Advancing Open RAN Deployment and Management on the OpenRAN@Brasil Testbed

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NOMS 2025-2025 IEEE Network Operations and Management Symposium | 979-8-3315-3163-8/25/$31.00 ©2025 IEEE | DOI: 10.1109/NOMS57970.2025.11073589

***Abstract*—The OpenRAN@Brasil project has been advancing the evolution of Open RAN technology by enabling private 5G networks in various fields, such as education, government, and industry. With this, there has been progress in techniques and developments to improve the adoption of the technology and spread the use of Open RAN. This demonstration addresses the challenges of fragmentation and complexity inherent in transitioning to open and disaggregated networks, leveraging an intent-based strategy to simplify the deployment and management of network services. The results demonstrate the feasibility of the solution by successfully provisioning 5G core network functions (Open5GS) and edge functions (SRS-RAN) in different Kubernetes clusters, allowing UE registration and access to Internet services. The integration of technologies such as Open5GS, SRS-RAN, and Nephio highlights the potential for automation, scalability, and operational efficiency in distributed environments.**

***Index Terms*—Open RAN, 5G, Orchestration, Management**

I. Introduction

Classical network environments have utilized vendor approaches in the network core, with network services developed to run on specific and dedicated hardware. Looking for cost reductions and increased efficiency, resource-sharing approaches began to be adopted, which open hardware and its partitioned resources were used and made available via virtualization techniques to provision network services; this approach is known as Network Function Virtualization (NFV). However, with the growing demand from users and applications, the environment requires more flexibility; thus, the use of containers as a more powerful alternative than the virtual machines (VMs). In this scenario, Virtualized Network Functions (VNFs) are partitioned and their components are executed in different containers, which may or may not be geographically distributed. This approach is called Cloud Native Network Functions (CNFs).

Collaboration between cloud service providers and telecommunications service providers has also driven the evolution of telecommunications networks. Virtualization of telecommunications solutions has enabled the transition from a traditional RAN model to a more distributed and open model, as evidenced by Open RAN (O-RAN). However, moving from a centralized to a distributed environment brings several challenges, such as the diversity and fragmentation of the ecosystem, the complexity of configuring policies and workflows, and the management of multiple domains and clusters. Consequently, performing any action in the environment is not trivial, requiring a high level of planning and coordination.

Thus, the implementation of O-RAN, which aims to disaggregate network functions (NFs) and adopt containers and distributed clouds, requires robust orchestration and advanced automation tools to integrate the various components and optimize operation in geographically distributed clusters. In this context, to surpass the challenges mentioned above and assist in the orchestration of NFs in multi-cluster environments, this work presents the implementation and demonstration of a management and orchestration solution for 5G/Open RAN stacks on the OpenRAN@Brasil testbed [1] using Nephio [2], providing a more agile and scalable operation.

The remainder of this paper is organized as follows. Section II describes our scenario and the tools used. In Section III, the results obtained in the demonstrated scenario are presented. Finally, final remarks are presented in Section IV.

II. Demonstration environment

A. OpenRAN@Brasil Testbed

The OpenRAN@Brasil program, launched in 2022 by the Brazilian Ministry of Science, Technology & Innovation (MCTI), is a three-phase research and development (R&D) initiative designed to advance the Brazilian Open RAN ecosystem. It focuses on promoting research, innovation, and training in open and disaggregated wireless technologies and applications for 5G and beyond [3]. The program aims to provide early access to state-of-the-art technologies, which are often unavailable during their initial development stages, providing an open source experimentation platform for the control and management of programmable network infrastructures composed of open and disaggregated equipment, *i.e.,* built from the integration of multiple components supplied by different hardware and software manufacturers. The testbed provides different experimentation capabilities, such as 5G, programmable networking, resource slicing, artificial intelligence, and service orchestration, among many other technological domains related to the open RAN stack.

