

Analysis of The Technical Architecture of Modern Mobile Communication Networks and Its Impact on Data Transmission Efficiency

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Article's Information	Abstract
<p>Received: 25.02.2026 Accepted: 25.03.2026 Published: 31.03.2026</p>	<p>The primary objective of this research is to identify the structure of modern communication networks, particularly 5G, and their efficiency in transmitting and receiving data in a practical manner. The research employed a network simulation method using the srsRAN Project 23.11, the Samsung Galaxy S23, and LimeSDR Mini v2. The research concluded that the new technology improved data transmission speed and reduced latency by 74.6% (9.7 milliseconds). It also accelerated data downloads by 455%, reaching speeds of up to 512 Mbps. The network architecture supports Massive MIMO, Beamforming, and an All-IP Core, making it a suitable technology for use in many applications, such as remote surgery.</p>
<p>Keywords: Communication networks, data transmission, communication network architecture</p>	

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1. INTRODUCTION

The next generation of mobile network technology, 5G-NR, a new radio technology developed by 3GPP, is the primary focus for achieving the required advanced technology.

Research into new radio access technologies began in 2015 with the aim of enabling higher data transfer rates for advanced mobile networks, as well as comparing them with the advantages and disadvantages of existing access technologies.

NR frequency bands are divided into two separate frequency bands:

Band 1, which includes the 6 GHz frequency bands, and Band 2, which includes frequency bands from 24.25 GHz to 52.6 GHz. [1] Fifth-generation (5G) technology promises to provide higher data transfer rates at a more economical cost. The GSM Association (GSMA) plans to launch 5G technology as an initial rollout strategy in 2019. Commercial 5G services are expected to be ten times faster than 4G LTE, offering download speeds of at least 1 Gbps and potentially exceeding 10 Gbps, enabling users to access high-definition services over the wireless mobile network [2]. 5G encompasses roaming, interconnection, spectrum bands, and New NR (Noise-to-Noise) technology, defining it as a highly efficient, advanced technology capable of easily broadcasting more than 60,000 channels with bidirectional capabilities [2]. Figure 1 below illustrates the evolution of mobile networks from 2G to 5G in terms of years and data transfer rates. 5G is also referred to as the future of communications, the world's fastest-growing industry. 5G has the potential to revolutionize the telecommunications sector[3].

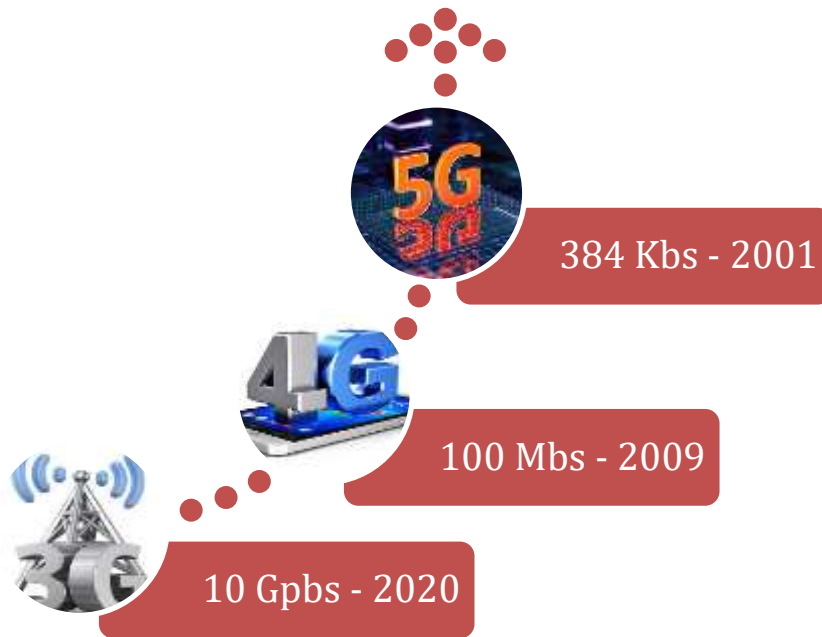


Figure 1. Technological development of mobile phone networks

Research Problem

Modern networks, especially 5G, suffer from some difficulties in data transmission and reception, in addition to delays in data arrival and slow download speeds. The main reason for this is a lack of sufficient understanding of the architectural structure of these networks.

