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5G NEW RADIO NON-STAND-ALONE CALL LOG ANALYSING AND DEBUGGING

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Abstract— The promise of 5G network has been lauded for a long time, but it is now finally becoming a reality. 5G was finally introduced into the market after years of creating buzz about the lightning-fast speeds offered by the latest generation of mobile network technology; and this was followed by massive rollout and deployment in 2020. The introduction of 5G is going to transform the way we connect in 2021 and beyond. It will influence the use of internet of things (IoT), mobile devices and sensor technologies in critical industries including smart cities, automotive, industrial, communication, wearables and consumer electronics. 5G is set to usher in a new phase of better and more effective connection and service. Though the arrival of 5G technology and its futuristic future applications has been received with great excitements and high hopes, it is important to note that the 5G implementation is still in its infant stage. Therefore, it is believed that the current excitement about its transformational impact is too early as there is a great deal of work that is required before the network can begin to deliver on its promises. This paper examines the possible future applications of 5G network, where the technology is today, its implementation issues, and what the industry is doing about it.

I. INTRODUCTION

5G NR NSA (New Radio Non-Standalone) is the name of the deployment architecture for the fifth generation (5G) wireless network. Using the 4G LTE (Long-Term Evolution) infrastructure already in place is the first step towards the implementation of 5G technology. Because the underlying LTE network is reused, NSA enables a quicker rollout of 5G services. The design and architecture of the 5G and 4G packet cores, as well as how the 5G and 4G network functions interact, will be covered in this article. This article explains the control and user plane redundancy taken into account in the Amarisoft-implemented 4G CUPS and 5G NSA gateway systems. In the traditional cellular network architecture, the core network and the radio access network (RAN) are tightly integrated. However, with 5G NR NSA, the core network remains the same as the 4G LTE core, while the RAN is upgraded to support 5G NR technology. This approach provides a transitional solution for network operators to introduce 5G capabilities without completely overhauling their existing infrastructure.

Key components of 5G NR NSA include:

LTE Core Network: The core network remains unchanged from the 4G LTE architecture, including components like the Evolved Packet Core (EPC) and related network elements. The LTE core handles functions such as authentication, billing, and mobility management.

5G NR Radio Access Network: The RAN is upgraded to support 5G NR technology, enabling faster data rates, lower latency, and improved network capacity. This includes the deployment of new base stations, known as gNBs (gNodeBs), which support both 4G and 5G connectivity.
Dual Connectivity: One of the fundamental features of 5G NR NSA is the ability to establish dual connectivity between 4G LTE and 5G NR networks. This means that a user equipment (UE), such as a smartphone, can simultaneously connect to both 4G and 5G networks. The 4G network provides control plane and mobility management functions, while the 5G network enables faster data transmission.
Anchoring in LTE: In 5G NR NSA, the LTE network acts as the anchor for signaling and mobility management. The initial connection setup and mobility handling are handled by the LTE core, while the data transmission can be offloaded to the 5G NR network for higher speeds and improved performance.
Evolutionary Path: 5G NR NSA is designed to provide a smooth evolutionary path from 4G LTE to full standalone 5G networks. As operators upgrade their infrastructure, they can gradually transition from NSA to a standalone (SA) architecture, where the 5G core network is fully deployed and independent from LTE.
Benefits of 5G NR NSA:
Faster Data Rates: 5G NR NSA offers significantly higher data rates compared to 4G LTE, enabling faster downloads, streaming, and real-time applications.
Reduced Latency: With lower latency, 5G NR NSA enhances the responsiveness of applications and services, making it ideal for applications like gaming, autonomous vehicles, and industrial automation.
Increased Capacity: The advanced 5G NR technology allows for increased network capacity, accommodating a higher number of connected devices and supporting data-intensive applications in crowded areas.
Improved Spectral Efficiency: 5G NR introduces new modulation schemes and advanced techniques, enhancing spectral efficiency and allowing for more efficient utilization of the available frequency spectrum.
Enhanced User Experience: The combination of faster speeds, lower latency, and increased capacity provides an improved user experience for various applications, such as virtual reality (VR), augmented reality (AR), and high-definition video streaming.
Deployment Challenges:
Coexistence with Legacy Infrastructure: Since 5G NR NSA relies on existing 4G LTE infrastructure, network operators need to ensure seamless integration between the two technologies and manage compatibility issues.
Backward Compatibility: 5G NR NSA networks must be backward compatible with older generations of cellular technology, ensuring that devices without 5G capabilities can still connect and operate on the network.
Core Network Upgrades: While the RAN is upgraded to support 5G NR, full deployment of standalone 5G networks requires the upgrade of the core network to a 5G core (5GC). This transition involves significant investments and infrastructure upgrades.
Network Slicing: Network slicing, a key feature of 5G, allows the partitioning of a single physical network into multiple virtual networks to cater to different services and applications.

