Implementation and Evaluation of OpenAirInterface 5G Core and RAN Using RF Simulation

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***Abstract*— This paper presents a step-by-step implementation of OpenAirInterface (OAI) 5G Core Network (5GC) along with OAI gNB and OAI NR-UE using commercial off-the-shelf (COTS) user equipment. The setup is designed to evaluate the performance and feasibility of OAI-based 5G deployment in a controlled test environment. Additionally, an RF simulator is employed to validate the end-to-end connectivity. The objective is to establish an experimental setup that ensures reliable communication between the NR-UE and the 5GC, verifying successful packet transmission through IP address monitoring. The results provide insights into the feasibility of deploying OAI for real-world 5G testing environments**

Keywords*— *5G, gNB, NR-UE, OpenAirInterface, RF simulator

I. INTRODUCTION

The rapid evolution technology & networks have led to the development of 5G technology, which lead to increased data rates, ultra-low latency, and enhanced network reliability. OpenAirInterface (OAI) provides an open-source platform for implementing and testing 5G networks, allowing researchers and developers to experiment with real-world network scenarios without requiring expensive proprietary solutions.

This paper explores the deployment of an OAI-based 5G network, including setup of the 5G Core (5GC), gNB (Next-Generation Node B), and NR-UE (New Radio User Equipment). The use of RFsimulator further enhances the testing environment by enabling NR-UE to interact with the core network, and simulating the realistic network conditions. The objective is to validate the functionality of an OAI-based 5G system by assessing its end-to-end connectivity and packet transmission capabilities.

II. THEORETICAL FOUNDATIONS

A. 5G Network Overview

The evolution of mobile networks has led to the emergence of the fifth generation (5G) network, which aims to provide high-speed, low-latency, and ultra-reliable communication. According to Al-Falahy and Alani, various enabling technologies essential for 5G include millimeter-wave communication, massive multiple-input multiple-output (MIMO), network slicing, and software-defined networking (SDN). These advancements present both opportunities and challenges, particularly in terms of spectrum allocation, infrastructure deployment, and security. A key component of 5G implementation is the *gNodeB (gNB)*, which replaces the *eNodeB (eNB)* used in 4G LTE to provide improved spectral efficiency and higher capacity. The gNB handles wireless communication with user equipment (UE) through the *New Radio (NR)* interface, supporting high-speed and low-latency connections. The *NR-UE* refers to devices operating under the 5G NR standard, offering enhanced data rates and network performance compared to LTE-based devices. The interaction between gNB and NR-UE plays a crucial role in delivering efficient, reliable communication that defines 5G, enabling transformative impacts on industries such as healthcare, smart cities, and autonomous systems, making it a fundamental aspect of modern wireless communication research [1].

B. OpenAirInterface (OAI)

OpenAirInterface (OAI) is an open-source platform designed to implement 3GPP technologies for 4G and 5G networks on general-purpose computing hardware. It enables researchers and developers to deploy and test end-to-end mobile networks, making it a key tool for advancing 5G innovation. OAI supports the implementation of the *5G Core (5GC)*, the *Radio Access Network (RAN)*, and user equipment (*UE*), allowing seamless integration and testing with commercial network components [2]. The *5GC* serves as the backbone of the 5G system, handling data management, network slicing, and service-based architecture, while the *RAN* ensures high-speed, low-latency communication between UE and the core network. OAI's flexibility in implementing and testing these components makes it a crucial platform for validating real-world 5G deployments and optimizing network performance.

C. gNB and NR-UE

The implementation of a 5G *gNodeB* (gNB) is leveraged to enhance angle-of-arrival (AoA) estimation accuracy through a model-driven deep neural network (MoD-DNN) [3]. The gNB serves as the 5G base station, facilitating high-speed, low-latency communication with user equipment (UE) via the *New Radio (NR)* interface. In this research, the gNB collects uplink signals from UE, which are then processed to estimate AoA—a critical parameter for precise positioning in wireless networks. The MoD-DNN framework integrates a convolutional neural network (CNN) with a sparse conjugate gradient (SCG) algorithm to calibrate angular-dependent phase errors and improve AoA estimation [3]. This approach demonstrates the gNB's pivotal role in advancing positioning accuracy within 5G networks.

III. METHODOLOGY

This study follows a structured approach to deploy and validate an OAI 5G network.

A. *Installation of OAI 5GC*

- Clone the OAI repository and set up dependencies.
- Configure the AMF, SMF, UPF, and NRF components.
- Establish network connections for 5GC operation.

B. *Deployment of OAI gNB and NR-UE*

- Download and build the OAI gNB and NR-UE components.
- Adjust configurations to ensure compatibility with 5GC.
- Connect gNB to 5GC and associate NR-UE with gNB.

