ViLTE and ViNR: Battery Consumption Comparison Between Video Calls over IMS Technologies

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***Abstract*— Video calls are commonly used for fast communications, such as remote meetings. This feature must match user expectations and provide Quality of Service (QoS). The main objective of this paper is to evaluate a real-time testbed for Video Over Long-Term Evolution and New Radio (ViLTE and ViNR) in terms of battery usage during an IP Multimedia Subsystem (IMS) video conversation. According to the data, ViNR achieved 27.7% lower battery consumption than ViLTE. Our research reveals how to analyze power usage for ViLTE and ViNR services while also proving that employing New Radio (NR) technology for video calls is more efficient in terms of power consumption.**

***Keywords*— ViLTE, ViNR, IMS, Battery Consumption**

I. Introduction

There have been numerous talks about the influence of the fifth-generation (5G) communication system on the evolution of mobile networks. According to [1], the number of devices linked to mobile networks is expected to expand by about 48.9% between 2018 and 2023, indicating an increase from 8.8 to 13.1 billion smartphones connected to networks.

Due to the confinement caused by COVID-19, there has been a significant increase in the use of video calling services, a fast and efficient way to reduce the distance between families [2]. As Video Over Long-Term Evolution and New Radio (ViLTE and ViNR) are video streaming technologies, their use increases the data traffic rate (throughput); consequently, there will be higher battery consumption [3]. To solve this problem, many smartphone vendors invest in advancing and improving battery technology, but energy storage is developed more slowly than is demanded by the market. Therefore, the consequence of that demand is an amplification of the power consumption of the user equipment (UE) and the End-to-End (E2E) communication network [4]. As a result, each year $20 million is spent on electricity costs due to keeping smartphones plugged in longer than necessary to maintain a full charge [5].

Because of the high demand for video services, there has been an increase in research related to 4G services to provide high-definition (HD) video calls with better Quality of Service (QoS). In addition, 5G, inspired by 4G, has offered users Full High Definition (FHD) video calls and reliable communication services [3]. Recent research [6] has evidenced that 5G provides Improved Mobile Broadband (MBB), which supports high data rates, low latency video streaming, continuous mobility, and low power consumption.

The investigations have produced important databases on battery usage and efficiency in UEs. The author of [7] performed a power consumption study when employing Voice Over LTE and NR (VoLTE and VoNR) services over IP Multimedia Subsystem (IMS) technology. These services were compared from the standpoint of battery drain. Meanwhile, the paper only displayed results for voice services. According to the research in [2] research, communication services go beyond voice conversations, demonstrating that video calls can even provide face-to-face meetings. Thus, UE battery consumption analysis is critical for video streaming services.

According to the literature, one of the difficulties associated with smartphone battery drain is UE current consumption during carrier aggregation in LTE-A systems [8]. Furthermore, the authors demonstrated that when a UE requests a service that requires more data traffic, it combines bands to increase throughput. This process is analyzed for different combinations of Interband Carrier Aggregation (CA), Carrier Components (CCs) when two 10+10 MHz CCs consume 15% more power than a scenario without CA with the same bandwidth. Therefore, to supply the demand for more bandwidth in video streaming, the mobile network and UE need to be compatible to exchange high data rates.

In the literature on ViLTE and ViNR services, there is no talk about energy use. Furthermore, based on the study in [9] study, this research will perform a comparative analysis of a high-end smartphone between video call services provided by LTE and NR over IMS technologies. As a result, the main objective is to evaluate battery consumption performance to determine if 5G technology is beneficial in increasing or decreasing power consumption, as illustrated in [10]. On top of that, the evaluation of battery consumption for ViLTE and ViNR over IMS technologies is a contribution to this work.

