A comparison between Emergency Calls over 4G and 5G Network Slicing

Maria G. Lima Damasceno[1], **Jussif J. Abularach Arnez**[1], **Renata K. Gomes Dos Reis**[1], **Caio B. Bezerra De Souza**[1], **Jéssica Da Silva Gomes**[1], **Isaac A. Barros Gomes**[1]

[1]Sidia Institute of Science and Technology
Manaus – AM – Brazil

{maria.lima, jussif.arnez, renata.gomes, caio.souza, jessica.gomes-e, isaac.gomes-e}@sidia.com

Abstract. *Emergency calls (eCall) via IP Multimedia Subsystem (IMS) were already used in Fourth Generation (4G) mobile networks so they were provided in high-definition (HD) voice calling. With the evolution to Fifth Generation (5G) networks, the concept of Network Slicing (NS) was introduced where the IMS network and its services are part of the Enhanced Mobile Broadband (eMBB) slice. This article seeks to compare the Quality of Service (QoS) of emergency calls over 4G and 5G by applying the eMBB slice. The results present the evaluation of QoS metrics i.e. packet loss, throughput and jitter for each eCall architecture, demonstrating the best performance of 5G in terms of QoS.*

1. Introduction

Emergency calls are one of the main services offered by network operators, since they are responsible for connecting mobile users that are in dangerous situations with agents who can provide assistance. In the Fourth Generation (4G) networks, these calls were made in high definition (HD) by using IP Multimedia Subsystem (IMS) network, which significantly improved this service from a Quality of Service (QoS) point of view. With the advent of Fifth-Generation (5G) networks, the emergency service began to be studied with more complexity, relating service prioritization through Network Slicing (NS) [Kukkalli et al. 2020].

The 5G mobile network introduced improvements in terms of flexibility and adaptability through the adoption of new concepts, such as NS, Software Defined Networking (SDN) and Network Function Virtualisation (NFV). In contrast to 4G, the core network is divided into functions and the services are grouped in categories, namely: Enhanced Mobile Broadband (eMBB), Ultra-Reliable Low Latency Communications (URLLC) and Massive Machine-Type Communications (mMTC) [Shafi et al. 2017]. The eMBB is a type of 5G service category implemented through NS that is utilized to provide higher throughput, better bandwidth, increased reliability and lower latency as well as improved multimedia functionality for the end user e.g. HD voice services [G.C. et al. 2019]. On the other hand, the NS also contributed to the evolution of 5G features since NS proposes the division of control and user planes that enable the QoS flow prioritization of 5G services, such as, emergency calls over New Radio (NR) [De Souza et al. 2022].

Since emergency services require resilient and reliable communication, a few studies in the state-of-the-art have explored the integration of eCalls scenarios. However, there are some restrictions regarding energy consumption and the absence of a common protocol available for an end-to-end 5G slice, as presented by [Fan et al. 2023], [Kukkalli et al. 2020]. Moreover, [Arnez et al. 2023] presented an emergency service using standardized architectural frameworks, such as IMS network to offer connectivity for group communication over voice and video using the 5G network. It discusses how the eMBB slice in NS can be used by rescuers and describes a platform that provides enhanced capabilities for the division of emergency-related services.

It is against this background that the contribution of this article is to analyze the QoS of emergency calls in 4G and 5G by using Voice over Long Term Evolution (VoLTE) and Voice over New Radio (VoNR), respectively. Therefore, it is possible to evaluate the differences in QoS i.e. throughput, packet loss, delay and jitter. It also stands out among the objectives of the article to show the emergency call via IMS as belonging to the eMBB slice. In this way, the article is structured as follows: Section 2 introduces the essential concepts, Section 3 describes the testbed methodology and Section 4 explores the results and upcoming approaches.

2. Background and Key Concepts

This section presents the background and fundamental concepts related to eCalls over 4G and 5G, explaining also the relationship of IMS architecture with emergency calls, as well as the protocols and procedures performed for the provision of the service. At last, an overview of the service category is presented in which eCall services are provided and its relationship with the operating requirements.

2.1. Emergency Call over IMS

The emergency call service is one of the most essential services for mobile operators, so the quality of this service in terms of mobility is highly taken into consideration, in this sense the way to offer the emergency service with an HD voice call is by using the IMS network. Both VoLTE and VoNR communication technologies are examples of IMS multimedia services, with the difference that VoNR calls have improved network capabilities compared to VoLTE in terms of power consumption, prioritization and it is expected that these requirements will also extend to emergency calls [De Souza et al. 2022]. The IMS architecture aims to offer multimedia services through the IP network, such as voice, video, text messages and emergency services. IMS applications are based on the Session Initiation Protocol (SIP), and their main function is to provide services in a Packet Switching (PS) network infrastructure, such as 4G and 5G, evaluating the quality of the network through the throughput and jitter [Arnez et al. 2023]. The IMS network had an internal organization carried out by the Call State Control Functions (CSCF) and Home Subscriber Service (HSS) database.