C. *RFsimulation & End-to-End Connectivity*

- Simulate NR-UE instances to evaluate connectivity.

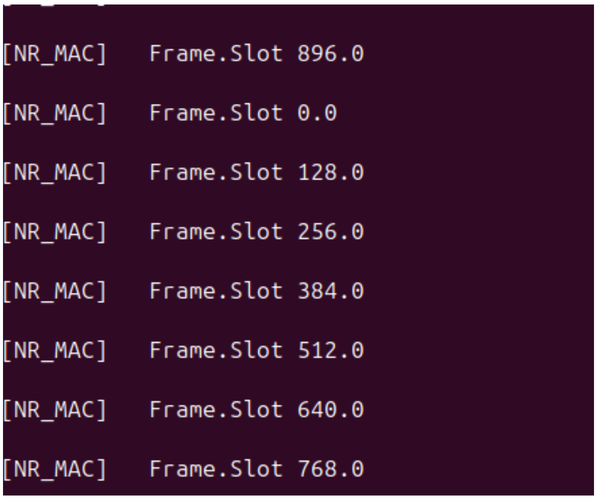
  Monitor network behavior under simulated conditions.
- Verify IP assignment for NR-UE devices.
- Transmission tests to confirm successful data flow.
- Analyze the RTT and throughput performance.

For clearer information, it can be accessed on [4]

IV. RESULTS AND ANALYSIS

A. *OAI CN5G gNB*

This is the result after running the OAI CN5G gNB



```
[NR_MAC]   Frame.Slot 896.0
[NR_MAC]   Frame.Slot 0.0
[NR_MAC]   Frame.Slot 128.0
[NR_MAC]   Frame.Slot 256.0
[NR_MAC]   Frame.Slot 384.0
[NR_MAC]   Frame.Slot 512.0
[NR_MAC]   Frame.Slot 640.0
[NR_MAC]   Frame.Slot 768.0
```

Figure 1. Core Network test

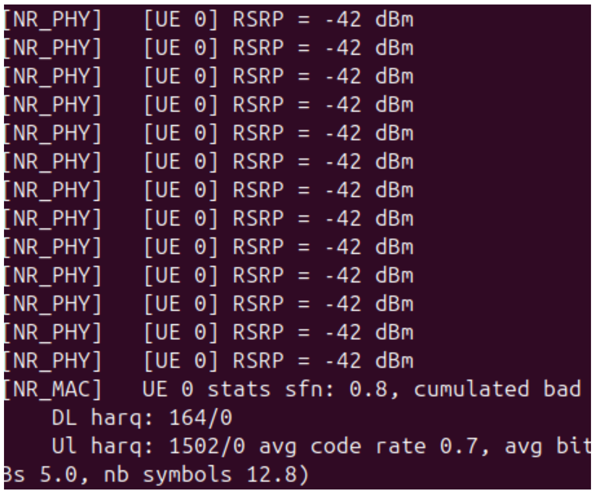
Figure 1 shows the OAI gNB MAC layer is running continuously to process the frames and slots after using the RFsimulator.

The structure is **[NR_MAC] Frame.Slot A.B**. The A and B are numbers that indicate the frame and slot numbers in the 5G NR time-division.

After running this, it is needed to detect the UE (User Equipment). This is a must to check whether the UE have been registered with the 5GC through gNB before receiving/transmitting data.

B. *OAI CN5G gNB*

This is the result after running the OAI CN5G UE



```
[NR_PHY]   [UE 0] RSRP = -42 dBm
[NR_PHY]   [UE 0] RSRP = -42 dBm
[NR_PHY]   [UE 0] RSRP = -42 dBm
[NR_PHY]   [UE 0] RSRP = -42 dBm
[NR_PHY]   [UE 0] RSRP = -42 dBm
[NR_PHY]   [UE 0] RSRP = -42 dBm
[NR_PHY]   [UE 0] RSRP = -42 dBm
[NR_PHY]   [UE 0] RSRP = -42 dBm
[NR_PHY]   [UE 0] RSRP = -42 dBm
[NR_PHY]   [UE 0] RSRP = -42 dBm
[NR_PHY]   [UE 0] RSRP = -42 dBm
[NR_PHY]   [UE 0] RSRP = -42 dBm
[NR_PHY]   [UE 0] RSRP = -42 dBm
[NR_MAC]   UE 0 stats sfn: 0.8, cumulated bad
    DL harq: 164/0
    Ul harq: 1502/0 avg code rate 0.7, avg bit
3s 5.0, nb symbols 12.8)
```