This work was performed within the OpenRAN@Brasil Program, which is supported by the Ministry of Science, Technology, and Innovation, with resources from Law No. 8,248, of October 23, 1991, in accordance with the guidance of the Secretariat for Entrepreneurship and Innovation.

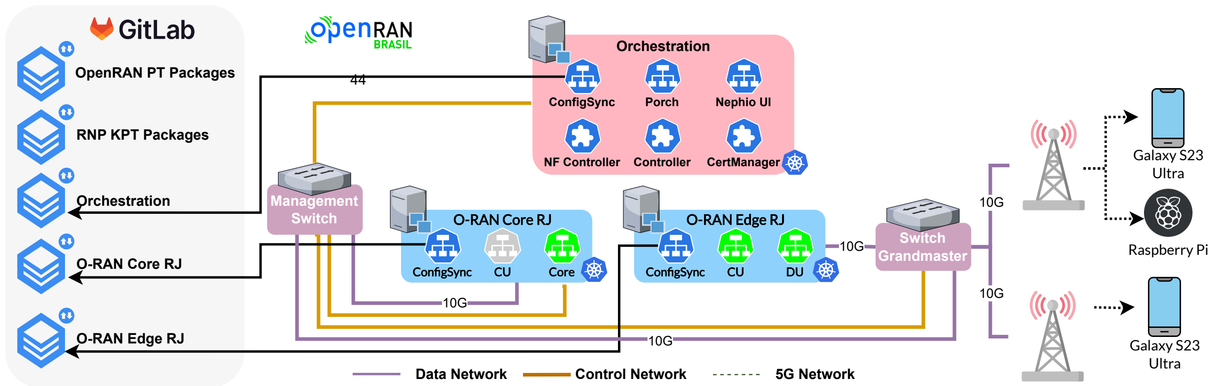

Fig. 1. Experimental Environment

B. Experimental Scenario

The OpenRAN@Brasil testbed was used in this demonstration, with the scenario presented in Figure 1. The setup includes three Kubernetes clusters: one responsible for orchestration, hosting the Nephio components, and two serving as the central cluster (O-RAN Core RJ) and the edge cluster (O-RAN Edge RJ). Communication between the clusters and the Radio Units (RUs) is managed using the Falcon-RX O-RAN Switch and PTP Grandmaster, ensuring accurate synchronization, while different UEs interface with the radio units. Each cluster maintains a dedicated Git repository to store the packages necessary for its operation. The Orchestration, O-RAN Core RJ, and O-RAN Edge RJ clusters are linked to their respective repositories. Additionally, the Open RAN KPT Packages and RNP KPT Packages repositories are used to manage project-certified packages and customized packages specific to the RNP environment, respectively. We employ Nephio [2] for network resource management and orchestration, a Kubernetes-based automation platform designed to simplify the deployment and lifecycle management of NFs and their underlying infrastructure through intent-based automation.

C. Tools

We decided to employ Nephio in our environment given its support to the deployment of NFs across both cloud and edge infrastructures, managing the complete lifecycle of provisioned entities within clusters. This lifecycle includes initial provisioning, continuous updates, rejection of unwanted modifications, and decommissioning NFs. Nephio adopts an intent-based automation paradigm for cloud-native environments, using declarative intent and continuous reconciliation, allowing users to define only the desired end state of the system without requiring detailed instructions on how to implement them. By integrating intent-based automation, Nephio not only simplifies network management but also improves operational efficiency and scalability, offering seamless integration with cloud-native infrastructure, core networks, and edge computing environments.

