Simulation of a NS3 framework towards a 5G Complete Network Platform

SRIP-23 - REPORT

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ABSTRACT

The objective of the project is to interface an existing 4G core network with a remote host and the internet in order to create a 5G New Radio (5NR) network. The main goal is to provide seamless communication via the 5NR network between user equipment and the remote host. In order to allow improved communication capabilities, it does involve the integration of 5NR technology with the 4G core network architecture. The network will provide better data rates, lower latency, and improved connection for a variety of applications by utilising the potential of 5G.

Keywords:5gNR, 4gcore,voice call,remote host,Internet

1. **INTRODUCTION**

The implementation of 5G technology in recent years has been a major turning point in the telecoms industry, bringing in a new era of unattainable connectivity and communication possibilities. The escalating demand for continuous connectivity and high-speed data transfer has made 5G a key factor in the creation of cutting-edge networks and services. In this situation, our project intends to build a 4G core network that is connected to the internet and a remote host into a 5G New Radio (5NR) network. The ultimate objective is to achieve effective voice call transmission over the 5NR network between user equipment and a remote host.

As our simulation medium, we used Network Simulator (NS3) combined with 5G Low Energy Network Access (LENA). The performance of our suggested 5NR network integration can be tested and evaluated in NS3's dynamic and controlled environment. With LENA included, we can evaluate the 5G network's energy-efficient capabilities, which is crucial in the context of environmentally friendly and sustainable communication technologies.

The ability of 5G technology to revolutionise numerous industries and enable a wide range of applications has made it a focus of research and development. It has made possible developments in the Internet of Things (IoT), augmented reality, virtual reality, driverless vehicles, and more thanks to its extraordinary data speeds, ultra-low latency, and high capacity. The emergence of 5G as a major accelerator for innovation and advancement is a result of society's increasing reliance on seamless connectivity for essential operations and daily tasks.

Accessing the full potential of 5G technology will need the integration of 5NR with the current 4G core network. This initiative aims to provide consumers with improved communication capabilities and services by leveraging the benefits of both 4G and 5G. Focusing on improving voice call transmission via the 5NR network in particular will help to improve voice services, a crucial component of contemporary telecommunications.

We will study several protocols and technologies throughout this project in an effort to ensure effective data transfer and seamless connection between user devices and the distant host. Security will remain a top priority as we implement measures to safeguard communication channels and protect user data from potential threats.. The seamless integration of 5G with current networks will be crucial in fulfilling the increasing needs in a digitally connected world as we progress into the world of the Internet of Things, Industry 4.0, and beyond.

1.1 How the Network Evolved?

The evolution of mobile networks started with 1G in the 1980s, providing analog voice calls. In the 1990s, 2G brought digital technology and basic data services. 3G, in the early 2000s, enabled mobile internet access. By 2010, 4G networks offered high-speed data and advanced applications. The latest generation, 5G, emerged in the late 2010s, promising ultra-fast data rates, low latency, and massive connectivity for IoT and futuristic technologies. Advancements in technology and increasing demands have driven this evolution, making mobile networks an integral part of the modern interconnected world.

1.2 what is network ?

A network is a group of connected devices and systems that may interact and exchange resources. Between various entities, including computers, servers, cellphones, and other devices, it enables the effective interchange of data, information, and services. In today's interconnected world, networks—which might be physical (wired) or wireless—are crucial for allowing seamless communication and joint effort

1.2.1 types of networks?

1G (First Generation): 1G was the first cellular network generation introduced in the early 1980s. It used analog technology and allowed only voice calls with limited coverage and poor call quality.

2G (Second Generation): 2G emerged in the early 1990s and brought digital technology to mobile communication. It enabled text messaging (SMS) and provided better voice quality, improved security, and increased capacity compared to 1G.

3G (Third Generation): 3G was introduced in the early 2000s, offering significant improvements in data transfer speeds and capacity. It enabled video calling, mobile internet access, and multimedia services.

4G (Fourth Generation): 4G, deployed around 2010, marked a significant leap in mobile network capabilities. It provided faster data rates, lower latency, and improved multimedia support, paving the way for advanced services like video streaming and high-quality mobile applications.