The remainder of this work is structured as follows: Section II covers the fundamentals of mobile networks, 4G and 5G, and the concepts of IMS, ViLTE, and ViNR. Section III will go into the methods used to analyze battery consumption during video calls over the IMS network in detail, as well as a description of the situation and the equipment used to implement the method. Section IV will offer an analysis of the acquired data. Section V displays the work-related considerations.

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II. Key Concepts and Theoretical Background

A. Long-Term Evolution (LTE) Network

According to the Third Generation Partnership Project (3GPP), LTE is a defined and standardized communication protocol based on The Universal Mobile Telecommunication System (UMTS) that offers high-speed data services for mobile telecommunications technology [11]. LTE was the first All-IP mobile Internet technology, and IP was employed to allow subscribers to move from one network to another with the same IP address. This architecture consists essentially of three layers with specific functions [7].

In the first layer, the UE recognizes the user's smartphone and connects it to the LTE network. In this process, the UE performs operations such as processing, data transmission, signal reception, and decoding while adhering to 3GPP standards and technical specifications to ensure that all of these processes succeed. In the second, as shown in Fig. 1, the Evolved UMTS Terrestrial Radio Access Network (E-UTRAN) is related to radio communication services between the UE and the Evolved Packet Core (EPC) via base stations known as evolved NodeBs (eNBs), which are based nodes that control the UEs in single or multiple cells [12].

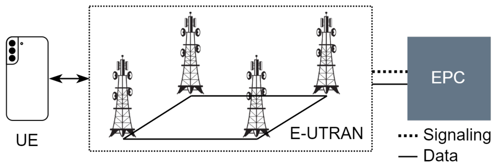

Fig. 1: The access network by E-UTRAN

The EPC, as shown in Fig. 2, is the essential communication gateway of 4G, and it consists of several key components. The Home Subscriber Server (HSS) component is a database that includes subscriber information. The UE's authentication, security, and mobility management are all dependent on the Mobility Management Entity (MME). The Serving Gateway (SGW) controls data traffic between the E-UTRAN and the UE to function as the gateway to the LTE network [13]. By allocating IP addresses and routes, delivering IP packets, and offering a seamless and efficient data experience, the Packet Data Network Gateway (PGW) connects the UE to other mobile wireless networks. All three components communicate using standard protocols such as the GPRS Tunneling Protocol (GTP) and Diameter.

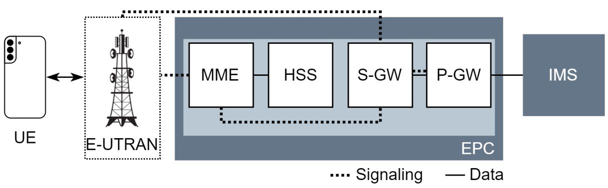

Fig. 2: Simplified LTE architecture

Finally, two essential components that are not depicted in Fig. 2 are the Policy Charging Rules Function (PCRF) and the Policy Charging Enforcement Function (PCEF). With the ability to receive varied network information, PCRF is mainly responsible for assessing data traffic, enforcing policy regulations, and making decisions about various network traffic. PCEF, on the other hand, will be in charge of implementing the PCRF's policies by modifying traffic throughput to satisfy policy criteria [14]. The basic architecture of an LTE network may be defined as a result of these functionalities.

B. New Radio (NR) Network

As the fifth generation of mobile networks, 5G technology introduces a new core network structure inspired by Service-Based Architecture (SBA), in which control plane functionality and standard network data storage are offered and accessed by a group of Network Functions (NFs). The NF makes its services available to all other authorized NFs via Application Programming Interfaces (APIs) called Service-Based Interfaces (SBI), which identify the set of available service data and specify the allowable activities. Due to SBA, the 5G architecture depicted in Fig. 3 is composed of five major components: the Access and Mobility Management Function (AMF), the Session Management Function (SMF), the Policy Control Function (PCF), Unified Data Management (UDM), and the User Plane Function (UPF) [15]. These functions will be discussed further below.