Open5GS [4] is used for the 5G core network, an open source project that implements the primary functions responsible for User Equipment (UE) access, authentication, and data exchange with the network. Open5GS supports private network deployments and NFs compliant with 3GPP Release-17 [5], including slicing capabilities. The supported NFs are as follows: Access and Mobility Management Function (AMF), which manages UE connection and mobility, encompassing registration, authentication, mobility handling, message encryption, and ensuring the integrity of Non-Access Stratum (NAS) communications; Session Management Function (SMF), responsible for establishing and managing UE data sessions with a data network (DN); User Plane Function (UPF), which handles the transport of user data packets between radio access network (RAN) functions (CU/DU) and external data networks; User Data Repository (UDR), Unified Data Management (UDM), and Authentication Server Function (AUSF), which store and generate authentication vectors for UEs; Network Repository Function (NRF), serving as a repository for discovering and connecting NFs; and Network Slice Selection Function (NSSF), responsible for storing and managing slicing information, including Slice/Service Type (SST) and Slice Differentiator (SD).

To deploy 5G/Open RAN NFs, including the Centralized Unit (CU) and the Distributed Unit (DU), the SRSRAN project [6] is employed. Developed by Software Radio Systems (SRS), this open-source initiative provides CU and DU implementations for 5G technology. SRSRAN supports Open RAN architecture through compatibility with E2 connections, using the E2SM-KPM and E2SM-RC service models within the E2AP protocol. SRSRAN complies with 3GPP and O-RAN Alliance standards, featuring a complete protocol stack for L1, L2, and L3 layers. Designed for flexibility, it operates on processors with diverse models and architectures.

D. Workflow

Provisioning an NF in a target cluster using Nephio involves multiple steps and interactions among various components of its architecture. Figure 2 outlines the sequence of steps and the components involved, from user interaction with the system to NF deployment within the cluster. Figure 2 also highlights the Nephio enablers that enable intent-based interaction, a core feature of automation and orchestration.

A PackageVariantSet artifact is sent to the orchestration cluster. These artifacts encapsulate provisioning intents, which

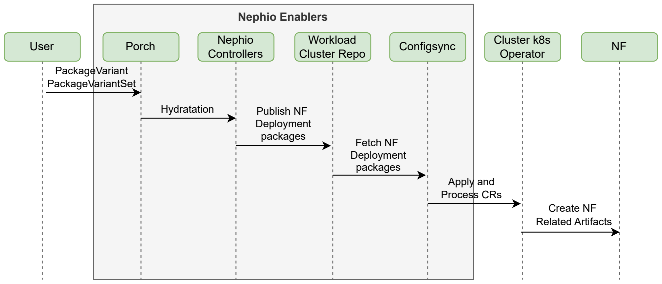

Fig. 2. Nephio sequence flowchart

outline the desired NFs and their target clusters. Nephio interprets these user-defined specifications, identifies the required NFs and clusters, and publishes the corresponding NF deployments to the repository linked to the target cluster. ConfigSync in the target cluster retrieves and processes updates from the repository, applying the configurations to the cluster. Finally, the cluster operators complete the NF provisioning.

III. Demo Overview

The components of the 5G core network were deployed in the "O-RAN Core RJ" cluster, while the CU and DU network functions were placed in the "O-RAN Edge RJ" cluster. Provisioning was carried out by sending PackageVariantSet artifacts to the orchestration cluster, as depicted in Figure 3.

```
apiVersion: config.porch.kpt.dev/v1alpha2
kind: PackageVariantSet
metadata:
  name: noms-oran-core
spec:
  upstream:
    repo: demo-noms
    package: open5gs-flux
    revision: v7
  targets:
  - objectSelector:
      apiVersion: infra.nephio.org/v1alpha1
      kind: WorkloadCluster
      matchLabels:
        nephio.org/site-type: core
#         nephio.org/region: rj
    template:
      adoptionPolicy: adoptExisting
      deletionPolicy: delete
      downstream:
        package: noms-open5gs-flux
      annotations:
        approval.nephio.org/policy: initial
      pipeline:
        mutators:
        - image: gcr.io/kpt-fn/apply-setters:v0.2.0
          configMap:
            nameValuesConfig: "open5gs-values-noms-cloud2"
```

```
apiVersion: config.porch.kpt.dev/v1alpha2
kind: PackageVariantSet
metadata:
  name: noms-oran-edge
spec:
  upstream:
    repo: demo-noms
    package: srsran5g-cu-du-flux
    revision: v6
  targets:
  - objectSelector:
      apiVersion: infra.nephio.org/v1alpha1
      kind: WorkloadCluster
      matchLabels:
        nephio.org/site-type: edge
#         nephio.org/region: rj
    template:
      adoptionPolicy: adoptExisting
      deletionPolicy: delete
      downstream:
        package: noms-srsran5g-flux
      annotations:
        approval.nephio.org/policy: initial
      pipeline:
        mutators:
          - image: gcr.io/kpt-fn/apply-setters:v0.2.0
            configMap:
              nameValuesConfig: "srsran5g-values-noms-cloud5-ru1"
```