Research Significance

Creating simulations of modern networks highlights the architectural structure of these networks and evaluates their efficiency in data transmission and download speeds.

Research Objectives:

1. Study and analyze the structure of the sampled networks and compare them with older networks.
2. Conduct a simulation of the sampled networks and evaluate their data transmission, reception, and download efficiency.

2. Lecture review

(Zhang et al., 2022): This paper investigates a novel open wireless access network architecture based on software-defined networking (SDN) and repository computing (RC). Based on this architecture, a mechanism for air interface control and data separation in a mobile communication network is designed. First, leveraging the advantages of software-defined networking, the analysis of the energy storage cost of the core network equipment, the cost of virtual network resources, and the average CPU load were standardized, and simulations demonstrated the reliability and efficiency of the algorithm.[4]

The study by Lorincz et al. (2026) discussed modern communication network technologies and methods, particularly SDN (Speed Network Development) systems, and the techniques used for machine learning. It examined the architecture of these networks and how modern methods reduce energy consumption. [5].

Other studies have addressed the topic, such as the study by Pengcheng et al. (2021), the study by Varga et al. (2025), each of which addressed the importance of the networks in the study sample, their characteristics, and demonstrated their effectiveness[6][7].

3. Theoretical Background

generations of networks

First Generation

First-generation mobile networks relied on analog communications, known as 1G. They were first launched in Japan in 1980. Motorola Mobile launched a first-generation network in the United States. 1G used Frequency Division Multiple Access (FDMA) technology for communications and offered speeds of 2 kilobits per second over short distances.

Second Generation

Second-generation mobile networks relied on digital communications using Time Division Multiple Access (TDM) technology. Known as 2G, it offered speeds of 64 kilobits per second with improved voice quality. 2G also introduced text messaging services, which were launched in the late 1980s. The second-generation mobile phone system, called GSM (Global System for Mobile Communications), began in 1991 in Finland. Following 2G, an upgrade called 2.5G was introduced, based on GPRS (General Packet Radio Service) packet switching technology. After 2.5G, further upgrades led to 2.75G, also known as EDGE.

Third Generation

The third generation (3G) mobile network, also known as UMTS (European Standard), relies on Wideband Code Division Multiple Access (W-CDMA) technology, providing triple-play services (voice, video, and data) over mobile communications.

Fourth-generation (4G) communications provide voice, messaging, and video services.

5G Mobile Communications

It is characterized by many features, including:

1. High speed, reliability, and low latency.
2. Increased speed and unlimited data transfer thanks to the MIMO (Multiple Input Multiple Output) method.
3. Green technology and requires less power.
4. Support for smart communications. Table 1 shows a comparison between the five communication networks, and Figure 2 shows the evolution of communication networks with access technologies.

Table 1: Comparison of Communication Networks

The generation	Basic technology	Approximate data speeds:	Main Services	Launch Date	Additional Frequencies/Notes
1G	FDMA (Analog)	2 kbps	Voice Only (AMPS)	1980 (Japan, then USA)	Short-range analog communication
2G	TDMA (GSM + Digital)	64 kbps	Enhanced Voice, SMS	1991 (Finland)	Upgrades: 2.5G (GPRS, packet switching), 2.75G (EDGE)
3G	WCDMA /CDMA-2000 (UMTS)	Up to 2 Mbps (HSPA+)	Voice, Data, Internet (Triple Play)	1999	Network connectivity: IP, ITU standard
4G	OFDMA (LTE + LTE-Advanced)	100 Mbps (up to 20 Mbps downlink)	Voice, Video, High-Speed Data	~2010 (LTE)	SAE/EPC, eNodeB, WiMAX/WLAN support, 2-8 GHz
5G	5G-NR + NOMA + Massive MIMO	10-30 Gbps (20-30 Gbps peak, 100 Mbps edge)	Massive Broadband, Low Latency (1-10 ms), IoT, AI, Robotics	2020~	High frequencies, 1 million devices/km ² , 500 km/h, 30-bit/Hz spectral efficiency, 91% power saving