However, 5G NR NSA has limited capabilities for network slicing compared to standalone 5G networks.

Transition to Standalone 5G:

5G NR NSA serves as an intermediate step towards full standalone 5G networks. In the standalone architecture, both the core network and RAN are upgraded to fully support 5G technology. The transition to standalone 5G involves the deployment of a 5GC and enables the full potential of 5G, including advanced features like network slicing, ultra-reliable low latency communication (URLLC), and massive machine-type communication (mMTC).

The move towards standalone 5G networks allows for greater flexibility, scalability, and innovation, as the network infrastructure is purpose-built for 5G technology from the ground up.

It's important to note that the deployment strategies and timelines may vary among different network operators and regions, depending on their individual infrastructure, regulatory requirements, and market demands.

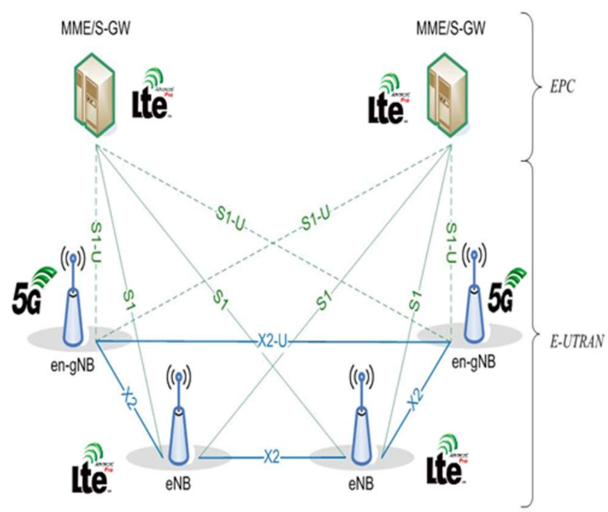
5G NR NSA allows network operators to quickly introduce 5G services while leveraging their existing investments in 4G infrastructure. It provides faster data rates, lower latency, and enhanced network capacity, setting the stage for the future deployment of standalone 5G networks.

PROPOSED RESEARCH

1. Analyzing call logs in a 5G NR NSA (New Radio Non-Standalone) system can provide valuable insights into network performance, user experience, and troubleshooting. Here is a proposed approach for analyzing 5G NR NSA call logs: Data Collection: Gather call logs from the 5G NR NSA network, which typically include information such as timestamps, call durations, signal quality indicators, handover events, and error codes. These logs can be obtained from network elements like base stations, core network elements, and network management systems.
2. Call Setup Success Rate: Calculate the call setup success rate by analyzing the call setup attempts and successful call completions. This metric indicates the effectiveness of the network in establishing connections and providing service to users. A low success rate may indicate issues with network coverage, capacity, or configuration.
3. Call Drops and Disconnects: Identify call drops and disconnects from the call logs. Analyze the reasons for call terminations, such as handover failures, radio link failures, or user-initiated disconnects. Monitoring and minimizing call drops are crucial for ensuring a seamless user experience.
4. Handover Analysis: Evaluate handover events between 4G LTE and 5G NR networks. Analyze handover success rates, handover latency, and the number of handovers per call. This analysis helps identify any issues related to handover algorithms, coverage overlap, or radio conditions impacting the handover performance.
5. Signal Quality Analysis: Examine signal quality indicators like signal strength, signal-to-noise ratio (SNR), and modulation quality. Assess variations in signal quality across different areas and identify areas with weak coverage or interference that can impact call quality and user experience.