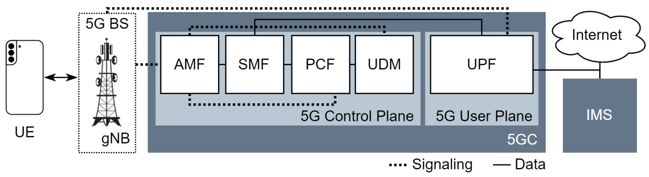

Fig. 3: Simplified NR architecture

In the 5G network, AMF is primarily in charge of managing UE access and mobility. Additionally, to performing tasks like managing QoS, the SMF also enforces policies and bills for user data sessions, and it performs mobile access management on the 5G network. The PCF is responsible for applying the policies and rules regarding QoS, utilization, and network access. The UDM is in charge of managing user-related data, including user profiles, authentication, and signatures. Lastly, UPF is responsible for data routing between the UE and the network. The UPF's functions include data forwarding, filtering, and routing. It employs QoS policies, like the PCF, to ensure high speed and usability for the provided data [15].

C. IMS Architecture

The IMS architecture includes a set of components and protocols that deliver network IP-based multimedia services such as voice, conference, video, and quick messaging. The elements that are part of the IMS architecture, as illustrated in Fig. 4, are the Proxy-Call Session Control Function (P-CSCF), which is responsible for providing an interface between the UE and the IMS network. It also serves as a session control proxy, routing, and forwarding communication sessions between the user's terminal and the IMS network. Session Border Controller (SBC) responsible for controlling and managing the streaming media traffic between the IMS network and the

Internet; Interrogating-Call Session Control Function (I-CSCF) working as a gateway for the UEs who want to access the IMS network [16]; Breakout Gateway Control Function (BGCF) responsible for controlling and managing the routing of calls among IMS networks and to other networks [17]; Serving-Call Session Control Function (S-CSCF) necessary for managing the communication session between the UE and IMS network. Furthermore, it provides services like forwarding, rejecting, and transferring calls, and at least HSS, according to LTE, is a database that maintains user information such as user profiles, service settings, and authentication data. It is also the database that the IMS network session control components use to authenticate and approve users [16].

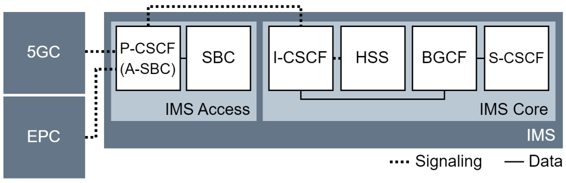

Fig. 4: IMS architecture

D. Video over LTE (ViLTE)

Conversational ViLTE services include full-duplex phone calls and simplex/full-duplex video media with precise synchronization between the constituent streams. The call can be a point-to-point call or a multiparty conference call. Conversational video services, for example, can be used to converse with dial-in video conferencing systems. ViLTE is described in GSMA specifications as a minimal set of mandatory features that wireless devices and the network itself must implement to provide interoperability for high-quality IMS-based conversational video service over LTE; in addition, these features are defined in [18].

To define a ViLTE session, signaling messages must be exchanged on the IMS platform to activate the Dedicated Bearers for the carriage of video and audio RTP data. The signaling processes for initiating a ViLTE call are detailed in [18], [19] and [20]. In short, the User Equipment (UE) connects to the LTE network through an eNodeB and delivers a ViLTE request to the IMS platform via the IMS signaling protocol, Session Initiation Protocol (SIP). The request is received by the IMS network via the CSCF, and the PCRF is required to reserve bearer resources for the relevant media. The CSCF in the EPC processes network signals and re-transmits them to the Application Servers (ASs). As a result, the AS performs the service following the information supplied by CSCF. The PCRF is in charge of establishing the EPC bearer path and controlling charges. PCRF notifies the PGW and the SGW to assign the resource and establish the ViLTE call bearers. In terms of VoLTE, ViLTE services necessitate the transfer of UE video capabilities to the LTE network. It is worth noting that in a ViLTE conversation, the PGW and SGW create two dedicated bearers for the video call, which are usually both Guaranteed Bit rates (GBR). The corresponding QCI is 1 for audio traffic and 2 for video traffic [18], [19], and [20].