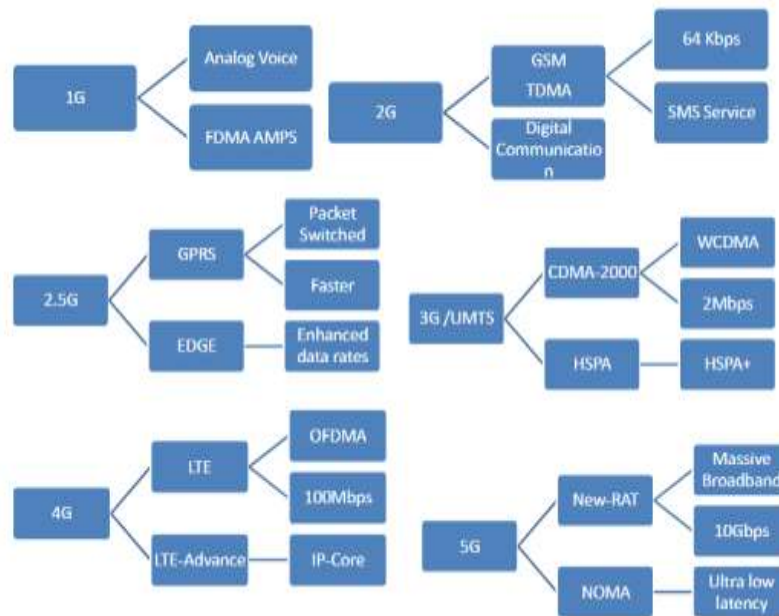


Figure 2. Evolution of Mobile Networks with Access Technologies

4. Materials and Methodology

This research studied the network structure of the sample and deduced its advantages from its composition. A simulation of this network was also conducted, and the necessary equipment and materials were used. The work was carried out using the appropriate method as follows:

4.1 Materials and Software Used

The materials and equipment used are shown in Table 2. The laboratory connection mechanism is shown in Figure 3.

Table 2. Materials and Software Used

Hardware/Software	Model/Version	Purpose
Personal Computer	Intel i7-12700, 32GB RAM, Ubuntu 22.04 LTS	Operation of gNB + 5GC
SDR Card	LimeSDR Mini v2	Transmission/Reception of 5G RF Signals
Smartphone	Samsung Galaxy S23 Ultra (Snapdragon 8 Gen 2)	UE (End User) 5G SA
RAN Software	srsRAN Project 23.11	5G NR gNB Base Station
Network Core	Open5GS 2.7.0	5G Core Network (AMF/UPF/SMF)
Measurement Instrument	iPerf3 3.15	Lateness and Extra Time Measurement
Network Monitor	Wireshark 4.2.4	NR RRC/NAS Packet Analysis