6. Latency Analysis: Analyze call setup latency, packet round-trip time (RTT), and data transfer latency. Latency is a critical factor in 5G NR NSA networks, and high latencies can impact real-time applications and services. Identify any sources of delay, such as network congestion, processing delays, or transmission issues.
7. Error Code Analysis: Investigate error codes and error messages from the call logs. Correlate specific error codes with network events and user complaints to identify potential network issues, such as authentication failures, resource allocation problems, or protocol errors.
8. Customer Experience Evaluation: Combine call log analysis with customer feedback and complaints to gain a holistic understanding of the user experience. Identify patterns or trends that can help prioritize network optimization efforts and improve overall customer satisfaction.
9. Troubleshooting and Optimization: Use the insights gained from the call log analysis to identify areas of improvement in the network. Optimize parameters, adjust coverage, and address specific issues that impact call quality, handover performance, latency, or signal strength.
10. Remember that call log analysis should be performed regularly to track network performance over time, identify trends, and address emerging issues promptly. It's also essential to consider other performance metrics and network KPIs in conjunction with call log analysis to gain a comprehensive understanding of the network's performance and user experience.

II. ARCHITECTURE



LTE-

LTE stands for Long-Term Evolution, which is a standard for wireless broadband communication for mobile devices. It is often referred to as 4G LTE because it is the fourth generation (4G) of wireless technology.

LTE provides high-speed data transmission and improved network performance compared to previous generations of mobile networks. It offers faster download and upload speeds, lower latency, and better overall network capacity. These advancements allow users to enjoy faster internet browsing, smoother video streaming, and better quality voice calls on their mobile devices.

LTE technology uses packet switching to transmit data, which breaks down information into small packets and sends them separately over the network. This allows for efficient data transfer and supports various applications and services, such as web browsing, video streaming, online gaming, and VoIP (Voice over Internet Protocol) calls.

LTE networks operate on different frequency bands, typically ranging from 700 MHz to 2600 MHz, depending on the region and network operator. Multiple LTE bands can be combined to provide wider coverage and faster speeds.

It's important to note that LTE is a stepping stone towards even more advanced wireless technologies, such as 5G (fifth generation). 5G networks build upon the foundation of LTE and offer even faster speeds, lower latency, and support for a larger number of connected devices.

5G-

5G, short for fifth generation, is the latest generation of wireless technology for mobile networks. It represents a significant leap forward in terms of speed, capacity, and connectivity compared to previous generations.

Key features and benefits of 5G include:

Faster speeds: 5G offers significantly faster download and upload speeds compared to 4G LTE. While LTE can provide speeds up to several hundred megabits per second (Mbps), 5G can potentially reach multi-gigabit per second (Gbps) speeds, enabling ultra-fast downloads, seamless streaming of high-definition content, and quicker data transfers.

Lower latency: Latency refers to the delay between sending and receiving data. 5G networks have much lower latency compared to previous generations, which means there is less delay in transmitting data. This is crucial for real-time applications like online gaming, autonomous vehicles, remote surgery, and other time-sensitive services.

Greater capacity: 5G networks can handle a significantly larger number of connected devices per unit area compared to 4G. This increased capacity is essential for supporting the growing number of internet-connected devices, including smartphones, IoT devices, smart home appliances, and industrial sensors.

Improved reliability: 5G networks are designed to be more reliable, with better coverage and reduced signal interference. This ensures a more consistent and stable connection, even in densely populated areas or crowded events.

Network slicing: 5G introduces the concept of network slicing, which allows network operators to partition their networks into virtual slices tailored to specific services or industries. This enables customized network configurations to meet the unique requirements of different applications, such as autonomous vehicles, smart cities, industrial automation, and more.

Enhanced IoT capabilities: 5G provides the infrastructure to support the massive deployment of Internet of Things (IoT) devices. It offers improved connectivity, energy efficiency, and scalability, allowing for seamless integration and communication between numerous IoT devices and systems.

It's worth noting that the rollout of 5G networks is ongoing, and its availability and capabilities may vary across different regions and network providers. While some areas may already have extensive 5G coverage, others may still be in the early stages of deployment.

eNB-

eNB stands for Evolved Node B, which is a component of the LTE (Long-Term Evolution) and 5G wireless networks. It refers to the base station or cell site that serves as the interface between mobile devices and the core network.

