Comprehensive Journal of Science
Volume (10), Issue (37), (NOV. 2025)
SICST2025, www.sicst.ly
ISSN: 3014-6266

مجلة العلوم الشاملة
عدد خاص بالمؤتمر الدولي الثالث للعلوم والتقنية
المجلد (10)، العدد (37)، (نوفمبر2025)
ردمد: 3014-6266

Design and Implementation of a 5G Radio Access Network Using srsRAN and Software Defined Radio (SDR)

Mohamed M. Sowalem [1*], Abdulah A. Alhny [2], Abdulhadi A. Amer [3]
Electronic Engineering Dept., The college of Industrial Technology, Misrata, Libya
*Corresponding author: mohamed_sowalem@cit.edu.ly
ORCID: 0009-00058345-0609

تصميم وتنفيذ شبكة الوصول الراديوي للجيل الخامس باستخدام srsRAN والراديو المعرف برمجيًا (SDR)

محمد سوالم[1*]، عبد الله الهني [2]، عبد الهادي عامر[3]
قسم الهندسة الإلكترونية، كلية التقنية الصناعية، مصراتة، ليبيا

Received: 30-09-2025; Revised: 10-10-2025; Accepted: 31-10-2025; Published: 25-11-2025

Abstract:

This study focuses on the design and implementation of a 5G Radio Access Network (5G RAN) using open-source platforms, specifically srsRAN in combination with SDR devices, within a Standalone (SA) architecture. The functional split of the radio node was applied into CU/DU/RU units, which were physically integrated with the core network through standard interfaces (NG, F1). The experimental scenario involved connecting a virtual phone using SDR to the radio network, thereby enabling the emulation of an end-user connection. The results demonstrated successful registration and establishment of a PDU Session between the user and the network, with stable performance observed in the downlink (DL), where appropriate CQI values were achieved alongside suitable data rates and nearly negligible error rates. In contrast, the uplink (UL) showed less stability due to the limited transmission power of the user equipment, as reflected in fluctuating signal levels and higher error rates in certain cases. These findings confirm the feasibility of deploying 5G RAN networks using open-source tools, offering a practical and flexible testbed that not only supports academic research but also paves the way for future innovations in next-generation mobile networks.

Keywords: 5G, Radio Access Network (RAN), srsRAN, Software Defined Radio (SDR).

الملخص:

تركز هذه الدراسة على تصميم وتنفيذ شبكة الوصول الراديوي للجيل الخامس (5G RAN) باستخدام منصات مفتوحة المصدر، وبشكل خاص (srsRAN) بالاعتماد على أجهزة (SDR)، وذلك ضمن معمارية التشغيل المستقل (SA). تم تطبيق الفصل الوظيفي للعقدة الراديوية إلى وحدات (CU/DU/RU) وربطها فعليًا بالشبكة الأساسية عبر واجهات قياسية (NG، F1). شمل السيناريو التجريبي ربط هاتف افتراضي عبر جهاز (SDR) بالشبكة الراديوية، بما يتيح محاكاة اتصال واقعي لمستخدم نهائي. أظهرت النتائج نجاح عملية التسجيل وإنشاء جلسة بيانات (PDU Session) بين المستخدم والشبكة، حيث تحقق أداء مستقر في الوصلة الهابطة (DL) مع قيم (CQI) مناسبة ومعدلات بيانات ملائمة ونسبة أخطاء شبه معدومة. في المقابل، أظهرت الوصلة الصاعدة (UL) استقرارًا أقل نتيجة محدودية قدرة الإرسال من طرف المستخدم، وهو ما انعكس في تذبذب مستويات الإشارة وارتفاع نسب الخطأ في بعض الحالات. تؤكد هذه النتائج إمكانية تكوين شبكات وصول راديوي للجيل الخامس بالاعتماد

على أدوات مفتوحة المصدر، بما يوفر بيئة اختبار عملية ومرنة تدعم البحث الأكاديمي وتفتح آفاقًا واسعة للتطوير المستقبلي في شبكات الاتصالات المتقدمة.