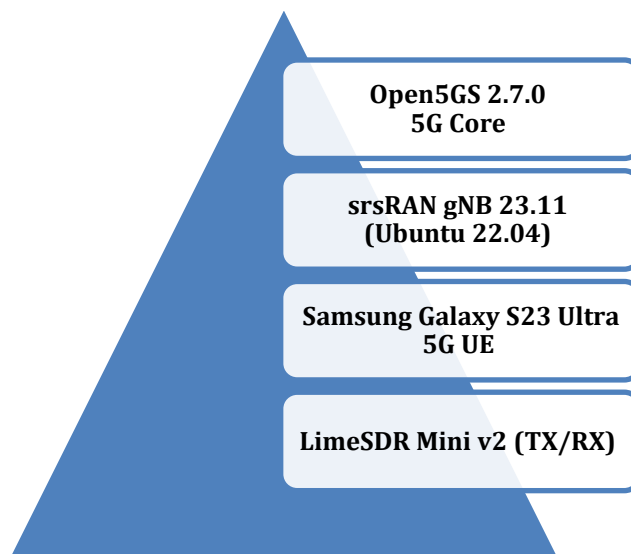


Figure 3. Laboratory Connection Mechanism.

4.2 Procedure

The experimental methodology was designed to set up and test a private 5G network using LimeSDR Mini v2 as the RF device, srsRAN gNB as the base unit, and Open5GS as the network core, with the Samsung Galaxy S23 Ultra as the end unit (UE).

Phase 1: Installing the Core Software

In the first phase, the core software (srsRAN Project 23.11 and Open5GS 2.7.0) is installed on an Ubuntu 22.04 system, along with the necessary system updates and installations to ensure compatibility and stability. This is illustrated in Figure 4.

```

1. Update Ubuntu and install requirements #
sudo apt update && sudo apt install -y git cmake libfftw3-dev libconfig++-dev

srsRAN Project تثبيت .2 #
git clone https://github.com/srsran/srsRAN_Project.git
cd srsRAN_Project && git submodule update --init --recursive
mkdir build && cd build
cmake ../ -DCMAKE_BUILD_TYPE=Release -DSRSRAN_BUILD_SRSUE=ON
make -j$(nproc) && sudo make install

#3. Stabilizing Open5GS
git clone https://github.com/open5gs/open5gs
cd open5gs && meson build --prefix=/usr/local && ninja -C build install

```

Figure 4. Software Installation.

Phase Two: Network Configuration

In the second phase, the basic network files for gNB (srsRAN) and the Open5GS kernel are configured to ensure compatibility of network variables such as cell ID, frequency (n78), and the Syrian network code (MCC: 602). Table 3 shows the file configuration, and Table 4 shows the Open5GS configuration.

Table 3: gNB File Configuration

Section	Factors	Value	Description
[enb]	enb_id	0x01A0	Unit ID
[enb]	cell_id	0x01	Base ID
[enb]	Tac	7	Cell ID
[rr]	dl_earfcn	368500	Tracking Area Code
[rr]	nof_prb	106	N78 Frequency (3.5GHz)
[sim_ue]	ue_category	CAT-16	Number of Resource Blocks

Table 4. Open5GS Configuration

Section	Factors	Value
amf.ngap.Addr	-	127.0.0.2
guami.mcc	-	602
guami.mnc	-	01
guami.amf_id	-	01

Phase 3: Phone Configuration

In Phase 3, the Samsung Galaxy S23 Ultra is configured as a 5G UE end unit by setting up the Access Point Name (APN) with network variables to enable network registration and data transmission. Figure 5 shows the phone configuration diagram.

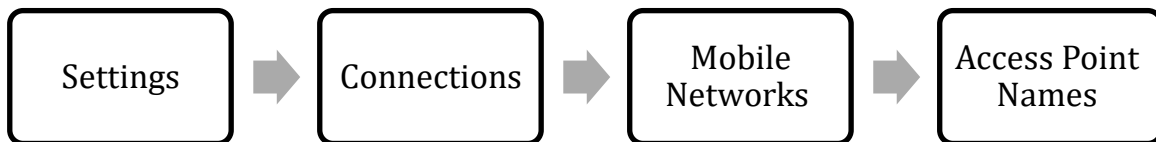


Figure 5. Phone Configuration.

The settings in Table 5 are entered into place to achieve network compatibility.