Figure 2. UE logs from OAI NR

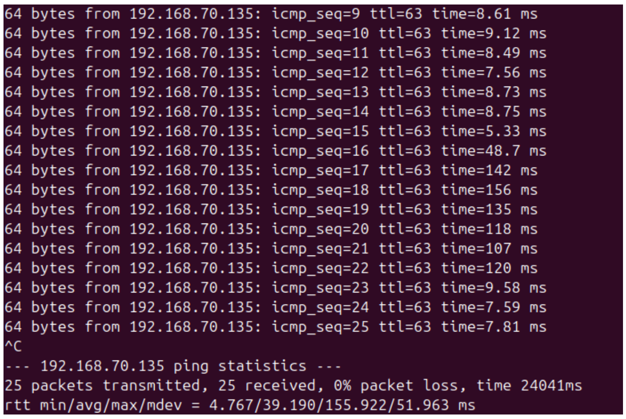
Figure 2 shows the logs from OAI with specific to NR (New Radio) PHY and MAC layers after running the RFsimulation.

The structure is **[NR_PHY] [UE 0] RSRP = -42 dBm** and can be breakdown as:

- **[NR_PHY]** refers to physical layer of the 5G NR which responsible for transmitting data over the air and deals with the strength, frequency, and quality of the signals.
- **[UE 0]** refers to User equipment, such as simulated device. The 0 is the number of the UE (usually starts from 0) and in this case, the virtual UE is trying to connect to the core network from figure 1, which is the 5G base station.
- **RSRP** refers to signal strength that is received by the UE and it is measured in dBm (decibels-milliwatts).

C. *End-to-End Connectivity Test*

This is the result after doing the ping test from the UE host to the CN5G.



```
64 bytes from 192.168.70.135: icmp_seq=9 ttl=63 time=8.61 ms
64 bytes from 192.168.70.135: icmp_seq=10 ttl=63 time=9.12 ms
64 bytes from 192.168.70.135: icmp_seq=11 ttl=63 time=8.49 ms
64 bytes from 192.168.70.135: icmp_seq=12 ttl=63 time=7.56 ms
64 bytes from 192.168.70.135: icmp_seq=13 ttl=63 time=8.73 ms
64 bytes from 192.168.70.135: icmp_seq=14 ttl=63 time=8.75 ms
64 bytes from 192.168.70.135: icmp_seq=15 ttl=63 time=5.33 ms
64 bytes from 192.168.70.135: icmp_seq=16 ttl=63 time=48.7 ms
64 bytes from 192.168.70.135: icmp_seq=17 ttl=63 time=142 ms
64 bytes from 192.168.70.135: icmp_seq=18 ttl=63 time=156 ms
64 bytes from 192.168.70.135: icmp_seq=19 ttl=63 time=135 ms
64 bytes from 192.168.70.135: icmp_seq=20 ttl=63 time=118 ms
64 bytes from 192.168.70.135: icmp_seq=21 ttl=63 time=107 ms
64 bytes from 192.168.70.135: icmp_seq=22 ttl=63 time=120 ms
64 bytes from 192.168.70.135: icmp_seq=23 ttl=63 time=9.58 ms
64 bytes from 192.168.70.135: icmp_seq=24 ttl=63 time=7.59 ms
64 bytes from 192.168.70.135: icmp_seq=25 ttl=63 time=7.81 ms
^C
--- 192.168.70.135 ping statistics ---
25 packets transmitted, 25 received, 0% packet loss, time 24041ms
rtt min/avg/max/mdev = 4.767/39.190/155.922/51.963 ms
```

Figure 3. Round test trip (RTT) result

Figure 3 shows the logs of ping test. The UE is communicating to the core network with transmitting over the OAI 5G system.

The structure shows that the IP responded with 64 bytes of data with ttl (time to live), and the rtt (round test trip). Those logs show multiple ping responses that explicitly means the connection is stable with RTT vary as indication of latency fluctuations (variations in network delay**)**.

In the end, when it is ended, the final ping statistics stated that 25 packets transmitted, 25 received, 0% packet loss, time 24041ms, meaning all of the packet is received and transmitted successfully around 24 seconds.

The network latency is also stated that:

rtt min/avg/max/mdev = 4.767/39.190/155.922/51.963 ms

Which means :

- Min RTT: 4.76ms (best case of the RTT)
- Avg RTT: 39.19ms (average of the RTT)
- Max RTT: 155.92ms (indicates delays from the RTT)
- Mdev: 51.96 ms (latency variation of the RTT)

V. Conclusion

All of the test results and analysis show that logs indicated UE has successfully connected to the 5G network and successfully to receive/transmit data to the core network and vice versa.

References

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