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Experiences with disaggregated RAN integrations

Moussa Guemdani, Chi-Dung Phung, Stefano Secci
CNAM, Paris, France. first-name.last-name@cnam.fr.

Abstract—With the availability of open-source RAN projects, and the option to operate private 5G networks, 5G gets accessible for deployment in campus environments across industry and academia, in support of experimental research on new scheduling, allocation, orchestration solutions. This paper details our experience in deploying a 5G Standalone (SA) system at the Conservatoire National des Arts et Metiers (CNAM) campus, integrating some disaggregated RAN features as well. By using Commercial Off-The-Shelf (COTS) our deployments include comprehensive integration tests, and basic connectivity setups. We provide integration details in support of reproducing the testbed in other campuses to help practitioners in reproducing and improve the designs we demonstrate.

Index Terms—5G, virtualized RAN, Standalone (SA) 5G, Handover, Open RAN, O-RAN, Disaggregated RAN.

I. INTRODUCTION

Cellular mobile access systems have been gradually migrating since 2010 from vendor-locked dedicated real-time systems with specialized hardware, to open software-based systems and protocols with a loosely coupled large-scale and more flexible distributed system. Under the general umbrella of virtualized/Software-Defined/Open Radio Access Network (v/SD/Open RAN) initiatives, the 5G system consists mainly of three interconnected segments, each composed of multiple distributed nodes: (1) Radio Access Network (RAN), (2) Core Network (composed in turn of multiple physical and virtualized network functions, possibly duplicated in different locations), and (3) User Equipment (UE), i.e. a mobile node with its Universal Subscriber Identity Module (USIM) [1].

The so-called new generation radio access network (NG-RAN) has as its main component the g-Node B (gNB); a gNB is connected to one or multiple radio heads so composing a base station, connected to the 5G Core (5GC). The ‘disaggregated’ RAN sees the gNB functionally decomposed in three main parts: the Centralized Unit (CU), the Distributed Unit (DU), and the Radio Unit (RU), that roughly take respectively high, middle and low physical and datalink layers functions, and which can be localized at different physical nodes.

In this paper, we report our efforts in the campus deployment of the 5G Stand-Alone (SA) system (ultimate deployment strategy of the 5G system standard as per Release 17), which outperforms the non-standalone (NSA) one (the first deployment strategy) by reducing device power consumption, simplifying deployment, and lowering costs [2]. We also explore intra-gNB Handover (HO) between DU cells connected to the same CU-CP, a basic operation that allows the UE to move between two cells, which however poses important integration difficulties we document. We then examine disaggregated 5G RAN settings, and in particular its flexible

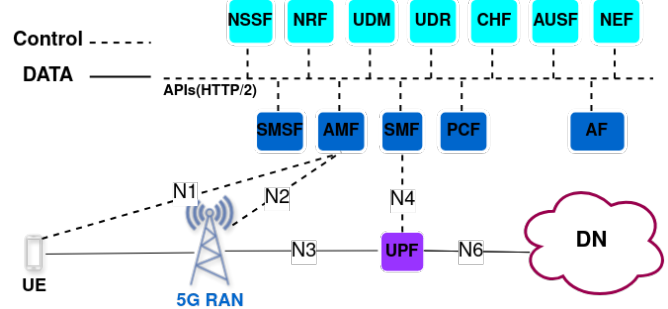


Fig. 1. 5G network infrastructure elements.

deployment across various network locations and hardware platforms, and report how we have designed their deployment on top white box servers at the edge along with RUs and near RF antennas [3]. We detail a 5G SA deployment aligned with 3GPP Rel. 17, covering essential functionalities.

Next, Section II outlines the 5G SA system and RAN disaggregation. Section III details the integration and deployments steps for the 5G SA testbed. Section IV concludes the paper and gives directions for future work.

II. 5G SA ARCHITECTURE AND RAN DISAGGREGATION

Let us present the general 5G SA system, and the components specifically deployed in our private 5G SA system at the CNAM. A comprehensive 5G SA system consists of four major parts: service management and orchestration (SMO) platform, 5G Core Cluster(s), gNB(s), and UEs. Each of these parts covers several 5G components organized as a service-based architecture (SBA) for handling some (if not all) communications among them.

CNAM 5G testbed: The 5G SA system deployed at the CNAM comprises 3 main components: a 5G core, 3 gNBs, and multiple UEs. Figure 1 illustrates the overall 5G SA system architecture, highlighting key control and user plane core components. For our deployment, we leverage the Open5GS core architecture, which offers a highly flexible 5G SA core compatible with 3GPP Release 17 specifications [4].

To cover 5G basic features, the Access and Mobility Function (AMF), Session Management Function (SMF), User Plane Function (UPF), and Network Repository Function (NRF) are essential ones among those in the 5G system standard.

In our campus deployment, we enabled the AMF, SMF, UPF, NRF functions. We used the Ettus Research USRP X310 as the RU in our open 5G system. The USRP X310 is a high-performance, scalable software-defined radio (SDR) platform, ideal for designing and deploying next-generation wireless

communication systems [5]. The UE connecting to the 5G SA system must be compatible; in our setup, we successfully integrated the OnePlus 8 Pro, iPhone 13 and 15, Samsung S24 Ultra and Apal plug-and-play 5G USB dongles.