الكلمات المفتاحية: الجيل الخامس، شبكة الوصول الراديوي، الراديو المعرف برمجياً.

i. Introduction

Communication technologies have witnessed rapid advancements with the emergence of fifth-generation (5G) networks, which are designed to deliver data rates of up to (20 Gbps) and latency as low as (1 ms), in addition to supporting more than (10^6 devices/km^2). These characteristics establish 5G as a foundation for applications such as autonomous driving, augmented reality, the Internet of Things (IoT), and smart factories [1].

The Radio Access Network (RAN) constitutes the core component in enabling these capabilities, functioning as the interface between the User Equipment (UE) and the Core Network. In 5G, its architecture has evolved into the Next-Generation RAN (NG-RAN), which comprises the Central Unit (CU), Distributed Unit (DU), and Radio Unit (RU), along with open interfaces (O-RAN) that enhance flexibility and reduce dependency on proprietary equipment [2].

Within this context, the integration of Software-Defined Radio (SDR) with open-source platforms such as srsRAN provides a cost-effective and practical environment for deploying and testing 5G RAN systems. This integration enables processes ranging from user registration to data transmission, thereby strengthening the applied aspects of research and development.

This study aims to design and implement a 5G RAN using srsRAN and SDR, with a particular focus on system architecture, interconnection mechanisms with the Core Network, and practical testing results.

This paper is divided into four main sections. Section I presents the introduction, highlighting the importance of 5G networks and the motivation behind this research. Section II outlines the methodology, describing the design and implementation of the radio access network using open-source platforms. Section III discusses the results, providing practical measurements and performance analysis within the test environment. Finally, Section IV concludes the paper with a summary of the main findings and key recommendations for future research.

ii. Methodology

This study was based on the implementation of a 5G RAN using the srsRAN platform as an open-source emulator. The deployment followed a Standalone (SA) architecture, which connects directly to the 5G Core without relying on the infrastructure of previous generations. To achieve this, the methodology adopted involved separating the radio node components into independent units, in alignment with the NG-RAN architecture recommended by the (3GPP).

a. Functional Split

The radio node (gNB) was structured into three main units:

Centralized Unit (CU): Responsible for managing Radio Resource Control (RRC) and processing the Packet Data Convergence Protocol (PDCP), in addition to handling resource management and Quality of Service (QoS) [3].

Distributed Unit (DU): Executes higher-layer radio link protocols such as Medium Access Control (MAC) and Radio Link Control (RLC), along with scheduling mechanisms and Hybrid Automatic Repeat Request (HARQ) [1].

Radio Unit (RU): Represents the physical endpoint responsible for transmitting and receiving signals through antennas, as well as performing lower Physical (PHY) layer operations [1].

For this study, Split (8) was selected to distribute processing tasks among the units. This split provides high deployment flexibility and reduces internal latency, making it particularly suitable for Ultra-Reliable Low-Latency Communications (URLLC) [4]. Figure (1) illustrates the processing units of the next-generation radio node (gNB), represented by the aforementioned functional entities.

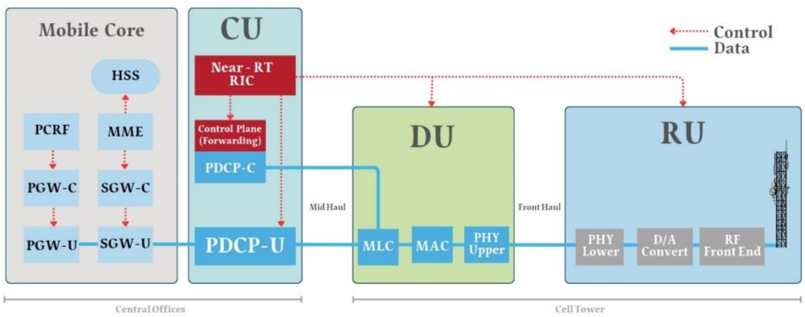

Figure 1: Detailed Functional Units of Next-Generation Radio Nodes [2]

b. Testbed Setup

The design and implementation of a fifth-generation Next-Generation Radio Access Network (5G NG-RAN) require a comprehensive environment that integrates both software and hardware components to ensure performance stability and accuracy of results. The following setup was adopted in this study :

Operating System: Ubuntu (22.04) was employed as a stable and reliable environment, deployed on a virtual instance (CISCO’s LABVM) pre-configured with the necessary tools for experimental testing. This system provides robust support for open-source utilities and telecommunication projects.