The HSS has a database of user information and allows access to other servers through authentication, authorization and location procedures. The CSCF is fundamental in the IMS architecture and is divided into three parts: Proxy CSCF (P-CSCF), point of contact between the User Equipment (UE) and the IMS network, having the function of validating and guaranteeing security and forwarding of SIP message requests; Interrogation CSCF (I-CSCF), connects the P-CSCF with S-CSCF and has the function of querying the HSS and Serving CSCF (S-CSCF), responsible for session control, SIP calls, service triggers and authentication [De Souza et al. 2022]. When an IMS subscriber dials an emergency number, the UE identifies and sends an INVITE SIP with a URN to P-CSCF, which is responsible for identifying the emergency numbers. There are settings in the IMS network to treat, prioritize and handle emergency sessions, such as Emergency CSCF (E-CSCF) and Public Safety Answering Point (PSAP). The PSAP is a physical place where emergency calls are sent and answered, i.e., police stations, firefighters, hospitals, and other emergency centers [Damasceno et al. 2023].

2.2. Enhanced Mobile Broadband (eMBB)

One of the main proposals of the 5G network is to meet multiple requirements that are part of different services, in this way, the concept of network slicing is introduced, in which network operators can divide the resources of virtualized or physical structures in a way to different applications according to pre-established criteria [Kourtis et al. 2021]. These criteria are in line with the standards of the 3rd Generation Partnership Project (3GPP), which defined three types of network slicing: eMBB, which supports stable connections with high data rates; URLLC, which supports low latency transmissions with high reliability; and mMTC, which supports many Internet of Things (IoT) devices [Popovski et al. 2018]. For the provision of IMS services in 5G networks, the eMBB service category is used, among these services are the emergency calls, which are one of the main forms of communication of emergency rescue teams. IMS services are presented in the eMBB slice to make use of its high communication bandwidth capabilities. Therefore, to analyze the relationship between IMS emergency services and the eMBB, experiments were performed to compare 4G and 5G eCall scenarios, they are described in Section 3.

3. Methodology

The Device Under Test (DUT) is a high-tech mobile device that is capable of making VoLTE and VoNR calls. Table 1 lists its main components.

Table 1. DuT technical specs

Components	Specification
Chipset	Qualcomm SM8550-AC
CPU	Octa-core, 1x3.36 GHz Cortex-X3, 2x2.8 GHz Cortex-A715 2x2.8 GHz Cortex-A710, 3x2.0 GHz Cortex-A510
Modem-RF	Snapdragon 8 Gen 2 (4 nm)
RAM	12 GB
OS	Android 13
Radio Technology	4G LTE, 5G NR
Release Support	17.0

The configuration testbed was set to a default network operator using a Public Land Mobile Network (PLMN) value of 00101. Fig. 1 describes the testbed that consists of two radio communication equipment (i.e. 4G and 5G) that work as eNode-B and gNode-B base stations. Then, a local host deployed the virtualized elements for the two core networks through the 4G or 5G Radio Communication Station and the IMS network server, as shown in Figure 1. Once the emergency call via VoNR or VoLTE is set up into the DuT, radio test station and network operator requirements, the service is available. In the controlled laboratory experiment, an emergency call was made by dialing the standard 911 emergency number. Emergency calls lasted 30 s and voice packets were collected using Wireshark [Lamping and Warnicke 2004] network packet software (see

Fig. 1). Section 4 reports the results related to eMBB to the 5G emergency call as well as comparing them with the 4G emergency call.

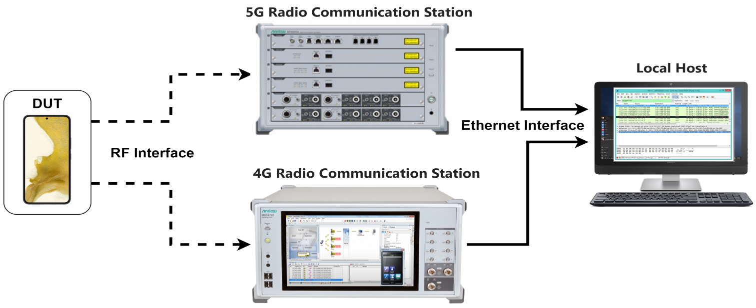

Figure 1. Setup 4G LTE and 5G NR

4. Results

When the emergency call in VoLTE was made, a throughput value of approximately 50 kbps was obtained. In contrast, for the VoNR call, the throughput was approximately 45 kbps, as seen in Fig. 2. This result demonstrates that the VoNR call required less data rate to send the voice packets. Jitter is a QoS measure associated with the delay variation between packets, which is related to the latency. The lower the jitter, the less delay was in the call between one packet and another. The highest jitter values were 1 ms and 0.4 ms for eCall over VoLTE and VoNR, respectively as shown in Fig. 3. Nevertheless, both jitter values are within the 20 ms threshold as explained in [Damasceno et al. 2023].