RAN disaggregation: OpenRAN primarily consists of three key components: the Open Centralized Unit (O-CU), the Open Distributed Unit (O-DU), and the Open Radio Unit (O-RU). The system supports disaggregated RAN with open interfaces following the O-RAN initiative, enabling flexible and cost-effective 5G deployments using multi-vendor components. This approach simplifies network management and reduces operational costs by integrating AI-driven automation at both the component and network levels. Figure 2 illustrates the disaggregation of the RAN as per O-RAN specifications (CU and DU at the edge and RU at cell site).

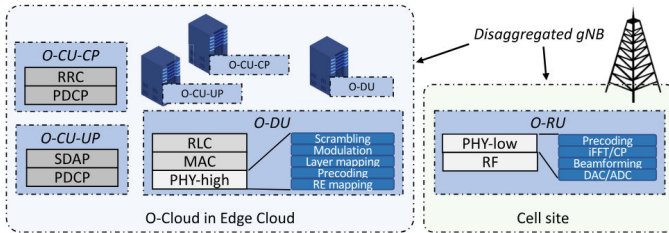


Fig. 2. Disaggregated gNB setting [3].

The 3GPP considers multiple functional split variants in the NG-RAN [6], illustrated in the figure 3.

III. TESTBED INTEGRATION

This section outlines the deployment of our end-to-end 5G SA system, both with and without RAN disaggregation. We detail the deployment of the key components of the network.

Our 5G testbed leverages the open-source srsRAN-Project release 24.4 for the RAN system. However, the descriptions and components provided are equally relevant to other 5G deployments, owing to the standardized architecture.

1) 5G SA Core Network: The deployment of the core network involves configuring several critical parameters to ensure the network operates according to specific subscriber requirements. These parameters include the Public Land Mobile Network (PLMN) ID, Tracking Area Code (TAC), and Single Network Slice Selection Assistance Information (S-NSSAI). The PLMN is a mobile network that provides communication services to subscribers within a specific geographic area. The PLMN ID is composed of two parts: the Mobile Country Code (MCC), a 3-digit code that identifies the country or geographic area, and the Mobile Network Code (MNC), a 2-3 digit code that identifies the specific mobile network within the country. In our case MCC and MNC are set to 001-01.

Each cell served by a gNB is part of a tracking area, and identified by two parameters: the Tracking Area Code (TAC), a local identifier, and a Tracking Area Identifier (TAI), a universal identifier. The TAI is a combination of the PLMN ID and the TAC. The gNB broadcasts one or more TAIs, with each TAI corresponding to a host PLMN ID. The TAI and TAC in our scenario are set arbitrary to 1.

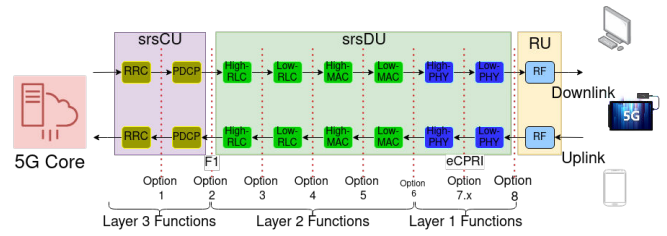


Fig. 3. gNB functional split options.

Network slices are defined within a PLMN. In RAN sharing, where multiple PLMNs use the same cell, each operator must link S-NSSAIs to the PLMN ID. Network slices are also tied to a tracking area, as S-NSSAIs are managed per tracking area. In our case, it is set to 1 to align with the TAC.

2) gNB: The gNB is deployed on a server equipped with 6 Intel(R) Core(TM) i7-8700 CPUs, each clocked at 4.2 GHz (overclocked from the base 3.20 GHz to suite high-frequency transmission and processing requirements). It also has 16 GB of memory, providing sufficient computational requirements.

Before deploying the gNB, it is crucial to ensure that each RU, we run using USRP is installed and configured properly. This involves a series of steps to build and install the USRP Hardware Driver (UHD) from source.

- **Monolithic RAN Deployment:** Parameter settings are done via a yaml file. First, the clock source for the USRP is set to internal or external depending on whether we are using an external clock source. using an external clock source is useful when the RU is far from the gNB and durin HO when using multiple RUs. Cell configuration parameters include the Down Link Absolute Radio Frequency Channel Number (DL_ARFCN) is configured to 663264, which allows the gNB to operate in a spectrum band of 3950MHz, the Channel Bandwidth is set to 80 MHz, and the Subscriber Spacing to 30 KHz.
- **Disaggregated RAN deployment:**

Figure 4 represents our deployment topology. For the CU-DU split option, two distinct YAML configuration files are required: one for the CU and one for the DU. This deployment requires configuring the F1 interface, which involves setting up the F1-C (Control Plane) in the section labeled *cu_cp*. This setup involves updating the maximum number of connected DUs to the CU, the maximum number of CU-UPs, the number of UEs the CU-CP can support, and the list of PLMNs and TACs. Additionally, the F1-U (User Plane) needs to be configured in the section labeled *FIAP*, which includes specifying a bind IP address for the CU node. Configuring the DU requires setting up the F1 interface, similar to the CU. In addition, it involves configuring the RU and cell parameters. For the F1-U section, the same IP than the CU one is used, and a bind address must be specified for the DU.