The eNB performs several essential functions in the network:

Radio transmission: The eNB is responsible for transmitting and receiving radio signals to and from mobile devices within its coverage area. It communicates with user equipment (UE), such as smartphones, tablets, and other devices, using wireless radio frequencies.

Radio resource management: The eNB manages radio resources and handles tasks like assigning frequencies, allocating bandwidth, and managing power levels. It optimizes the use of available resources to ensure efficient and reliable communication between the network and mobile devices.

Mobility management: The eNB tracks and manages the mobility of mobile devices as they move within the network. It handles tasks such as handovers, which involve transferring the connection from one eNB to another as a user moves between different coverage areas.

Connection establishment: The eNB establishes and releases connections with mobile devices. When a device wants to access the network or make a call, the eNB handles the necessary procedures to establish a secure and reliable connection.

Security and encryption: The eNB ensures the security and privacy of communications by implementing encryption and authentication mechanisms. It protects user data and prevents unauthorized access or tampering.

In 5G networks, the eNB is replaced by a similar component called the gNB (Next-Generation Node B). The gNB serves as the base station for 5G and provides enhanced capabilities and features compared to its predecessor.

Overall, the eNB is a critical component in LTE and early stages of 5G networks, playing a crucial role in facilitating wireless communication between mobile devices and the core network infrastructure.

gNB

gNB stands for Next-Generation Node B, and it is a key component of the 5G (fifth generation) wireless network infrastructure. The gNB serves as the base station in 5G and provides various functions to enable high-speed, low-latency, and reliable wireless communication.

Here are some important aspects of the gNB:

Radio transmission: The gNB transmits and receives radio signals to and from user equipment (UE) or devices within its coverage area. It utilizes advanced radio technologies, such as beamforming and massive MIMO (Multiple-Input Multiple-Output), to enhance signal quality, coverage, and capacity.

Radio resource management: The gNB manages the allocation and utilization of radio resources. It dynamically assigns frequency bands, allocates bandwidth, and adjusts power levels to optimize the overall network performance and efficiency.

Mobility management: The gNB tracks the mobility of user devices as they move across different coverage areas. It handles tasks like handovers, where the connection is seamlessly transferred from one gNB to another to maintain uninterrupted communication during device movement.

Connection establishment: The gNB is responsible for establishing and releasing connections with user devices. It manages the initial access procedures, authentication, and security mechanisms to ensure secure and reliable communication between the network and the user devices.

Network slicing: The gNB supports network slicing, which allows the network to be logically partitioned into multiple virtual networks. Each network slice can be customized to meet specific requirements, providing tailored connectivity and services for different industries or use cases.

Low latency and high data rates: The gNB is designed to provide significantly lower latency and higher data rates compared to previous generations. This enables real-time applications, such as autonomous vehicles, remote surgery, virtual reality, and augmented reality experiences.

The gNB is a fundamental element in 5G networks, enabling the deployment of advanced wireless services, supporting massive device connectivity, and driving innovations across various industries and sectors.

MME / S-GW

MME and SGW are components of the Evolved Packet Core (EPC), which is the core network architecture used in LTE (Long-Term Evolution) and 5G networks. Let's explore their roles:

MME (Mobility Management Entity): The MME is a key component of the EPC responsible for mobility management and control plane functions. Its main functions include:

Tracking the location of mobile devices (UE) within the network and managing mobility-related procedures like handovers.

Authenticating and authorizing user devices during network access.

Managing session establishment, modification, and termination for UE connections.

Handling paging requests to locate and alert devices for incoming calls or messages.

Coordinating with other network elements, such as the serving gateways (SGW), to facilitate seamless mobility and uninterrupted connectivity.

SGW (Serving Gateway): The SGW is another vital component of the EPC, responsible for user plane functions and data routing within the network. Its primary functions include:

Acting as a point of entry and exit for user traffic between the mobile network and external networks (e.g., the internet).

Managing and routing data packets between the UE and the PDN (Packet Data Network), which can be an IP-based network like the internet.

Performing IP address allocation for user devices.

Handling packet buffering and forwarding to ensure reliable and efficient data transmission.

