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# IMPLEMENTATION AND OPTIMIZATION OF 5G NETWORKS USING SOFTWARE-DEFINED RADIO (SDR) AND OPENAIRINTERFACE (OAI)

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**Abstract.** In response to the rapidly growing demand for data speed and quality, modern communication systems are evolving to meet increasingly stringent requirements. This study presents the implementation and optimization of 5G networks using Software-Defined Radio (SDR) technology and the OpenAirInterface [1] (OAI) software framework. A complete Standalone (SA) 5G network model is developed and tested using USRP x410 hardware and Ubuntu-based servers. Experimental results demonstrate stable network performance, low latency, and data rates suitable for both academic and prototyping use cases.

**Keywords:** 5G, Software-Defined Radio (SDR), OpenAirInterface (OAI), USRP X410, Standalone 5G, gNB, Core Network

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## 1. Introduction

Over the past two decades, the exponential growth of mobile data consumption has driven a continuous evolution in wireless communication technologies. While 3G and 4G networks have served as critical milestones in enabling broadband connectivity, the emergence of bandwidth-intensive applications, massive device connectivity (e.g., IoT), and ultra-reliable low-latency services has revealed their limitations. As a result, the global telecommunications industry has shifted focus toward the development and deployment of fifth-generation (5G) networks.

5G is designed to meet the demands of modern society by providing enhanced mobile broadband (eMBB), ultra-reliable low-latency communication (URLLC), and massive machine-type communication (mMTC) [2]. This technology offers peak data rates of up to 20 Gbps, latency below 10 milliseconds, and support for up to one million devices per square kilometer. These capabilities make 5G suitable not only for mobile applications but also for smart cities, autonomous transportation, Industry 4.0, and healthcare innovations such as remote surgery and real-time diagnostics.

Central to 5G's design is the adoption of new radio access technologies, use of mmWave frequency bands (FR2), and architectural disaggregation between the radio access network (RAN) and the core. It introduces network slicing, virtualization, and cloud-native principles that enhance scalability and efficiency [3]. However, testing and validating such complex systems in real-world environments require advanced tools that offer flexibility, reconfigurability, and realistic emulation of hardware-software interaction.

In this context, Software-Defined Radio (SDR) platforms like the USRP X410 [4] combined with open-source frameworks such as OpenAirInterface (OAI) play a pivotal role. They allow researchers and developers to implement and evaluate 5G networks under various configurations and scenarios. SDRs abstract hardware control, enabling reconfigurable frequency ranges, flexible bandwidth allocation, and compatibility with diverse modulation schemes. OAI, on the other hand, offers a complete software stack for 5G RAN and Core Network functionality, allowing standalone (SA) and non-standalone (NSA) modes to be deployed and tested on commodity hardware.

This study presents a practical implementation of a 5G Standalone network using OAI and USRP X410 hardware [4]. The objective is to validate the performance of such a system by measuring key performance indicators such as latency, throughput, and user equipment (UE) registration. The experiments are carried out using standard mobile phones with test SIM cards and Ubuntu-based hosts with high-performance CPU specifications. The outcomes of this research are expected to contribute to prototyping, education, and early-stage validation of custom 5G deployments.

## 2. System Setup and validation

5G utilizes FR1 (sub-6 GHz) and FR2 (mmWave) frequency bands and is built upon flexible, modular architectures such as CU/DU split and virtualized RAN (vRAN). Key components of the 5G core network include AMF, SMF, UPF, UDM, NRF, AUSF, and others, supporting advanced features like network slicing, cloud-based scalability, and enhanced mobile broadband (eMBB). In our study we have obtained the FR1 (sub-6 GHz) [5, 6].

The experimental setup for 5G network implementation includes the USRP X410 device functioning as the Software Defined Radio (SDR) platform. Two high-performance Ubuntu-based computers were used -one as the Core Network host and the other as the OAI gNB (monolithic mode). These machines were connected via a high-speed switch to allow communication and data exchange between the gNB and the core network. The USRP X410 is interfaced with the gNB machine using SFP+ ports and RF coaxial cables.