Software Platform (srsRAN 5G): The *srsRAN 5G* platform was utilized to configure the CU, DU, and RU units according to the Functional Split principle, with support for the (F1) and (NG) interfaces for integration with the open source Core Network, *Open5GS*. Additionally, the *srsUE* module was used to emulate user equipment functionality and test network registration [5].

Radio Equipment: The (USRP B200/B210) device from Ettus Research was employed due to its support for a wide range of frequency bands suitable for 5G environments, as well as its full compatibility with (UHD) and (GNU Radio) libraries [6] This configuration enables practical transmission and reception of signals in a realistic setting. To enhance transmission efficiency, a signal amplifier with a gain of (24 dB) was integrated with an antenna operating in the (FR1) frequency band with a gain of (12 dBi). Figure (2) illustrates the adopted configuration of the radio equipment.

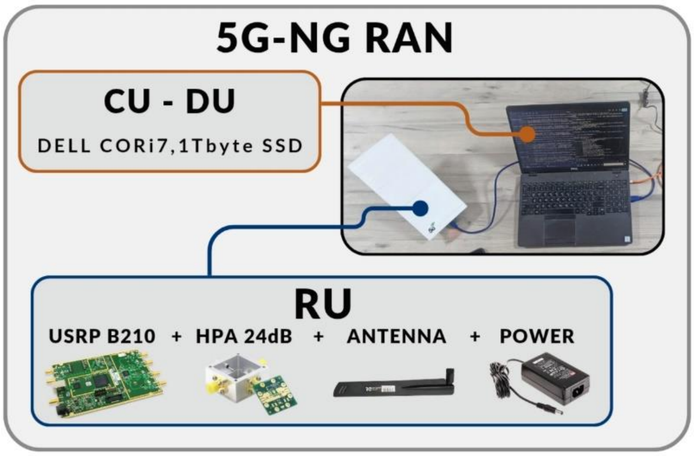

Figure 2: adopted configuration of the radio equipment.

Computational Requirements: The setup was deployed on computers equipped with Intel Core i7 processors, (6–8 Gbyte) of RAM, and SSD storage to enhance performance. Table (1) summarizes the adopted specifications:

Table (1) : Specifications of the Devices Used in the Simulation

Specification	Device 1	Device 2
Processor	Intel Core i7 vPro 8th (Dell)	Intel Core i7 11th (HP)
RAM	(8 Gbyte)	(6 Gbyte)
Virtualized Storage	(200 Gbyte)	(60 Gbyte)
Usage	srsRAN	srsUE

Dependencies & Tools: The software environment included GNU Radio and UHD drivers to operate the USRP devices, in addition to development tools such as CMake and GCC.

Networking & Configuration: Dedicated network interfaces were assigned to both CU and DU, interconnected using the GTP-U protocol via the (F1-U) interface. The CU was linked with the Access and Mobility Management Function (AMF) of the Core Network through the (NG) interface. Static IP addressing was adopted to simplify communication management among components.

Radio Configuration: The network was operated in the FR1 band (Sub-6 GHz) with a (20 MHz) bandwidth, theoretically supporting data rates of up to (100 Mbps) in the downlink and (50 Mbps) in the uplink. It should be noted that achieving such rates in practice requires access to high-capacity internet packages provided by service operators [7]

c. Operational Workflow

The operation of the RAN in this study is based on the distributed NG-RAN architecture (CU/DU/RU) under the 5G SA deployment mode. The workflow is structured into the following stages :

5GC Initialization : The Core Network (5GC) functions are deployed using the Open5GS platform. Control-plane components are activated, including the Access and Mobility Management Function (AMF) for registration and mobility management, the Session Management Function (SMF) for session handling, and the Authentication Server Function (AUSF) together with the Unified Data Management (UDM) for subscriber authentication and identity management. The User Plane Function (UPF) is responsible for user data path processing [8].