A ViLTE session can be created by adding video to an existing VoLTE session or by starting one from scratch. Furthermore, if a GBR bearer used for video fails to establish (or is lost in the middle of a session), the network can still allow the session to continue as a voice call or terminate the SIP session connected with the GBR bearer [18].

E. Video over NR (ViNR)

According to [21], similar to ViLTE, the video service in 5G NR technology uses the LTE architecture to provide ViNR communication based on IMS. In addition, it is important to note that voice and video services on 5G NR are defined as VoNR. The ViNR introduces innovation without fallback to 4G LTE technology, all due to the services offered by 5G RAN, 5GC, and IMS. Furthermore, this service enables the user to perform high-quality and real-time video calls through the support of audio and video encoding related to the Enhanced Voice Services (EVS) and H.264 codecs demanded by the 3GPP [22].

The service flow of ViNR is similar to ViLTE for performing a communication session, but it does not use E-UTRA and EPS since it is powered by 5G RAN and 5GS technologies instead [23]. Based on [24], the ViNR service can be divided into several stages. The EU identifies a 5G NR cell and carries out 5G gNB and 5GC registration. Moreover, the AMF PLMN server sends an indication to the UE to check if an IMS video session on the Packet Switch (PS) is supported. If the requirement is available, a default Packet Data Unit (PDU) will be defined with a non-GBR QoS stream using 5QI=5 for IMS Data Network Name (DNN), the Session and Service Continuity (SSC) mode as 1, and the ON signal is always set to TRUE. In the process of establishing the PDU for an AMF session, extended protocol configurations (ePCO) and IPv4 or IPV4/IPV6 request information elements to indicate a DNN IMS target are included by the EU. The AMF forwards this information to the Session Management Function (SMF), which fetches the Proxy-Call Session Control Function (P-CSCF) addresses according to the DNN profile that keeps track of the data with the IMS and which includes the IPv4 or IPv6 address of the P-CSCF in a PDU session modification request message to the AMF. Also, if the P-CSCF options are not set by the UE in the ePCO field, the SMF will not include the P-CSCF address. Thus, according to the type of service selected, for example, voice or video codec, the network will send the PDU session modification complete with negotiated QoS parameters to be confirmed by the UE to finally setup ViNR MO/MT calls over a specific PDU session employing 5QI=1 and GBR QoS flow.

III. Methodology

A high-level view of the LTE and NR setup configuration is displayed in Fig. 5. In the measurement environment, a high-end device under test (DUT), as described in Table I, with 5G Standalone (SA) support and some equipment was utilized to recreate the best atmosphere possible. As the Radio Communication Test Station, it was used a Keysight UXM 5G E7515B test instrument that can replicate both virtualized

4GC and 5GC, as well as an IMS network for the DUT (item 1 in Fig. 5) and to measure the consumption of the UE, it was used a Low Voltage Monsoon Power Monitor (FTA22D) (item 2 in Fig. 5) provides custom battery connection modification services that can be accessed by a laptop (item 3 in Fig. 5). All tests were performed in an RF-shielded room.

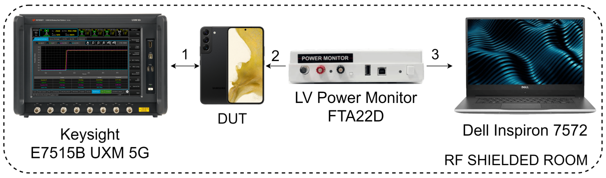

Fig. 5: High-level LTE and NR setup configuration

TABLE I: DUT Hardware Specifications

Components	Hardware specifications
Battery	3700 mAh
Chipset	Snapdragon 8 Gen 1
Modem-RF	Snapdragon™ X65 5G
Operating System	One UI 4.1, based on Android 12

With the help of all of these tools, a realistic setting was created. As a result, the measurement setup was based on [7], using Table II. The average current and jitter characteristics were taken into account for the extraction data. To ensure that the results were as accurate as possible, several rounds of experiments were performed to standardize the conditions, and for this paper, the twenty most relevant samples with six thousand data points were used for each technology.