Our testing utilized a standard 5G smartphone with a pre-configured test SIM card as the User Equipment (UE). The phone was able to search, register, and establish data sessions with the deployed OAI-based 5G standalone network. The physical setup and logical structure of the system are shown in the diagram below.

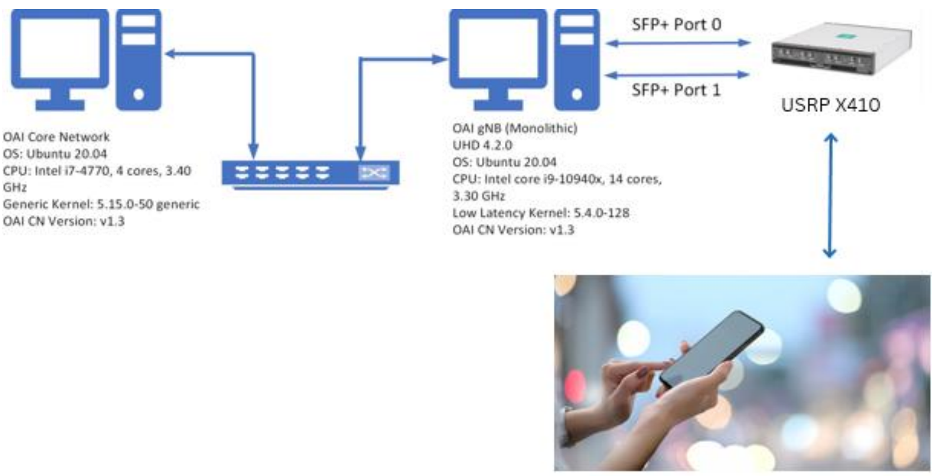


**Fig. 1.** 5G System Setup with USRP X410 and Smartphone as an UE.

In addition to the performance tests, further validation was performed by monitoring the registration status of the user equipment (UE) and confirming its connection to the test 5G network. Initially, the Access and Mobility Management Function (AMF) logs indicated that no UE was connected and no gNB had registered to the network. This status was reflected in the empty gNBs' and UEs' information tables logged by the AMF, as shown in the preliminary state.

Subsequently, a commercial 5G smartphone with a pre-configured test SIM card was used to search for available networks. During the manual network scan, the device successfully detected the custom-deployed 5G network identified as "Test PLMN 1-1", alongside existing commercial networks as shown in the Fig.2.

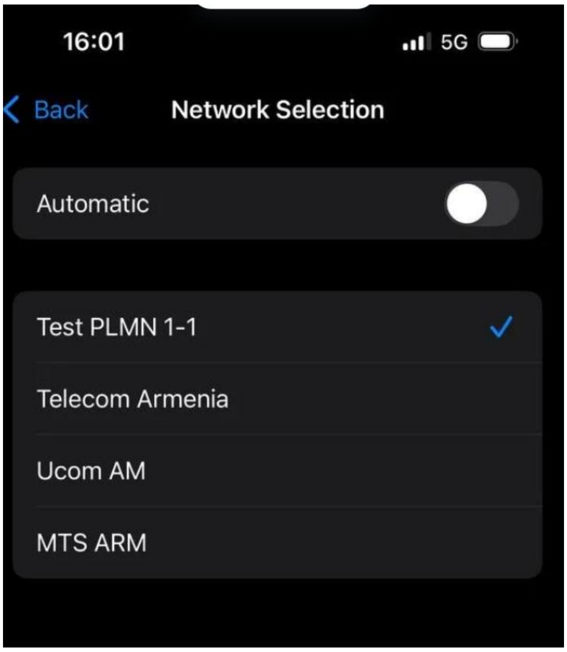


**Fig. 2.** Detected networks by UE.

This confirmed that the test network was broadcasting effectively and was visible in the local spectrum environment.

After selecting and connecting to the "Test PLMN 1-1" network, the AMF logs confirmed the successful registration of the UE. The gNB status changed to "Connected", and the UE's 5GMM state was listed as "REGISTERED", with complete identifiers such as IMSI, GUTI, and Cell ID being correctly populated in the AMF's database see Fig.3.