3) Handover: srsRAN Project release 24.04 introduces foundational HO functionality, specifically enabling intra-gNB HO between DU cells linked to the same CU-CP. To

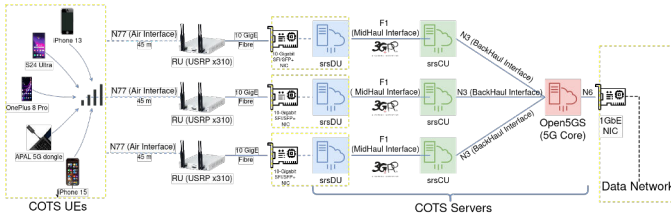


Fig. 4. Network topology

achieve this, the setup requires configuring two DUs within the srsRAN gNB binary, each paired with a separate RF chain of a USRP device. We configured the intra-frequency HOs to be triggered when the neighboring cell’s Reference signal Received Power (RSRP), a key metric to assess channel quality (i.e., the average received power of the reference signal, excluding noise and interference), is 1.8 dB better than the serving cell. During implementation, the initial UE, the Oneplus 8 Pro, experienced issues with cell selection, while using the S24 Ultra the handover process was seamless.

4) *User Equipment (UE)*: To begin, we ensure that the SIM card and the 5G NR carrier are enabled on the UE. It is also necessary to activate data roaming while ensuring that VoNR and VoLTE are disabled to prevent conflicts. Next, we configure the APN. The APN must match the DNN/APN set during Open5GS subscriber registration.

Once UEs and network are properly configured, the UE is able to recognise the APN. Successful attachment to the network is verified from the Open5GS console interface, followed by initiating data streaming to confirm proper functionality.

5) *Subscriber Identity Module (SIM) provisioning*: In this step, We employed the 5G SysmoSIM-SJA2, a programmable USIM, ISIM, HPSIM card. The MCC, MNC, IMSI, and other credentials within the SIM are manually updated using PySim. These parameters must match the parameters configured within the core. An additional critical step involves deactivating the Subscription Concealed Identifier (SUCI), which requires modifying the 5G-specific fields of the SIM card. The SUPI, a unique 15-digit identifier for each 5G subscriber, includes the MCC, MNC, and Mobile Subscriber Identification Number (MSIN). It uniquely identifies users within the 5G system and supports roaming by including the home network address. In our setup, we use the IMSI as the identifier, which is why we deactivated the SUPI field.

6) *Spectrum access*: We use the 5G NR band N77, referred to as the 3.7 5G band or C-band, has a frequency range from 3.3 - 4.2 GHz. It follows the Time Division Duplexing (TDD) mode. To legally transmit with the N77 band, CNAM obtained authorization from the *Autorité de Régulation des Communications Électroniques, des Postes et de la Distribution de la Presse (ARCEP)*. Specifically, CNAM was granted permission to use frequencies within 3.8 GHz to 4 GHz range, It is allowed to use 100 MHz of bandwidth at a time.

According to regulatory guidelines, for every terminal, the Effective Isotropic Radiated Power (EIRP) is limited to 23 dBm. Additionally, the maximum EIRP per 5 MHz carrier is

restricted to 36 dBm.

7) *Deployment challenges*: One significant challenge encountered during deployment was the UE network attachment failure. To resolve this, troubleshooting was performed by following guidelines for USRP type x300/310 devices on the manufacturer’s website, as well as engaging with the srsRAN community on GitHub. To verify the correct operation of the USRP, several tests were performed. We traced back the attachment issue to the USRP, which was running an outdated version of the UHD library that do not support the N77 band. You need to manually update the UHD library to version 4.3 or higher on both the USRP and the host machine (UHD for USRP, and libuhd for host).

IV. CONCLUSION AND PERSPECTIVES

We reported our 5G campus testbed at CNAM integrating preliminary RAN disaggregation features. We integrated the minimum necessary 5G SA core functions and validated the setting in a real-world environment using commercial UE, gNBs and 5G spectrum.

Our deployment includes RAN disaggregation scenarios, and exploration of handover processes, hard to perform with open-source tools. Additionally, the testbed evolves to deploy split options, starting with the split 7.2x option, and Voice over New Radio (VoNR) to assess Voice Quality of Service (QoS).

In the demonstration, we experiment HO processes under monolithic and disaggregated RAN deployments, comparing their performance in terms of latency and connection stability. We demonstrate the effects of different RAN architectures on latency and connection stability.

We plan to test novel radio scheduling algorithms, and hierarchical multi-resource scheduling coordinated across radio, link, and cloud stacks. We also intend to incorporate NetFPGA boards to accelerate network functions for RU, DU, CU, and 5GCN, hence enhancing the testbed versatility. The testbed will be used to generate new versions of the 5G3E dataset [7].

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