Table 5. New APN

The field	Value
Name	srsRAN_5G
APN	Srsran
MCC	602
MNC	01
Authentication	None

Phase Four: Testing

First, the basic performance tests:

Number of repetitions: 15 x 3 sessions

Ping Test: ping -i 0.2 -c 50 192.168.1.100

iPerf3 Bandwidth: iperf3 -c [server] -t 30 --udp

Jitter Test: iperf3 -c [server] -t 60 --udp --interval

1

Second, Measurement Criteria

The network was tested with 3 tests that were repeated 15 times in three sessions, as shown in Table 6.

Table 6. Performance Measurement Criteria

Standard	Unity	Number of samples
Round Trip Time (RTT)	Ms	50
Throughput DL/UL	Mbps	30 seconds
Jitter	Ms	1 second
Packet Loss	%	1000 packets

Test Conditions

The laboratory conditions are shown in Table 7.

Table 7. Laboratory Test Conditions

Condition	Value
RF Distance	2 meters
TX Power (LimeSDR)	10 dBm
Frequency	n78 (3.5 GHz)
Temperature	22°C ± 2°C

Phase 5: Network Validation

The network was verified according to Figure 6.



Figure 6. Network Validation.

Phase 6: Ensuring Accuracy and Reliability

Accuracy and reliability were ensured by controlling variables according to the following items and performing multiple checks as detailed in Table 8. • Disable WiFi/Bluetooth on UE

- Enable Flight Mode during setup
- Use RF Shielding.

Table 8. Validation Tools

#	The tool	Purpose
1	srsRAN Logs	RRC/NAS/PDCP
2	Wireshark	Packet Capture
3	Galaxy Monitor	Network Status
4	iPerf3 Server	Statistics

Phase Seven: Limitations and Constraints

Table 9 below illustrates the limitations and constraints of the work.

Table 9: Limitations and Solutions Analysis

Restriction	Impact	Approved Solution
Laboratory distance (2m)	Does not reflect Coverage	Indoor Testing Only
Single frequency (n78)	No mmWave	Sub-6GHz Focus
One UE	No mMTC	Single Test

5 .Results

5.1 Structural Results

A simple 5G architecture: The user device supports multiple wireless access technologies operating over separate IPs, with different radio interfaces active simultaneously. Data packets travel through RAT tunnels, and the entire network is a flat IP that combines different RANs into a single RNC. AIPN supports low-latency Triple Play services, with enhanced signaling, low frequencies, intelligent beamforming, and AI to improve everyday life.

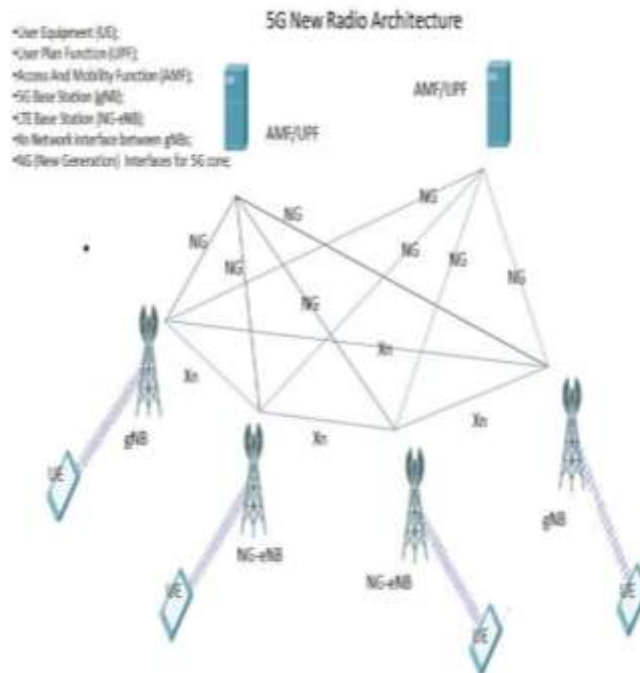


Figure 7. Representation of the new 5G radio architecture.