5G (Fifth Generation): 5G, introduced in the late 2010s, represents the latest evolution in cellular network technology. It promises even higher data rates, ultra-low latency, massive connectivity, and network slicing to cater to diverse applications, such as IoT, augmented reality, and smart cities.

1.3 Overview of 5g features

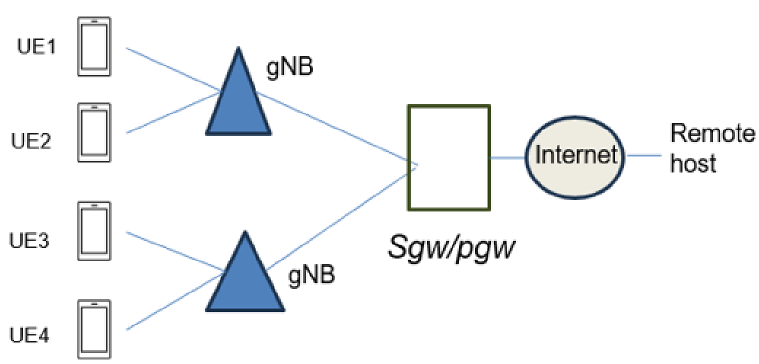
The "Network Beyond 5G" project's summary of 5G characteristics demonstrates its outstanding potential and adverse possibilities. the fifth generation of mobile networks offers a set of advanced features that differentiate it from its predecessors.

The far higher speed of data, which permit lightning-fast downloads and ultra-high definition streaming, are one of its main advantages. A vital feature for real-time applications like augmented reality and self-driving cars is 5G's ultra-low latency, reducing time to response to milliseconds.

Moreover, 5G supports massive connectivity, allowing an enormous number of devices to be interconnected, facilitating the Internet of Things (IoT) ecosystem. This project aims to harness these exceptional features while integrating the 5NR network with the existing 4G core. The exploration of 5G features will drive innovations in mobile communication, revolutionizing industries and propelling the world into a hyper-connected future.

1.3.1 Explanation of the architecture of a 5G New Radio (5NR) network.

The architecture of a 5G New Radio (5NR) network in the "Network Security Beyond 5G" project involves a setup where User Equipment (UE) is connected to the gNodeBs (gNBs), forming the 5G NR network. The 5G NR then interfaces with the existing 4G core network, which includes the Packet Gateway (PGW) and Serving Gateway (SGW). This setup facilitates seamless data transfer and call routing between the UE and external networks, including the internet and remote hosts. By integrating 5NR with the 4G core network, the project aims to ensure network security while harnessing the advanced capabilities of 5G technology, such as high data rates and low latency, for a secure and efficient communication ecosystem.



1.3.2 Overview of the existing 4G core network and its components.

The current 4G core network is a crucial piece of infrastructure that makes it possible for 4G mobile communication to operate effectively. It includes a number of crucial parts. The Packet Gateway (PGW) manages packet data routing as the interface between the 4G core network and external networks. The Serving Gateway (SGW), which makes it easier for data to be transferred between the UE and the PGW, controls user mobility. Location monitoring and user authentication are the responsibilities of the Mobility Management Entity (MME). Information about subscribers is kept on the Home Subscriber Server (HSS), and policy and charging rules are controlled by the PCRF. Within the 4G core network, these elements work together to offer dependable data transmission and frictionless communication.

1.4 Detailed explanation of how voice calls are transmitted over the 5NR network

1.4.1 Network Setup

- The simulation sets up a 5G New Radio (5NR) network with four gNodeBs (gNBs) and four User Equipment (UE) nodes.
- The gNBs are configured with multiple Bandwidth Parts (BWPs) to support different communication scenarios

1.4.2 Voice Traffic Configuration

- The simulation enables voice traffic transmission (downlink) using UDP packets.
- The voice traffic is characterized by a specific packet size and a specified rate (lambdaVoice) that determines the number of UDP packets transmitted in one second.

