMOFs. For example, the SMOS Communication exposes the RAN OAM functions such as Fault Management (FM) and Performance Management (PM) to be consumed by the NonRT-RIC and any other consumers. The rApps hosted by the NonRT-RIC analyze this data and generate actions of configuration changes that are transmitted by the SMOS Communication to the RAN Configuration Management (CM) SMOF, which then provisions network changes via O1 or Open Fronthaul M-plane interfaces. As we propose a similar inclusion of Transport and Core OAM functions, it is to be noted that the definition and integration of such TN and CN functions as SMOSs are crucial for several already existing use cases and functions. For example, the Topology Exposure & Inventory (TE&IV) SMOS is responsible for providing a global view of the network with up-to-date inventory information of O-RAN resources and their relationships. As defined by the O-RAN ALLIANCE in [9], these O-RAN resources include all elements that realize the O-RAN RAN including NFs, cloud, radio, and transport resources. Such a comprehensive view of RAN, cloud, and transport resources hence, aides services like Network Subnet Slice Management (NSSM) in identifying available or impacted

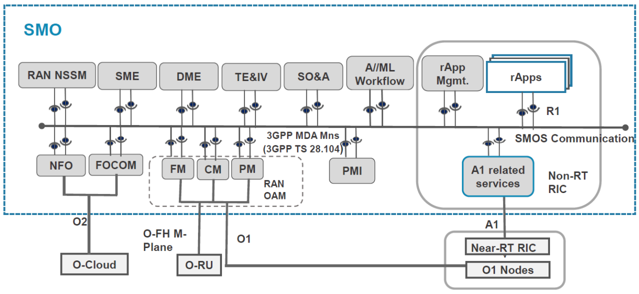

Fig. 2: Decoupled SMO architecture [9]

O-DU, O-CU, and O-RU instances. Additionally, the TE&IV SMOS supports O-RAN use cases and functions related to O-Cloud management.

Although the SMOS candidates to be standardized have been identified, the interfaces of the SMOS Communication are yet to be defined and specified. However, Working Group (WG) 2 of the O-RAN ALLIANCE extends the R1 interface such that it exposes services to the rApps that are not necessarily associated with the NonRT-RIC such as O1 access, data sharing services, or access to RAN inventory irrespective of the location of the provider of those services within the SMO Framework [11]. Being a RESTful interface that also supports Kafka for streaming data, the R1 interface thus, functionally is an integral part of SMOS Communication.

B. *Extension for CN Management*

Management mechanisms for CN management have evolved significantly across generations of mobile broadband networks. Consequently, the design of CNs as well as the Network Management Systems (NMSs) adopted Service-Oriented Architecture (SOA) principles, leading to the 3GPP's 5G Core's Service-Based Architecture (SBA) [12]. This modular and flexible framework allowed virtualization and cloud computing of CN functions further leading to the NFV architecture, referred to as ETSI GS NFV [13] allowing flexible deployment, scaling, orchestration, and provisioning of VNFs. Thus, a converged SMO should integrate the typical FCAPS management tasks for monitoring and provisioning of 5G Core NFs (CNFs) as well as the VNF orchestration and edge infrastructure deployment functions. Figure 3 representing the unified SMO architecture illustrates such as integration. 3GPP has already defined additional interfaces to directly access CNFs such as the Policy Control Function (PCF), User Data Management (UDM), and Unified Data Repository (UDR). However, the 5G Core's Network Exposure Function (NEF) provides services such as event notification, performance monitoring of User Equipments (UEs) and the network, retrieval and selection of network slices, policy enforcement, and QoS settings management to external