RAN Deployment: The RAN components, namely CU, DU, and RU, are activated, ensuring interconnection through the (F1) and (O-RAN) interfaces. This configuration enables functional flexibility and reduces latency.

UE Registration : The User Equipment (UE) initiates the registration process with the Core Network via the NG interface, during which Non-Access Stratum (NAS) messages are exchanged between the UE and the Access and Mobility Management Function (AMF) to verify the user’s identity using Software-Defined Radio (SDR) and the UERANSIM platform to emulate the UE functions [8].

PDU Session Establishment : Upon successful authentication, the SMF coordinates with the UPF to establish a (PDU Session), thereby enabling a bidirectional data channel between the UE and the external network (e.g., the Internet).

Performance Evaluation : Performance tests are conducted to evaluate the network according to key performance indicators (KPIs) [9], including :

Data throughput (Throughput) in both uplink and downlink.

End-to-end latency (Latency) between the UE and 5GC.

Packet loss rate (Packet Loss) and connection stability.

iii. Implementation and Results

This scenario represents a complete practical implementation of a standalone 5G Radio Access Network (5G SA RAN). A Software Defined Radio (SDR) device was employed as the User Equipment (UE) to enable network connectivity and facilitate experimental validation. The RAN was operated on a separate computer from the core network, as illustrated in Figure (3). Table (2) summarizes the key connection parameters for this scenario, which were selected in accordance with 3GPP standards for NG radio networks, including carrier band, subcarrier spacing, and bandwidth [10].

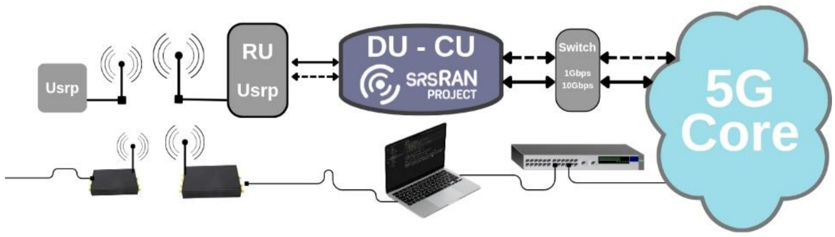

Figure 3: Network Diagram

Table (2): Key Connection Parameters for the Implementation Scenario

Parameter	Technology / Value
Duplexing Mode	TDD
Subcarrier Spacing (SCS)	(30 kHz)
Carrier Band	Band 78 (3.5 GHz)
Bandwidth (BW)	(20 MHz)
Tx-gain	50
Rx-gain	60
Plmn	00101

a. gNB Configuration

The gNB settings were configured and linked to the Core Network using external addresses. Subsequently, the radio interface and cell parameters were defined to ensure compliance with NG-RAN standards.

b. UE Configuration

In this scenario, the User Equipment (UE) was implemented using a Software Defined Radio (SDR) connected to a computer running the srsUE application. Subscriber identity and service attributes were defined through the srsUE configuration files, which serve as a substitute for traditional SIM cards. These files specify key parameters such as the Mobile Country Code (MCC), Mobile Network Code (MNC), Public Land Mobile Network (PLMN), and Access Point Name (APN). Tables (3) and (4) summarize the main attributes and services enabled for the UE within the test environment.

Table (3) : Network Attributes in srsUE Configuration Files

Field	Value	Description
MCC / MNC	001 / 01	Test network identifiers
PLMN	00101	Public Land Mobile Network for registration
APN	internet	Access Point Name for PDU sessions

Table (4) : UE Service Features in srsUE Configuration

Service	Status	Function
5GS Mobility	Enabled	Support for registration and mobility in 5G SA
NAS Authentication	Enabled	Secure authentication with the AMF
PDU Session Establishment	Enabled	Allows creation of data sessions

c. Network Operation

After completing the configurations, the gNB was successfully activated and established a connection with the AMF. As illustrated in Figure (4), the operational logs confirm the initialization of the Software Defined Radio (SDR) functions, including detection of the USRP B210 device, configuration of the master clock rate (set at 23.04 MHz), and proper synchronization of radio resources. The figure also highlights the setup of the wireless channel parameters, such as the carrier frequency (DL = 3410.1 MHz, UL = 3410.1 MHz, Band n78) and the corresponding bandwidth (20 MHz). Furthermore, the output shows the assignment of the cell identity and confirmation of the NGAP-based signaling connection to the AMF at IP address 192.168.15.208:38412, which verifies the readiness of the gNB to handle user registrations and session establishment.