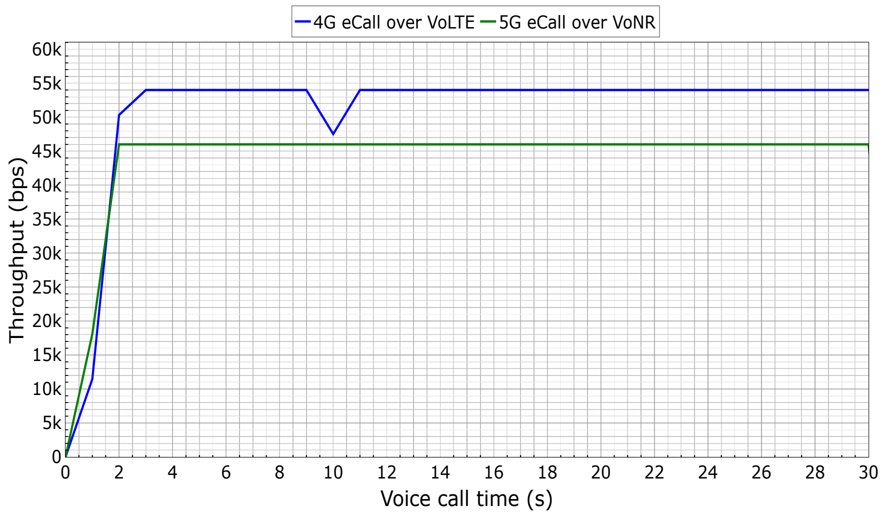

Figure 2. Throughput VoLTE and Throughput VoNR

Fig. 4 demonstrates the jitter results considering the Box Plot statistical graphics in Violin format to analyze the distribution, symmetry, concentration and dispersion of collected data. With the violin graph it is also possible to identify divergent values, since the more similar the graph is to the shape of the violin, the more uniform the data distribution. For eCall over VoLTE (blue density curve, i.e. the Gaussian kernel function), there are more data points in a region and the height of the density curve in that area increases with a probability equal to 50% to obtain a value of jitter equal to 0.62 ms (median value) and 0.63 ms (average value). For eCall over VoNR (green density curve), the highest probability at 50% presents a jitter value equal to 0.14 ms (median value) and 0.15 ms (average value). As the tests on both setups were carried out in a controlled simulation environment, packet loss was neglected.