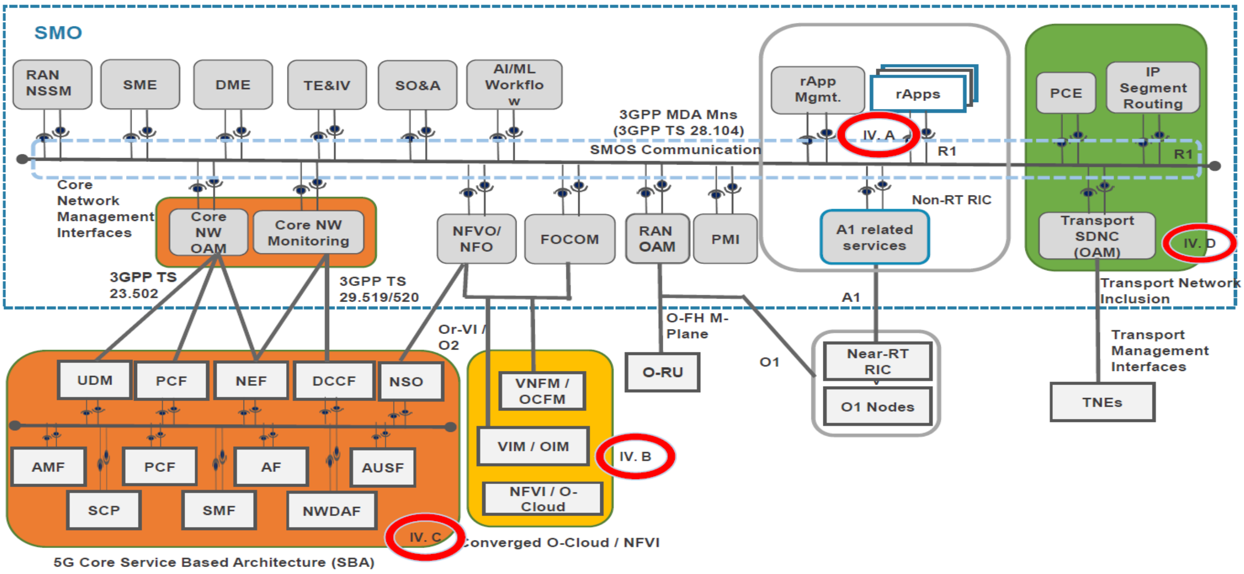

Fig. 3: Converged SMO Architecture for RAN, Core, Transport and Cloud Management

applications and management platforms. The NEF, indeed serves as the chief CNF to interwork with the SMO.

Automation is facilitated by the Network Data Analytics Function (NWDAF) that aggregates data from 5G Core NFs, the OAM, and the service domain. Although NWDAF simplifies data collection and is responsible for processing and producing analytics for consumers, such as SMO platforms and RICs, the interfaces allowing this exchange of information between the NWDAF and the SMO are still not fully defined. Furthermore, the actions that can be taken by the SMO based on the inferences of this data needs to be studied. 3GPP's Release 17 specifies the Data Collection Coordination and Delivery Function (DCCF) through which an SMO can request statistics and analytics from an NWDAF. Figure 3 presents the most relevant interfaces for an SMO to monitor and manage CNs, using the DCCF and the NEF as main interface points. Access to CN data can significantly enhance x/rApps, allowing to selectively apply and adjust x/rApps to specific subscribers, sessions, and applications. Access to static CN data such as subscriber and application profiles can serve to determine whether and how a subscriber, an application, or an end-device should receive specific x/rApp treatment (i.e., QoS, mobility, energy, etc.). optimizations). Access to dynamic CN data, such as session, UE status, location information and NWDAF analytics data can serve to dynamically adjust x/rApps to current network, UE and session states.

C. Extension for VNF Management

Similar to [14] this paper converges RAN-/Core- network management by extending ETSI's NFV approach [13] which predominantly focuses on CN function virtualization, orchestration, and management to include RAN VNF management functions, namely O-Cloud management functions. Fortunately, the O-RAN O-Cloud specifications [15] already adopt many NFV models and mechanisms. As shown in Figure 3 the SMO hosts an overarching NFV Orchestration (NFVO) function, akin to the NF Orchestration (NFO) and the Federated O-Cloud Orchestration and Management (FOCOM) function of the O-RAN architecture. These orchestrators issue high-level requests to NFV Managements (NFVMs) / O-Cloud Function Manager (OCFM) for CN and RAN NF management and orchestration, which interface with each specific Core and RAN VNF. Both NFVO/NFO and VNF Manager (VNFM)/OCFM interface with specific Virtual Infrastructure Managers (VIMs) / O-Cloud Infrastructure Managers (OIMs) for Core/RAN VNF orchestration across distributed compute resources. Future NFVOs should allow RAN and Core VNF deployment across core, regional, and edge Clouds to meet use-case/slice-specific latency requirements. Such NFVOs and VIMs should be further capable of dynamic deployment of RAN VNFs, such as CUs, NearRT-RIC and NonRT-RIC to minimize latency, outsource network management functions, and increase security and autonomy.