Fig. 3. PackageVariantSet used in the demonstration

Nephio interprets and executes the commands according to the flow described in Subsection II-D. Once all steps are completed, the components are accurately provisioned, enabling the registration of CU and DU functions in the core network's AMF. With the environment properly configured, the UEs can be registered on the network, as shown in Figure 4. Then, these UEs can access the internet services and perform connectivity tests, as illustrated in Figure 5, demonstrating proper operation and successful integration of the 5G/Open RAN stack within the testbed environment.

IV. Conclusions

The orchestration and deployment of an Open RAN architecture using multi-cluster orchestration tools, such as Nephio, demonstrates significant advances in network flexibility, scalability, and operational efficiency. This study contributes to optimizing network management in cloud-native and disaggregated environments through successfully provisioning NFs across distinct Kubernetes clusters, connecting the core network to the edge and enabling UEs to access network services, highlighting the practical viability of the proposed architecture. The integration of Nephio, Open5GS, and SRSRAN within the OpenRAN@Brasil testbed proved to be an efficient and scalable solution to orchestration challenges in distributed environments, positioning the testbed as a valuable platform for experimentation and innovation within the Open RAN ecosystem, offering critical insights into the management of disaggregated and cloud-native networks. The results show the potential of Open RAN solutions in transforming network management, paving the way for further research into optimizing distributed orchestration tools. Future studies may explore additional integrations and evaluate the scalability and performance of native cloud networks in real-world applications.

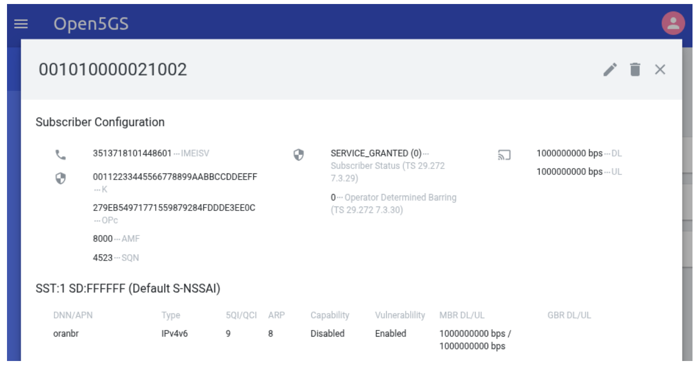

Fig. 4. View from the Open5GS interface of the UE registered on the network

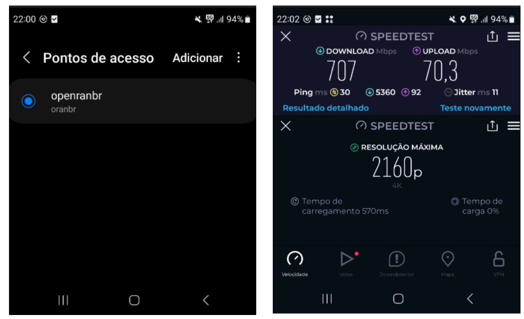

Fig. 5. UE Registration on the Network and Connectivity Testing

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