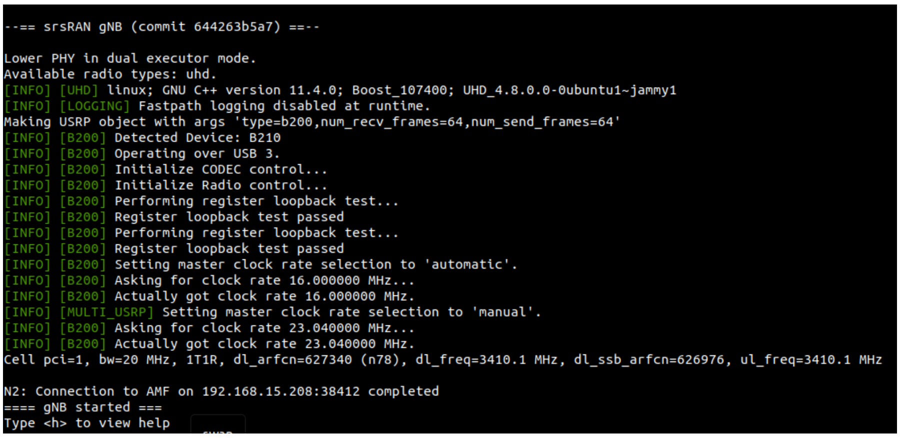

Figure 4: Operational Outputs of the Next-Generation Node (gNB)

d. Operation Scenarios

During this operation, both the network and UE shared the same public network identifier (PLMN: 00101). Upon entering the cell coverage area, the AMF received an InitialUEMessage via the (NGAP) interface, indicating a new connection. The network immediately assigned the UE identifiers (RAN_UE_NGAP_ID = 0 and AMF_UE_NGAP_ID = 1) and successfully processed geographic values, including the Tracking Area Code (TAC = 7) and Cell ID (CellID = 0x66c000), confirming the subscriber's connection via an active base station within the correct network range. Figure (5) illustrates the sequence of exchanged messages demonstrating this process.

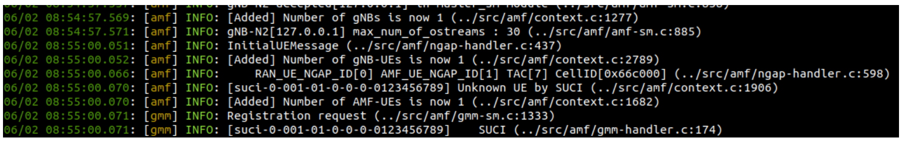

Figure 5: Message Exchange Sequence for Subscriber Registration

When inspecting the encrypted subscriber identity (SUCI: suci-0-001-01-0-0-0-0123456789), it was found to be unknown in the network database. The AMF added a new subscriber record, registering the UE as an active user, increasing the active subscriber count to one. Upon re-entry into the network after leaving the coverage area, the system recognized the subscriber immediately using the same encrypted identifier (SUCI), without treating it as a new user. This demonstrates the system’s ability to retain subscriber identity context and handle session changes efficiently, as illustrated in Figure (6).