Supporting mobility-related functions by communicating with the MME during handover procedures.

Both the MME and SGW work together to enable efficient mobility management, secure user authentication, and seamless data connectivity for mobile devices within the LTE and 5G networks.

S1 U-
S1-U refers to the user plane interface in the LTE (Long-Term Evolution) network architecture. It is an interface between the serving gateway (SGW) and the packet data network (PDN) gateway (PGW) within the Evolved Packet Core (EPC).
The S1-U interface is responsible for the transmission of user data packets between the SGW and the PGW. Here's an overview of its functions:
User Data Transmission: S1-U is primarily used for the transmission of user data traffic between the SGW and the PGW. It carries data packets associated with user applications, such as web browsing, video streaming, file downloads, and other data services.
Packet Forwarding: The SGW receives data packets from the base station (eNodeB) over the S1-U interface. It then forwards these packets to the appropriate PGW based on the destination address or session information. The PGW further routes the packets to the external networks, such as the internet or private networks.
Quality of Service (QoS) Handling: The S1-U interface supports QoS parameters to ensure the proper handling of different types of traffic. QoS policies and mechanisms are applied to prioritize and manage the transmission of user data packets based on their requirements, such as latency, bandwidth, and packet loss.

X2-
The X2 interface is used for control plane and user plane signaling between adjacent eNodeBs. While the X2 interface primarily focuses on control plane signaling, it indirectly facilitates user plane communication between the eNodeBs through a mechanism called S1-U bearers.
When it comes to user plane transmission between eNodeBs, the S1-U interface is used, as mentioned in my previous response. The S1-U interface carries user data traffic between the serving gateway (SGW) and the packet data network gateway (PGW) within the Evolved Packet Core (EPC)

III. HARDWARE

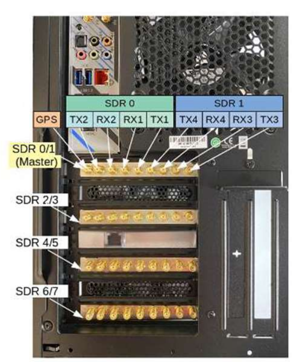
AMARI Callbox Ultimate is a 3GPP compliant eNodeB, gNodeB, EPC and 5GC allowing functional and performance testing of NR, LTE, LTE-M and NB-IoT devices. It also includes an integrated IMS server as well as an eMBMS gateway for VoLTE and eMBMs testing

The Callbox Ultimate is a turnkey solution running on Fedora 30 operating system. It embeds four PCIe SDR cards, all software components and licenses required to emulate your 4G/5G network. This document describes the first steps to start and configure your Amarisoft Callbox. For advanced configurations and testing, please refer to the application notes and other documents available under extranet.amarisoft.com or under the /root//doc/ folders of your Callbox

Amarisoft Callbox is a solution provided by Amarisoft, a company specializing in 4G and 5G network technologies. Callbox is a test tool designed to simulate a mobile network, allowing users to test various aspects of their network equipment and applications.
With Amarisoft Callbox, you can create a virtual mobile network environment using software-defined radio (SDR) technology. It enables you to simulate base stations and mobile devices, allowing you to perform comprehensive testing, troubleshooting, and optimization of your network infrastructure.
Callbox supports various features such as voice calls, SMS messaging, data transfer, and mobility management. It provides a flexible and customizable platform for network engineers, researchers, and developers to evaluate and validate their products and services in a controlled environment.

• Rx1/Rx2/Rx3/Rx4 are the receive antenna ports.
• Tx1/Tx2/Tx3/Tx4 are the transmit antenna ports.
• GPS is used for connecting an external GPS clock.

☛ Note: Each physical PCIe SDR card (100Mhz MIMO 4x4) is actually composed of two independent RF chips. Each chip is mapped to a separate logical SDR device and can handle 100MHz 2x2 MIMO as depicted below



Selection and Combination of SDR Cards

The selection of the SDR card is made in the enb configuration file, per cell, using the parameter "rf_port"..