D. Extension for TN Management

The TN connects all the RAN components including the base stations (eNodeBs in LTE, gNodeBs / RUs in 5G) and the core network. This connectivity is vital for the efficient transfer of user data as well as signaling and control data. As emphasized in the previous section, the O-RAN ALLIANCE already defines functionalities such as the TE&IV that also require information from the TN for efficient management of the RAN network. Other services from Figure 2 such as Service Management and

Exposure (SME), Data Management and Exposure (DME), and AI/ML Workflow as SMOSs, are capable of exposing and sharing services and data with any other SMOS. Thus, defining TN SMO functionalities as SMOS makes this decomposed SMO extensible to TN management. The TNEs include a diverse range of components including routers, switches, optical equipment such as Dense Wavelength Division Multiplexing (DWDM) systems, microwave links, and aggregation switches, managed and configured by the Transport SDN Controller (SDNC). Such a SDNC can further comprise individual controller functions or Domain Controller (DC) entities. As shown in Figure 3, the inclusion of the Transport SDNC therefore, includes and defines the FCAPS management capabilities for a TN as SMOSs. This makes the SMO extensible to transport-specific applications such as Path Computation Element (PCE) or Internet Protocol (IP) Segment Routing services that consume data from the Transport SDNC SMOS and produce configuration requests in return. Our previous paper [1] investigates the feasibility of such inclusion with Open Network Automation Platform (ONAP), one of the open-source SMO frameworks available today [16]. We utilized the SDNC component of ONAP to configure the Open reconfigurable optical add-drop multiplexer (OpenROADM) switches and transponders of an optical network based on the device configurations communicated by TransportPCE and a proprietary optimizer via REST API. The SDNC, serving as an SMOS to Transport rApps like TransportPCE further demonstrated the simultaneous control of non-optical real and simulated devices including gNodeBs and microwave devices, thereby aligning with Figure 3.

V. Extended SMO Architecture

As presented in Figure 3, the extended and decoupled SMO unifies control by exposing services across domains using common definitions and procedures. It not only empowers intercommunication across different domains and services but also eliminates the need for multiple SMO implementations and orchestration mechanisms, significantly benefiting small campus networks and NPNs. While this service-based SMO highlights its potential benefits, harmonizing these services and establishing efficient intercommunication can present significant challenges and complexities. NPNs are typically designed with a small and specific set of infrastructure tailored to serve specific use cases. Understanding these requirements and identifying the services required from different domains is thus, crucial for further simplifying and optimizing this architecture. Based on these challenges, our future research will focus on SMOS Communication and the existing data formats and protocols used by the different SMOSs in Figure 3. We will also focus on the simplification of this architecture by analyzing the various southbound interfaces. Establishing effective compatibility between interfaces such as O1, O-FH M-Plane, transport management and core interfaces, and extensibility of interfaces, such as R1, to facilitate SMOS communication are essential for the realization of this architecture. In the context of security vulnerabilities, self-contained NPNs have limited or no exposure to public or external networks. NPNs requiring external network access can be further secured by techniques such as end-to-end encryption and security principles like “least privilege”. However, resolving the aforementioned challenges with enhanced security and analyzing the performance will be another key focus of our future research.