TABLE II: Setup parameters

	LTE	NR
Band	[B7, B28]	[N7, N28]
Frequency	[2600, 700] MHz	[2600, 700] MHz
BW	20 MHz	20 MHz
SCS	15 kHz	15 kHz
Power Tx	-18 dBm	-18 dBm
PUSCH Power	[-10, -13] dBm	[-10, -13] dBm
Modulation	64 QAM	64 QAM

The process used to get the battery consumption value was carried out in four steps. The battery bypass procedure was carried out with the device attached to the DC power analyzer. For 20 seconds, the device was in airplane mode to measure its base energy usage. After that, the device's airplane mode was disabled so that connectivity to both mobile networks and a voice conversation through IMS could be performed. After the device connected to the network, 40 seconds passed before measuring the device's energy usage, which was just linked to the base station. At the end of the experiment, we made a ViLTE or ViNR call with a duration of 60 seconds. For both ViLTE and ViNR technologies, the total trial time was 120 seconds.

IV. Results

Taking into account the scenario described in the previous sections, Fig. 6 and 7 show the comparisons among LTE and NR for the B7, N7, and B28, N28 scenarios, respectively. Every result will be displayed for both scenarios as a function of current consumption. As a note, the results can be contrasted with the current voice call consumption shown in [7].

Considering the entire measurement period, 120 seconds, the NR technology presents a lower current consumption than LTE; however, this behavior varies at some specific points. When the DUT is in airplane mode, the two technologies perform equivalently, with very similar consumption in both cases (B7/N7 and B28/N28). This is due to the inactivity of services and the lack of connection with the network, and as expected, the consumption is the lowest and almost the same for technologies. As soon as the device exits airplane mode, the DUT attaches to the network, and the behavior tendency of NR is slightly higher than that of LTE. When the attaching step is completed and the DUT enters idle mode, LTE consumption exceeds the NR level, reaching values as high as 1823.2 mA for band N28. After the video call setup is finished, the call stabilizes at a significantly higher consumption level than the other intervals, and the consumption trend for LTE is a bit bigger than NR. Table III shows the average and maximum results for each step and technology.

TABLE III: Current profiling for LTE an NR stages

	Average Current Consumption (mA)			
	B7	N7	B28	N28
Idle	262.56	203.1	239.4	172.9
Video Call	762.8	681.3	713.0	658.3
Basal State	94.77			

Table III shows all of the average values for each measurement stage, as well as the maximum peak for each stage. In addition to demonstrating that the NR bands utilize less than the LTE bands, band 7 consumes more than band 28, both for LTE and for NR. The N7 band exhibited a 22.64% decrease in consumption compared to the B7 during the idle stage, whereas the N28 showed a 27.77% decrease compared to the B28. In the video call stage, the N7 band lowered consumption by 10.68% when compared to the B7 band, and the N28 band reduced consumption by 7.67% when compared to the B28 band. These findings reveal that NR bands are more efficient than LTE in all cases in an IMS network. It is also possible to detect that while using the same technology but various bands, the performances during the idle and video call stages differ. For the idle and video call stages, B28 decreases by 8.82% and 6.52% compared to B7, and N28 decreases by 14.86% and 3.37% compared to N7, respectively.