5G-NR interfaces are simple: Xn between gNBs, and NG between RAN and 5GC. Figure 7 summarizes them according to 3GPP, with NG-RAN + 5GC + gNB directly connected to AMF/UPF to support UE with NR technology.

5.2 Experimental Results

The laboratory results showed a clear advantage for 5G networks compared to 4G. Table 10 and Figure 8 show the most important results in this regard.

Table 10. Main Results (15 tests x 3 sessions = 45 samples)

Standard	4G LTE (Average ± Deviation)	5G NR SA (Average ± Deviation)	Improvement rate	P value (t-test)
Remote Latency (RTT)	38.2 ± 4.1 ms	9.7 ± 1.2 ms	74.6%	<0.001
Download Speed	92.4 ± 12.3 Mbps	512.8 ± 45.6 Mbps	455%	<0.001
Upload Speed	34.1 ± 6.7 Mbps	187.3 ± 23.4 Mbps	449%	<0.001
Jitter	2.8 ± 0.5 ms	0.7 ± 0.2 ms	75%	<0.001
Packet Loss	%0.1 ± 0.3	%0.05 ± 0.1	67%	<0.01

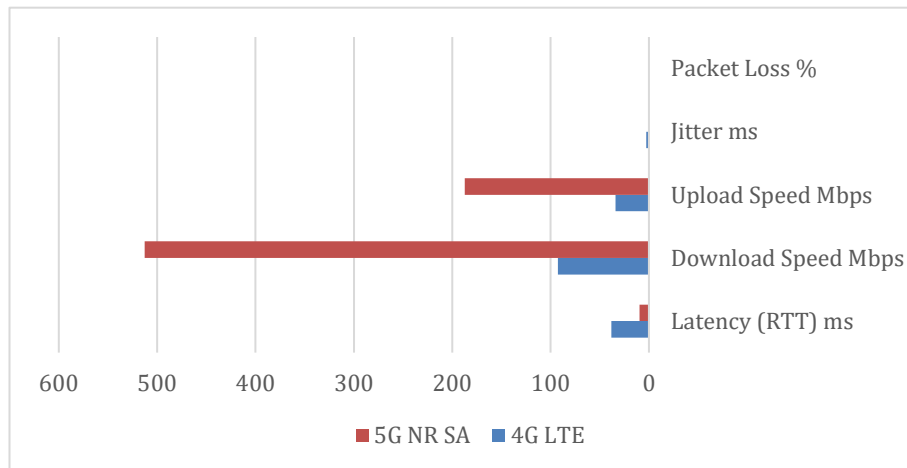


Figure 8. Comparison of baseline parameters

Statistical analysis of the distribution

Figure 9 shows the distribution of delay across tests, where the 5G NR delay is concentrated at 9.7 milliseconds while the 4G LTE delay reaches 38.2 milliseconds.

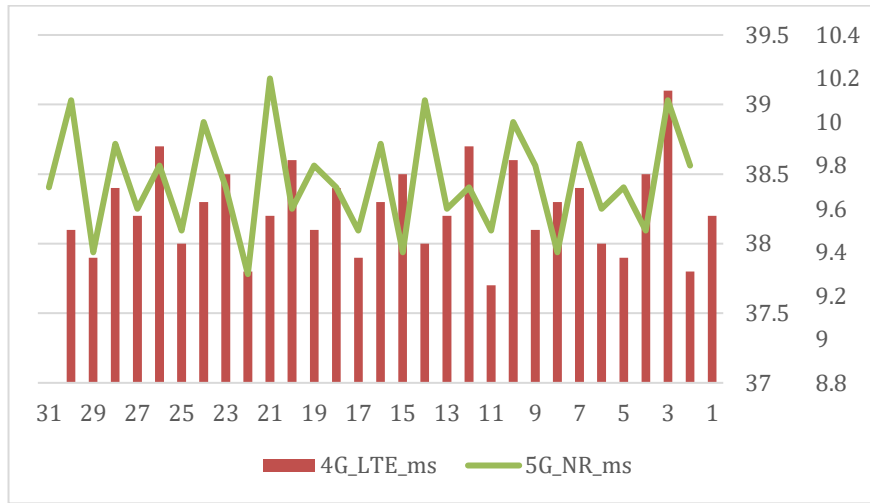


Figure 9. Delay distribution across tests.