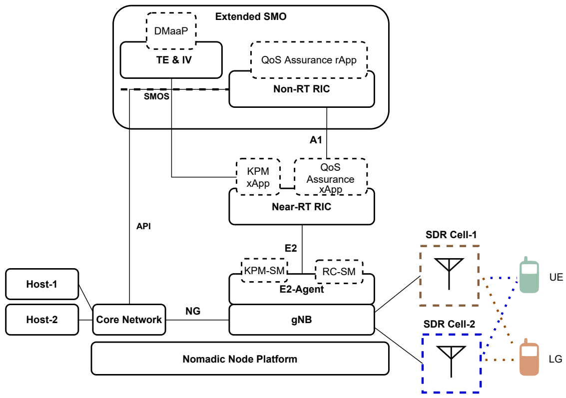

Fig. 4: Experimental Setup for RAN/Core-converged SMO Evaluation

VI. Evaluation

In this section, we present a prototype of a converged RAN- and Core- SMO, demonstrating its enhanced capabilities through a QoS assurance use case. The experimental setup as depicted in Figure 4 consists of an Amarisoft CN connected to an Amarisoft gNodeB (Next Generation (NG) Node B (gNB)) via the NG interface. The gNB hosts two cells, Cell1 and Cell2 realized by 5G NR Software-defined Radio (SDR)s. Two Nokia X20 COTS devices, namely the Load Generator (LG) and the UE are registered and attached to a private 5G network operated in the licensed spectrum 3700-3800 MHz in the n78 band. The gNB offers an E2 interface exposing Radio Control (RC) and Key Performance Metrics (KPM)-Service Models (SMs). FlexRIC [17] acts as the Near-RT RIC and interfaces with the E2 Agent via the E2 interface. The evaluated xApp is hosted by the Near-RT RIC using the FlexRIC API. Using the E2 KPM interface, the xApp continuously retrieves RAN monitoring data (particularly data on currently active UEs per cell) and forwards them to an extended SMO-based data lake, as part of a Data Movement as a Platform (DMaaP), an integral part of the SMO’s TE&IV module. As the RAN monitoring data is forwarded to the SMO, the SMO/rApp retrieves subscriber / bearer information for

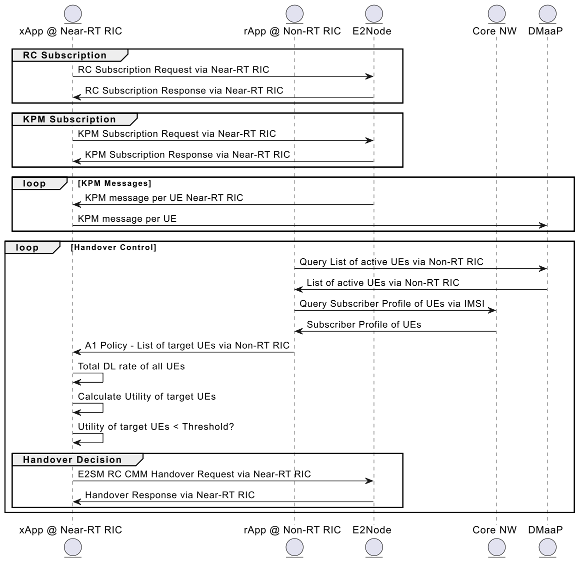

Fig. 5: Subsciber-profile specific QoS Assurance x/rApp Sequence Diagram

a given UE by querying the CN. By retrieving subscriber profiles associated with each UE / International Mobile Subscriber Identity (IMSI) from the CN via the SMOS Communication, the rApp steers the QoS assurance xApp by continuously providing a list of UEs to be treated by the xApp via the A1 interface . Fraunhofer FOKUS' Nomadic Node [17] platform hosts the software entities, namely, the CN, gNB, E2 Agent, RIC and SMO platform. Fraunhofer FOKUS' Network and Edge Data Management Interface (NEMI) [18], [19] encompasses the mentioned software entities for network management in beyond 5G and 6G networks.

The xApp leverages this additional CN data where the subscriber profile / bearer information for a given UE has been identified by rApp/SMO functions, assuring QoS for only those UEs for which the subscriber profile specifies a specific treatment. If the monitored available down-link throughput surpasses a specific threshold (i.e. the QoS threshold) the UE is seamlessly handed over to an alternative cell that provides higher capacities. Also shown in Figure 4, the LG generates background traffic to emulate different load situations. Since both, the UE as well as the LG enjoy the same priority level, the cell's capacity is equally shared between the UE and the LG. Figure 5 depicts in detail the procedural steps and logic used in this QoS assurance process. Initially, the xApp initiates subscriptions to the RC and KPM-SMs. Following a successful subscription, the xApp receives periodic indication messages from the KPM-SM. This further allows the xApp to extract through the KPM-SM among many other metrics, real-time down-link data rates. Based on each received indication message, the xApp first

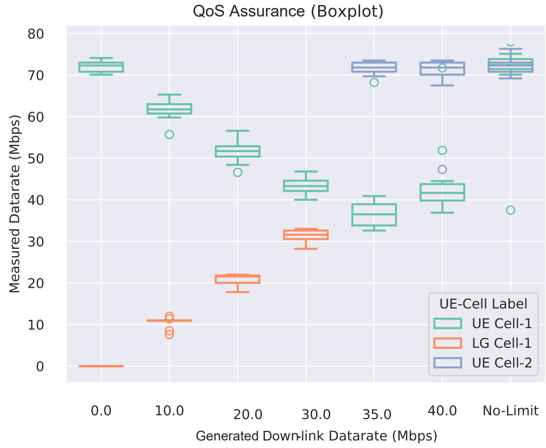

Fig. 6: Subscriber-specific QoS Assurance xApp - Boxplot

calculates the total down-link rate of all UEs. The rApp provides the xApp with a list of UEs to be treated (for which the QoS should be assured) after querying the CN for the related subscriber profile identified by the UE's IMSI. Once the UE to be treated is identified (via A1 policies), the xApp proceeds to calculate the available bandwidth for a given UE. In case the configurable threshold is surpassed (i.e. the QoS deteriorates / SLAs are violated), the xApp triggers the handover decision block, within which the xApp prepares a handover request message and forwards it to the gNB (E2Node) via the Near-RT RIC.