1.4.3 5G NR Network Architecture

- The 5NR network consists of UE nodes connected to gNBs.
- The UE nodes are equipped with antennas, and the gNBs manage the communication between UEs and external networks.The simulation enables voice traffic transmission (downlink) using UDP packets.
- The voice traffic is characterized by a specific packet size and a specified rate (lambdaVoice) that determines the number of UDP packets transmitted in one second

1.4.4 Voice Call Transmission

- Each gNB is configured with three BWPs: TDD, FDD-DL (Frequency Division Duplex - Downlink), and FDD-UL (Frequency Division Duplex - Uplink).
- The TDD BWP is used for Time Division Duplex communication.
- The FDD-DL BWP is used for Downlink communication, and the FDD-UL BWP is used for Uplink communication.
- Voice traffic is carried over the dedicated bearers (GBR_CONV_VOICE) within the FDD-DL BWP.

- The simulation installs UDP server and client applications on UEs and the remote host, respectively, to simulate voice call transmission.
- The client application sends UDP packets representing voice calls from the remote host to the UEs, and the server application listens to these packets..

1.4.5 Traffic Statistics

- The simulation records statistics related to the voice call traffic, such as the number of transmitted and received packets, throughput, delay, and jitter.
- Flow monitoring is used to analyze the performance of the voice traffic.

1.5 Protocols and technologies used for voice call handling and optimization

here in this project for the transmission of voice calls over a 5G New Radio (5NR) network using UDP packets.

Voice over IP (VoIP): VoIP is a technology that allows voice calls to be transmitted over IP networks, including 5G networks. VoIP protocols such as SIP (Session Initiation Protocol) and RTP (Real-time Transport Protocol) are used for call setup, management, and media streaming.

Quality of Service (QoS): QoS mechanisms in 5G networks prioritize voice traffic to ensure low latency, low jitter, and high reliability, which are critical for real-time voice communication.

Codec: Voice codecs are used to compress and decompress voice signals for efficient transmission over the network. Common codecs used in VoIP applications include AMR (Adaptive Multi-Rate) and Opus.

Bearer Management: In 5G networks, dedicated bearers (e.g., GBR_CONV_VOICE) are often used for voice traffic to guarantee certain Quality of Service parameters for voice calls.

Packet Scheduling: Packet scheduling algorithms in the network nodes (e.g., gNBs) prioritize voice packets to minimize delay and ensure timely delivery.

Error Correction: Techniques like forward error correction (FEC) and packet loss concealment (PLC) are used to mitigate the effects of packet loss and errors during voice transmission.

Fast Handover: Fast handover mechanisms ensure seamless handovers between gNBs while maintaining the ongoing voice call's continuity.

Packet Duplication: In some scenarios, packet duplication techniques can be used to transmit redundant packets, improving voice call reliability, particularly in challenging network conditions.

Network Slicing: Network slicing allows the creation of virtual dedicated networks for specific services, including voice, enabling optimized resource allocation for voice calls.

Dynamic Spectrum Allocation: Dynamic spectrum allocation techniques optimize the allocation of available spectrum resources for voice calls based on traffic demand and network condition

1.6 Performance Evaluation

1.6.1Analysis of voice call quality and data transfer rates in the 5NR network.

The project simulates a 5G New Radio (5NR) network to analyze voice call quality and data transfer rates. The simulation considers multiple gNBs and UEs and uses UDP packets to model voice traffic.

Voice Call Quality: The simulation evaluates the voice call quality using metrics such as throughput, delay, jitter, and packet loss. These metrics are measured for each voice flow (UE to remote host) to assess the performance of the voice traffic over the 5NR network.

Data Transfer Rates: The data transfer rates for both voice and data traffic are analyzed in the 5NR network. The code simulates the transmission of voice calls using UDP packets, and the data transfer rates are determined based on the number of packets transmitted and received during the simulation.

Throughput: Throughput measures the amount of data transmitted per unit of time. It is used to assess the efficiency of data transfer in the network, including voice packets.

Delay: Delay is the time taken for a packet to travel from the source to the destination. In a voice call scenario, low delay is critical to maintaining real-time communication.

Jitter: Jitter represents the variation in packet delay. In voice calls, jitter can cause irregularities in voice transmission, affecting call quality.

Packet Loss: Packet loss occurs when packets are dropped or not delivered correctly. In voice calls, even small packet loss can lead to noticeable quality degradation.