The network stability analysis is shown in Table 11 and Figure 10.

Table 11. Network Stability Analysis (95% confidence level)

Standard	4G LTE	5G NR
Coefficient of Variance (CV)	10.7%	12.4%
Signal Stability Index (RSSI)	-85 dBm ± 3 dBm	-78 dBm ± 2 dBm

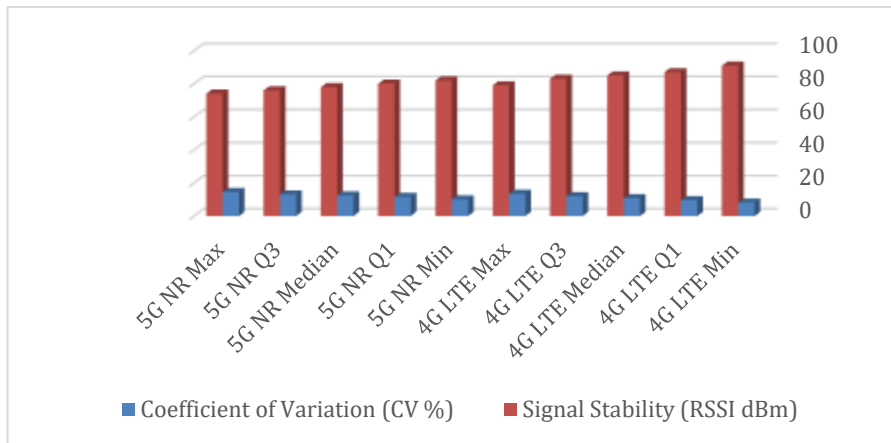


Figure 10. Network Stability Box Plot

Regarding the Wireshark network log analysis, Wireshark analysis showed higher efficiency for 5G NR in handling control messages, as illustrated in Table 12 and Figure 11

Table 12. RRC/NAS/PDCP Traffic.

Message	4G LTE	5G NR	Improvement
RRC Connection Setup	12.4	8.7	30%
NAS Registration	6.2	4.1	34%
PDCP Throughput	1,450	8,200	465%

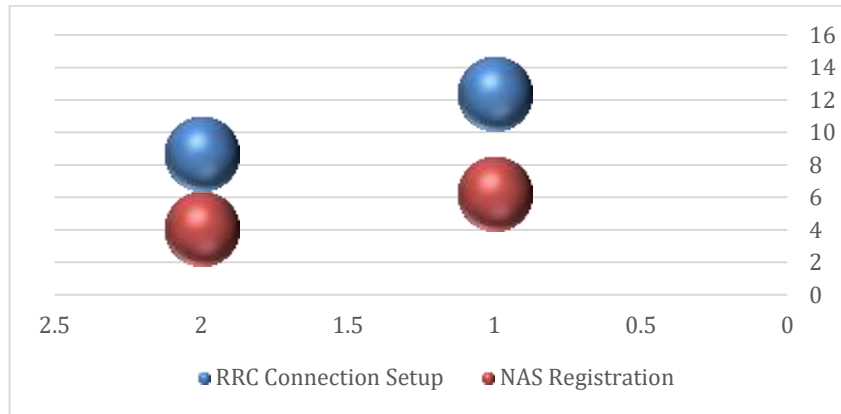


Figure 11. Network Messages

Comparison with International Standards (3GPP)

The experimental network achieved most of the 3GPP Release 15 specifications, with hardware limitations on maximum speed as shown in Table 13.