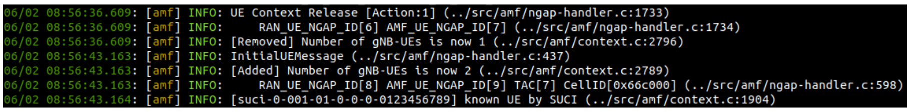
```
06/02 08:56:36.609: [amf] INFO: UE Context Release [Action:1] (../src/amf/ngap-handler.c:1733)
06/02 08:56:36.609: [amf] INFO:     RAN_UE_NGAP_ID[6] AMF_UE_NGAP_ID[7] (../src/amf/ngap-handler.c:1734)
06/02 08:56:36.609: [amf] INFO: [Removed] Number of gNB-UEs is now 1 (../src/amf/context.c:2796)
06/02 08:56:43.163: [amf] INFO: InitialUEMessage (../src/amf/ngap-handler.c:437)
06/02 08:56:43.163: [amf] INFO: [Added] Number of gNB-UEs is now 2 (../src/amf/context.c:2789)
06/02 08:56:43.163: [amf] INFO:     RAN_UE_NGAP_ID[8] AMF_UE_NGAP_ID[9] TAC[7] CellID[0x66c000] (../src/amf/ngap-handler.c:598)
06/02 08:56:43.164: [amf] INFO: [suci-0-001-01-0-0-0-0123456789] known UE by SUCI (../src/amf/context.c:1904)
```

Figure 6: Message Sequence for Subscriber Re-Identification

e. Results and Discussion

The experimental results were obtained by operating a 5G SA network using the srsRAN open-source platform. A Software Defined Radio (SDR) connected to a computer running the srsUE application was employed as the User Equipment (UE) to establish connectivity with the radio access network. Measurements were collected through physical layer (PHY) and medium access control (MAC) logs generated within srsRAN, providing detailed insights into link quality and system performance.

The key readings include: Channel Quality Indicator (CQI), Modulation and Coding Scheme (MCS), Bitrate, Error Rate, and Reference Signal Received Power (RSRP).

Downlink Results (DL) : The downlink (DL) demonstrated relatively stable performance, with CQI values ranging between (10–14) and MCS levels varying from (17–25). Most measurements achieved bitrates in the range of (2.8 kbps – 9.0 kbps) with nearly zero error rates.

The findings indicate that the DL maintained a high success rate and consistent CQI stability. However, the achieved bitrates were limited by the narrow channel bandwidth (20 MHz) and the constraints of the test environment،Table (5) presents the downlink (DL) readings.

Table (5) : Downlink Readings

Reading	CQI	RI	MCS	Bitrate (kbps)	OK	NOK	Error Rate (%)
1	13	1.0	22	9.0k	6	0	0%
2	14	1.0	25	5.1k	3	0	0%
3	13	1.0	21	2.8k	2	0	0%
4	13	1.0	0	0	0	0	0%
5	13	1.0	21	4.4k	3	0	0%
6	12	1.0	18	6.8k	6	0	0%
7	12	1.0	17	6.2k	5	2	28%
8	12	1.0	0	0	0	0	0%
9	12	1.0	0	0	0	0	0%
10	12	1.0	0	0	0	0	0%
11	14	1.0	25	5.2k	3	0	0%
12	12	1.0	20	4.0k	3	0	0%
13	10	1.0	13	848	1	0	0%

14	13	1.0	24	6.5k	4	0	0%
15	13	1.0	22	4.6k	3	0	0%

Uplink Results (UL) : The uplink (UL) exhibited less stability compared to the DL. RSRP values ranged between (–13 dB and –21 dB), while MCS levels varied between (23–27). Achieved bitrates ranged from (4.5 kbps to 36 kbps), but error rates fluctuated significantly between (25%) and (60%) in some readings.

These results reflect the UL's sensitivity to signal strength and the inherently weaker transmission power of the user equipment compared to the base station. This led to considerable fluctuations and relatively higher error rates, particularly under poor RSRP conditions،Table (6) presents the uplink (UL) readings.