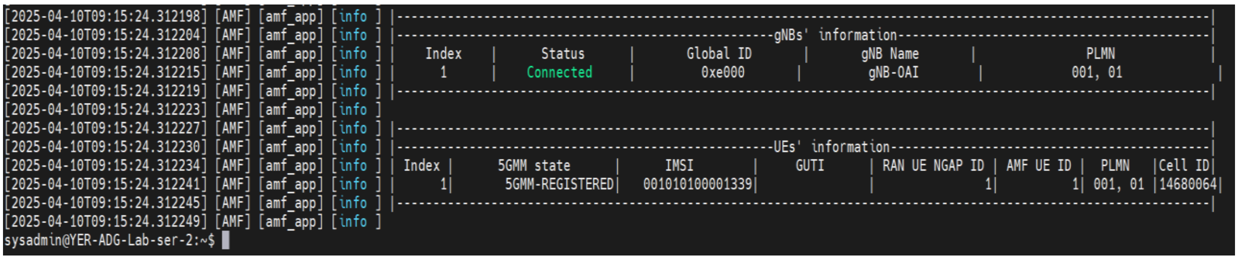


**Fig. 3.** AMF log.

These logs verified the complete attachment of the UE to the 5G core network, confirming the successful end-to-end operation of the deployed standalone 5G system.

This registration process validated the functionality of the OAI core and gNB stack, the performance of the USRP X410 as the SDR platform, and the interoperability with commercial mobile devices, thus demonstrating the system's reliability and practical applicability in real-world testing environments.

After we have successfully connected the UE to the gNB and Core Network we had validate the network stability using the Wireshark.

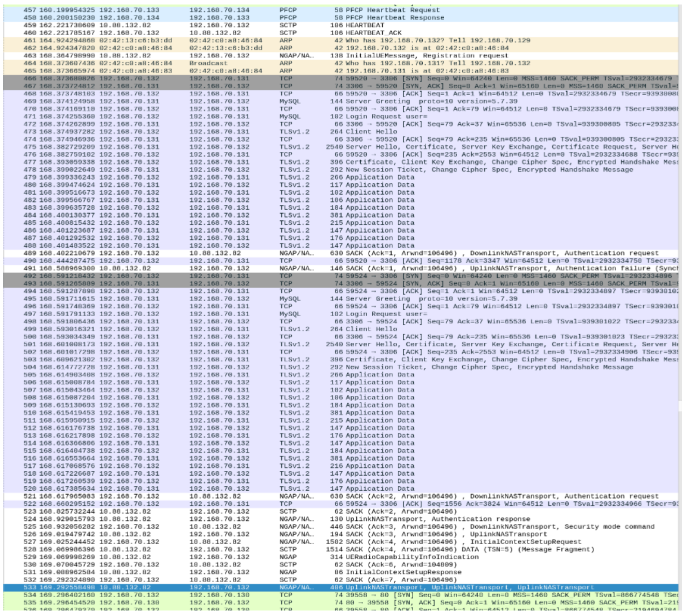

**Fig. 4.** Benchmark results.

The network speed and system latencies were measured using standard technologies.

## 3. Conclusions

In this article, the implementation and optimization of 5G networks was carried out using the OpenAirInterface (OAI) software environment and the USRP x410 device. As part of the research, a real model of a 5G network was successfully created, which includes a core network (Core Network), a base station (gNB) and a user equipment (UE). The tests were carried out at a frequency of 3.5 GHz and a bandwidth of 100 MHz. The results showed that the network operates stably, providing download speeds of up to 190 Mbps and upload speeds of up to 50 Mbps, as well as low latency, averaging 9.3 milliseconds. Based on the successful implementation of the registration process and the stability of data exchange, it can be concluded that the developed system is fully applicable for both academic research and prototyping purposes in the field of 5G technology implementation and development [7]. Thus, the work has both scientific and practical significance and can serve as a basis for future research.

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