Figure 6 shows the observations of the operation of the QoS assurance xApp. The x-axis depicts the down-link rate introduced as background traffic by LG. The plot shows the throughput of the UE and LG in Cell1 and the throughput of the UE after being handed over to Cell2. The iperf tool is used to measure the Transport Control Protocol (TCP) down-link throughput. The tool also offers functions to configure the load generated by the LG. iperf servers are executed on Host1 and Host2 to measure the throughput between the UE and Host1; and the LG and Host2 respectively. When both the UE and the LG are residing in Cell1, the UE and the LG share the bandwidth, gradually reaching equilibrium at 35 Mbps. The xApp triggers the handover of the identified UE, as soon as the available bandwidth drops below the threshold of 38Mbps. It can be observed that handover of the UE from Cell1 to Cell2 always takes place at 35-40 Mbps with an unlimited background traffic generation.

Figure 7 depicts the QoS of a UE for which the QoS assurance xApp controls handovers (in blue, "WH | UE") and the QoS of a UE not receiving special xApp treatment while the LG traffic increases. Initially when the LG does not introduce any background traffic, the UE enjoys the full available bandwidth / capacity of the cell. As the LG introduces incremental down-link traffic in steps of 10 Mbps, UE and LG ("WoH | LG" and "WH | LG" in Figure 7)

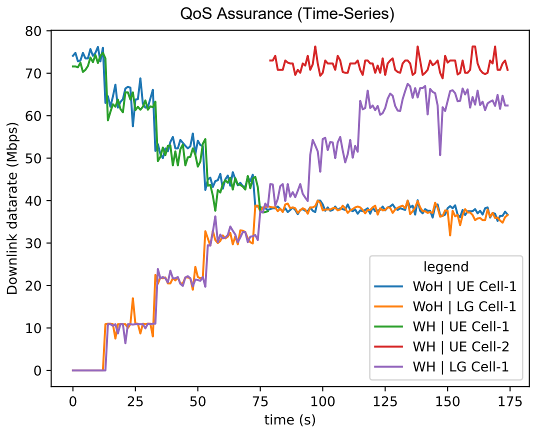

Fig. 7: Subscriber-specific QoS Assurance xApp - Time Series

begin to share the cell's capacity, reaching an equilibrium of around 38 Mbps without xApp treatment (labled "WoH | LG" in Figure 7). However, when the xApp is in operation, the UE (in blue, "WH | UE") gets transferred to Cell2 as soon as the cell's available bandwith drops below the threshold of 38 Mbps. As seen, after the handover to Cell2, the UE enjoys the full capacity without needing to share the cell's capacity with other UEs.

VII. Conclusion

This paper introduces a novel extension to the O-RAN SMO framework, addressing the complexity of deploying and operating fragmented network management systems in RAN, CN, and TN, which is particularly challenging for NPN deployments and operations. By integrating these domains into a unified orchestration layer, the proposed architecture allows for a significant enhancement of an SMO's network and service management capabilities, fostering greater automation and adaptability. The implementation showcases a seamless fusion of an SMO's RAN-/Core-network monitoring and control mechanisms. Enhanced QoS assurance mechanisms that successfully demonstrate the potential and benefits of a converged and unified SMO architecture are evaluated. Subsequent upcoming developments and evaluations will highlight the advantages of such a unified SMO in the domain of energy-, network performance-, resource- as well as reliability-optimization. The unified SMO framework establishes a foundation for highly autonomous Open RAN management capable of dynamically adjusting to real-time demands, which is particularly crucial for reducing NPN operation efforts.

VIII. Acknowledgments

This work has been partially funded by the German Federal Ministry of Education and Research (BMBF, Germany) as part of the 6G Research and Innovation Cluster 6G-RIC under Grant 16KISK020K, 16KISK032 and by the Federal Ministry of Digitization and Transport (BMDV, Germany) as part of its InnoNT program under Grant 19OL22004E and 19OI22015B.

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