Table (6) : Uplink Readings

Reading	RSRP (dB)	RI	MCS	Bitrate (kbps)	OK	NOK	Error Rate (%)
1	–16.0	1	27	36k	7	8	53%
2	–13.2	1	26	14k	3	3	50%
3	–21.2	1	27	9.6k	2	3	60%
4	n/a	1	0	0	0	0	0%
5	–14.3	1	26	19k	4	5	55%
6	–14.4	1	25	27k	6	5	45%
7	–19.3	1	24	18k	4	4	50%
8	n/a	1	0	0	0	0	0%
9	n/a	1	0	0	0	0	0%
10	n/a	1	0	0	0	0	0%
11	–13.7	1	25	14k	3	2	40%
12	–21.1	1	23	13k	3	2	40%
13	–13.2	1	25	4.5k	1	0	0%
14	–14.5	1	25	4.5k	1	1	50%
15	–13.9	1	26	14k	3	1	25%

iv. Conclusion

This study demonstrates the feasibility of designing and implementing a fifth-generation Radio Access Network (5G RAN) within an open-source environment comprising srsRAN and Open5GS, combined with SDR devices and physically connected to a smartphone equipped with a pre-programmed SIM card. The results confirmed the successful configuration of the radio network in Standalone (SA) mode, enabling complete connectivity between the user and the Core Network through standard interfaces (NG, F1), thereby simulating a fully integrated and realistic 5G network experience. In terms of downlink (DL) performance, the network exhibited stable operation with CQI values ranging between 10–14 and bitrates reaching up to 9.0 kbps, accompanied by very low error rates. Conversely, the uplink (UL) performance was less stable due to the limited transmission capability of the user equipment, with RSRP values ranging from –13 dB to –21 dB, bitrates reaching 36 kbps, and error rates up to 60% in some measurements, reflecting the inherent constraints of the uplink channel. From an academic and practical perspective, the combination of SDR and srsRAN provides a cost-effective and efficient platform for developing and studying 5G RAN networks in research environments. Moreover, the functional split of the radio node (CU/DU/RU) within the NG-RAN architecture offers deployment flexibility and scalability for future expansions. Finally, the developed model enables further research into advanced topics such as uplink performance optimization, application of MIMO and Beamforming techniques, and exploration of URLLC and mMTC scenarios.

References

[1] Khan, A., Dhar, S. P., Shanmugasundaram, R., & Jo, M. (2024). 5G networks: An overview of architecture, design, use cases and deployment (1st ed.). River Publishers.

[2] Peterson, L., & Sunay, O. (2020). 5G mobile networks: A systems approach (1st ed.). Morgan & Claypool Publishers.

[3] Chaudhari, B. S., & Zennaro, M. (2021). 5G and beyond: Fundamentals and standards (1st ed.). Springer Nature.

[4] Bourreau, M., & Lemstra, W. (2022). Open interfaces and innovation in telecommunications (1st ed.). Cullen International.

[5] Alves, R. P., da Silva Alves, J. G. A., Camelo, M. R., de O. Feitosa, W., Monteiro, V., & Cavalcanti, F. R. P. (2024, June 3). Experimental comparison of 5G SDR platforms: srsRAN × OpenAirInterface. In XLI Simpósio Brasileiro de Telecomunicações e Processamento de Sinais (SBrT 2023).

[6] Rouili, M., Saha, N., Golkarifard, M., Zangooei, M., Boutaba, R., Onur, E., & Saleh, A. (2024). Evaluating open-source 5G SA testbeds: Unveiling performance disparities in RAN scenarios. In Proceedings of the 2024 IEEE/IFIP Network Operations and Management Symposium (NOMS 2024) IEEE.

[7] Martian, A., Trifan, R. F., Stoian, T. C., Vochin, M. C., & Li, F. Y. (Year). Towards open RAN in beyond 5G networks: Evolution, architectures, deployments, spectrum, prototypes, and performance assessment. [Journal/Conference name]. National University of Science and Technology Politehnica Bucharest.

[8] Barbosa, M., Silva, M., Cavalcanti, E., & Dias, K. (2024, December 30). Open-source 5G core platforms: A low-cost solution and performance evaluation.

[9] Amini, M., Bozis, E. Z., & Varga, P. (2024). Performance analysis and comparison of full-fledged 5G testbeds: A comprehensive evaluation of throughput, latency, and radio parameters.

[10] ETSI. (2020). 5G; NR; NR and NG-RAN overall description; Stage-2 (3GPP TS 38.300, v16.2.0, Release 16).