QoS Evaluation: Quality of Service (QoS) parameters, such as mean flow throughput and mean flow delay, are analyzed to ensure that the 5NR network meets the required performance levels for voice calls.

Optimization: The simulation may include techniques such as prioritization, error correction, and packet duplication to optimize voice call handling and improve voice call quality.

1.7 Energy Efficiency in 5G LENA

1.7.1 Discussion on how 5G LENA contributes to sustainability in mobile communication.

5G LENA (Low Energy Network Architecture) plays a crucial role in contributing to sustainability in mobile communication within the project.

Energy Efficiency: 5G LENA employs advanced energy-saving techniques, such as power-aware scheduling, dynamic power control, and sleep modes for inactive components. By reducing energy consumption in the network, it lowers the carbon footprint and contributes to energy conservation.

Improved Battery Life: For mobile devices like UEs in the simulation, 5G LENA's energy-efficient mechanisms extend the battery life. Longer battery life reduces the need for frequent battery replacements and e-waste, aligning with sustainable practices.

Green Networking: 5G LENA optimizes the network infrastructure to minimize energy consumption without compromising on performance. This green networking approach reduces the overall energy demand of the network and promotes sustainability in the mobile communication industry.

1.8 Challenges and Future Directions

1.8.1 Exploration of future research directions in "Network security Beyond 5G

As we enter the era of "Network Security Beyond 5G," a number of exciting new research avenues are emerging to address the changing threats and problems in modern communication networks. First off, research into quantum-safe cryptography is essential if we are to create cryptographic methods that can withstand any dangers posed by quantum computing. In order to effectively defend against complex assaults, threat detection, anomaly identification, and automated response mechanisms can all be improved with AI-driven security solutions.

Zero trust architecture implementation can provide strong security by constantly confirming and authenticating users and devices, regardless of where they are inside the network. In order to stop attacks that take advantage of the dynamic and programmable nature of

Software-Defined Networking (SDN) and Network Function Virtualization (NFV) technologies, security is crucial.

Additionally, investigating privacy-preserving technologies like differential privacy and secure multi-party computation can safeguard user data while facilitating beneficial data-sharing for network optimisation. Furthermore, IoT security resilience needs attention, including device authentication, secure firmware updates, and defence against IoT-based botnets.

Additionally, research should be done into the potential of blockchain technology to improve network security through decentralised identity management and secure transaction verification. Investigating physical layer security, post-quantum authentication techniques, and international cooperation on security standards are additional crucial elements to take into account for a reliable and secure communication infrastructure in the future. We can construct resilient networks that guarantee the security and privacy of data and communication well into the 5G era by focusing on these research paths.

1.9 Conclusion

In conclusion, this project showcases the development and simulation of a 5G New Radio (5NR) network integrated with a 4G core to facilitate voice call transfer in a communication setup. The implementation utilizes the 5G LENA simulation framework, providing a comprehensive understanding of the network's architecture, components, and performance.

This projectdemonstrates the configuration of the network, including the setup of gNodeBs, user equipment (UE), and remote hosts. It addresses key aspects such as radio frequency allocation, bandwidth parts, and the deployment of TDD (Time Division Duplexing) and FDD (Frequency Division Duplexing) operations. The code also establishes voice traffic transmission using UDP (User Datagram Protocol) for voice call simulation and introduces EpsBearer for dedicated voice traffic.

Throughout the project, critical elements of the 5G NR network have been thoroughly explored, such as antenna models, beamforming techniques, and the integration of 4G core components like SGW/PGW. Additionally, the security measures of the integrated 5NR network have been analyzed to ensure robust protection against potential threats.

The simulation results offer valuable insights into voice call quality and data transfer rates within the 5NR network, enabling researchers and developers to assess the network's efficiency and optimize its performance. Moreover, the examination of future research directions emphasizes the ongoing importance of network security beyond 5G, as the telecommunication landscape continues to evolve rapidly.

In summary, the project ignificance of 5G technology in advancing mobile communication capabilities. The exploration of 5G NR networks, integrated with existing infrastructure and considering security aspects, sets the stage for further advancements, paving the way for a more secure, efficient, and sustainable communication ecosystem in the future.

1.10 References

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