☛ Note: the default rf_port used when only one cell is configured is 0, which corresponds to the SDR#0 card

RF connections for one cell in 4G or 5G NSA mode with 2x2 MIMO

In a configuration with one cell in 4G or 5G NSA mode using 2x2 MIMO, here's some information about the RF connections:

Cell Configuration:

In this setup, you have a single base station (eNodeB in 4G or gNB in 5G) serving the coverage area.

RF Connections:

The cell would have its own RF connections, typically consisting of two physical RF paths for communication with the user equipment (UE) devices. Each RF connection includes one transmit antenna and one receive antenna.

Auto Vox Antenna

The term "auto VOX antenna" is not a standard industry term or widely recognized concept in the field of antennas. However, it is possible that you are referring to an antenna system with automatic Voice Operated Transmission (VOX) capability. In this case, I can provide some information on VOX and antenna systems.

VOX refers to a feature in communication devices, such as radios or transceivers, that automatically activates the transmitter (i.e., begins transmission) when it detects audio or voice input above a certain threshold level. This feature is commonly used in hands-free communication systems, where the user's voice triggers the transmission without the need for manually pressing a push-to-talk (PTT) button.

An antenna, on the other hand, is a device designed to transmit or receive electromagnetic waves. It plays a crucial role in wireless communication systems by converting electrical signals into radio waves for transmission or vice versa.

IV RESULT

Analyzing and debugging 5G New Radio (NR) non-standalone (NSA) call logs can provide insights into network performance, troubleshooting issues, and optimizing network configurations. Here are some potential results that can be obtained from such analysis:

1. Call Setup Success Rate: The analysis can reveal the success rate of call setup procedures, including initial access, authentication, and connection establishment. It helps identify any issues affecting call setup failures or delays, allowing operators to optimize network parameters for improved performance.
2. Handover Performance: Handovers are critical in maintaining seamless connectivity as a user moves between different cells. By analyzing call logs, you can assess the handover success rate, latency, and the reasons behind handover failures. This information can guide optimizations to enhance handover performance.
3. Radio Resource Usage: The analysis can provide insights into how radio resources are utilized during the call, such as allocation of frequency bands, bandwidth, and power levels. It helps identify potential resource allocation inefficiencies or congestion issues, enabling operators to optimize resource allocation strategies.
4. Quality of Service (QoS) Parameters: Call logs can provide information about key QoS parameters, such as signal strength, signal-to-noise ratio (SNR), and packet loss rates. Analyzing these parameters helps evaluate the quality of the user experience and identify areas for improvement.
5. Network Latency: By analyzing call logs, you can assess the latency experienced during different stages of the call, including access, authentication, and data transfer. This helps identify latency bottlenecks and optimize network configurations to reduce latency for better performance.
6. Protocol Errors: Call logs contain information about protocol errors encountered during the call, such as radio link failures, synchronization issues, or authentication failures. Analyzing these errors can help diagnose specific issues and take corrective actions.
7. Throughput and Data Rates: The analysis of call logs can provide insights into the achieved throughput and data rates during the call. This information helps evaluate the network's capacity and performance and identify potential areas for improvement.

By conducting a thorough analysis of call logs from 5G NR NSA calls, network operators and engineers can gain valuable insights into the network's performance, identify areas for optimization, and address any issues affecting the user experience. These results can guide network enhancements, parameter optimizations, and troubleshooting efforts to ensure a robust and efficient 5G network deployment.

V CONCLUSION

In conclusion, analyzing and debugging 5G New Radio (NR) non-standalone (NSA) call logs provides valuable insights into the performance and optimization of the network. By examining various parameters such as call setup success rate, handover performance, resource usage, QoS parameters, network latency, protocol errors, and throughput, operators can identify areas for improvement and take appropriate actions to enhance the network's performance and user experience.

Analyzing call logs allows operators to optimize network configurations, improve handover success rates, allocate radio resources more efficiently, reduce latency, and address protocol errors. It also helps in assessing the quality of service parameters and throughput achieved during calls, allowing operators to evaluate network capacity and make necessary enhancements.

By leveraging the information obtained from call log analysis, operators can ensure a robust and efficient 5G network deployment, providing users with seamless connectivity, reliable performance, and high-quality services. Continuous analysis and debugging efforts based on call logs can lead to network optimizations and better overall user satisfaction in 5G NR NSA deployments.

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