According to the measurements, the ViLTE service consumes more battery than the ViNR over a 60-second interval. Thus, based on total battery charge and assuming that UE consumption stays linear, it can be proved that the ViNR service may give an average value of 6.4 seconds more for N7 and 4.6 seconds for N28 during the video call service, implying greater battery life for both short-term and long-term services than ViLTE.

V. Conclusion

In this article, results were presented in the scenarios for LTE and 5G NR for video calls (ViNR) using the IMS

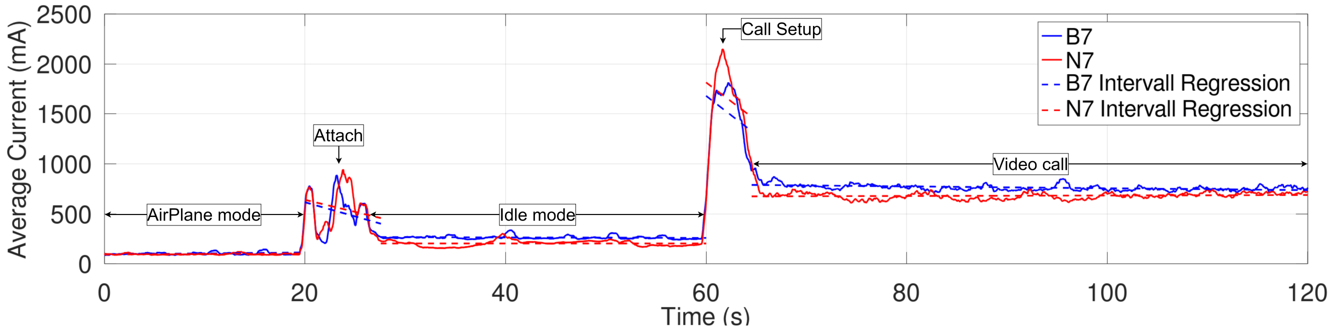

Fig. 6: Average Battery current consumption comparison between 4G and 5G network over IMS at 2600 MHz

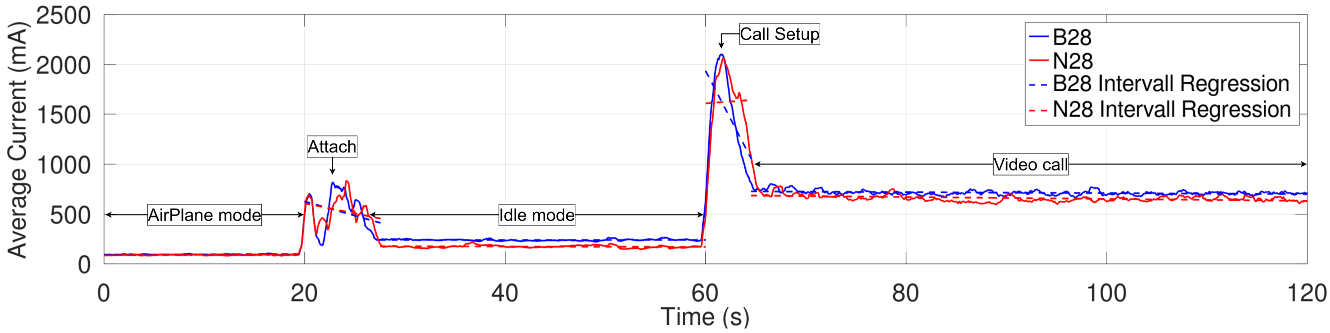

Fig. 7: Average Battery current consumption comparison between 4G and 5G network over IMS at 700 MHz

network to evaluate the current consumption of commercial devices and the impact of each technology on this service. The experimental results confirmed that 5G NR consumes less than LTE, managing to deliver a reduction of up to 7.67% in consumption when using the N28 band during the service stage and up to 10.68% in the same situation for the N7 band. It has also been demonstrated that using ViNR enhances battery life when compared to ViLTE, giving an average value of 6.4 seconds more for N7 and 4.6 seconds for N28 during the video call service.

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