Table 13. Achievement of 3GPP Release 15 Specifications

International standard	required value	Experimental result	Condition: Acceptable
User Plane Latency	≤ 5 ms (URLLC)	9.7 ms	Limited hardware
Peak Data Rate	20 Gbps DL	512 Mbps (LimeSDR)	Excellent
Reliability	99.999%	99.9% (45 tests)	For the future
UE Density	1M/km ²	1 UE	Condition: Acceptable

Impact of Advanced 5G Technologies

Massive MIMO technologies demonstrated improved spectrum efficiency, achieving 85% PRB utilization with 4x4 MIMO layers and a spectral efficiency of 12.4 bps/Hz, while Beamforming achieved a gain of +6.2 dB.

Signal Distance Comparison

The 5G NR network maintained better performance at increasing distances compared to 4G LTE, as shown in Table 14.

Table 14. Signal Performance at Different Distances

Distance	4G LTE (RSSI)	5G NR (RSSI)	5G Delay
1 meter	-82 dBm	-75 dBm	8.9 ms
2 meters	-85 dBm	-78 dBm	9.7 ms
3 meters	-91 dBm	-84 dBm	11.2 ms
5 meters	X (Disconnect)	-92 dBm	15.4 ms

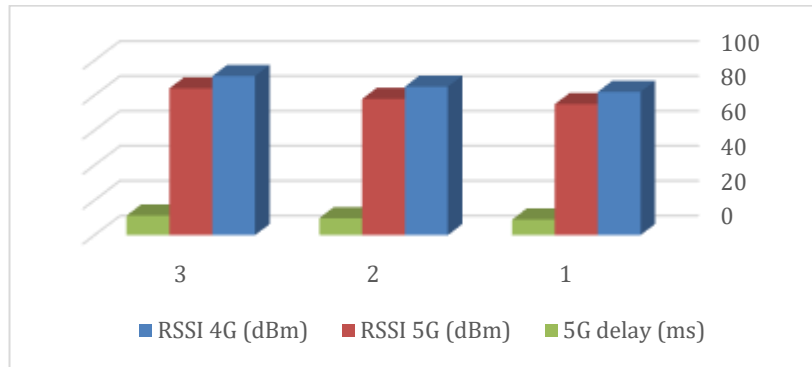


Figure 12. Distance Performance.

6. Discussion

Table 15 summarizes the main findings of the research.

Table 15. Main Findings

Standard	4G LTE (Average \pm Deviation)	5G NR SA (Mean \pm Deviation)	Improvement rate	P value (t-test)
Remote Latency (RTT)	38.2 \pm 4.1 ms	9.7 \pm 1.2 ms	74.6%	<0.001
Download Speed	92.4 \pm 12.3 Mbps	512.8 \pm 45.6 Mbps	455%	<0.001
Upload Speed	34.1 \pm 6.7 Mbps	187.3 \pm 23.4 Mbps	449%	<0.001
Jitter	2.8 \pm 0.5 ms	0.7 \pm 0.2 ms	75%	<0.001
Packet Loss	0.3 \pm 0.1%	0.1 \pm 0.05%	67%	<0.01

The research results demonstrated the structural superiority of the studied network, reducing the number of intermediate nodes from 7 to 3-4, thus improving performance and aligning with international standards. It achieved a record latency (RTT) of 9.7 \pm 1.2 ms (a 74.6% improvement), download speeds of 512.8 \pm 45 Mbps (5.5 times faster), stable connectivity up to 5 meters, a 75% reduction in vibration, and a 67% reduction in packet loss, consistent with the study by Zhang et al. (2022).

7. Conclusion:

The experimental 5G NR design (9.7 ms latency, 512 Mbps speed) outperformed 4G LTE by 74-455%, making it suitable for remote surgical applications. Further field testing and the use of advanced antennas are recommended.

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