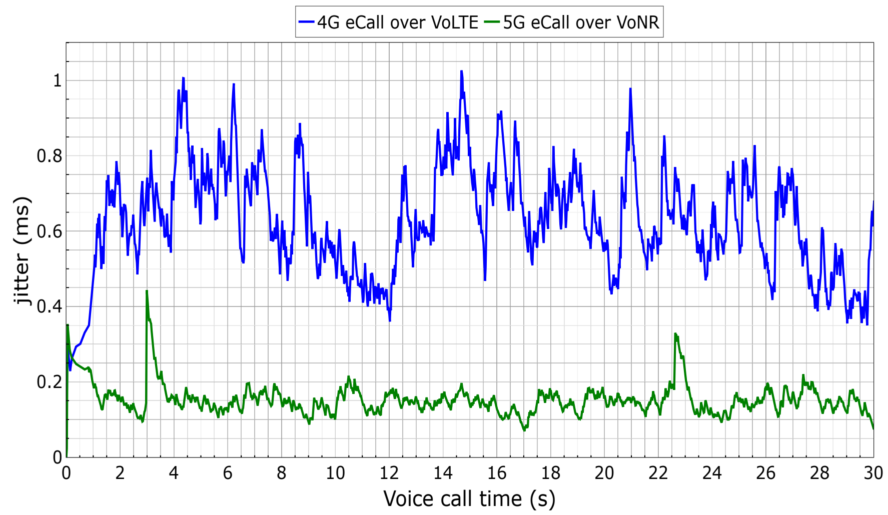

Figure 3. Jitter for eCalls over VoLTE and VoNR

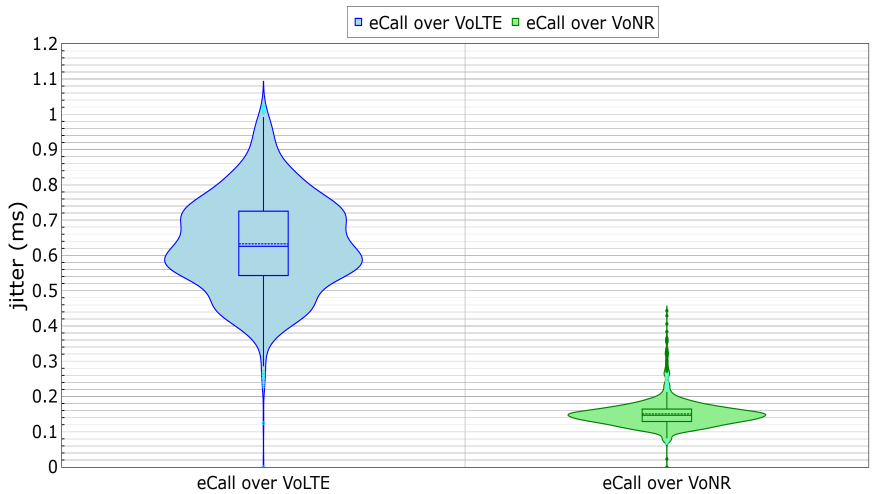

Figure 4. Jitter for eCalls over VoLTE and VoNR

5. Conclusion

The contribution of this work was to assess and compare the QoS of eCalls over 4G and 5G, which use eMBB slice. The improvement in throughput values, where VoNR needed less data rate to send voice packets and the reduction in jitter values by almost 80% demonstrated that the IMS network as part of the eMBB slice in 5G brought significant optimizations regarding the mobility of emergency calls, since, as observed in the violin graphs, the variation in jitter values throughout the 5G eCall are more homogeneous. However, both throughput and jitter values for 4G and 5G technologies are within the limit value of 20 ms, which demonstrates that the service is well established in both technologies and does not impact QoS. In future work, we intend to analyze more about the operation of emergency services in 5G, mainly related to the low latency and high reliability of the URLLC slice.

Acknowledgment

This work was presented as part of the result of the Project: AMAN, executed by the Sidia Institute of Science and Technology, in partnership with Samsung Eletrônica da Amazônia LTDA, according to Informatics Law n.8387/91 and Art.39 of Decree 10.521/2020.

References

Arnez, J. J. A., Damasceno, M. G. L., Gomes, J. D. S., Oliveira, F. F. D. S., De Oliveira, G. A. S., and Silva, W. M. (2023). Evaluation of emergency calls (eCall) using voice and video over IMS in 5G/NR mobile network. In *2023 IEEE International Conference on Engineering Veracruz (ICEV)*, pages 1–6. IEEE.

Damasceno, M. G. L., Arnez, J. J. A., Silva, W. A. E., Souza, C. B. B. D., Reis, R. K. G. D., and Tribuzy, L. C. (2023). Comparison between emergency calls over VoLTE and VoWiFi using IMS network. In *2023 6th International Conference on Advanced Communication Technologies and Networking (CommNet)*, pages 1–7.

De Souza, C. B. B., Arnez, J. J. A., Fernandes, T., Alves, C. A. T., and De Sousa, J. O. (2022). Analysis of power consumption in 4G VoLTE and 5G VoNR over IMS network. In *2022 IEEE 27th International Workshop on Computer Aided Modeling and Design of Communication Links and Networks (CAMAD)*, pages 59–64. IEEE.

Fan, Y., Su, T., and Chen, Z. (2023). Emergency communication network coverage method based on uav self-organizing wireless communication technology. In *2023 IEEE 6th International Conference on Pattern Recognition and Artificial Intelligence (PRAI)*, pages 1177–1181.

G.C., D., Ladas, A., Sambo, Y. A., Pervaiz, H., Politis, C., and Imran, M. A. (2019). An overview of post-disaster emergency communication systems in the future networks. *IEEE Wireless Communications*, 26(6):132–139.

Kourtis, M.-A., Batistatos, M., Xilouris, G., Sarlas, T., Anagnostopoulos, T., Chochliouros, I. P., and Kourtis, A. (2021). 5G slicing for emergency communications. In *2021 Eighth International Conference on Software Defined Systems (SDS)*, pages 1–6.

Kukkalli, H., Maheshwari, S., Seskar, I., and Skorupski, M. (2020). Evaluation of multi-operator dynamic 5G network slicing for vehicular emergency scenarios. In *2020 IFIP Networking Conference (Networking)*, pages 761–766.

Lamping, U. and Warnicke, E. (2004). Wireshark user's guide. *Interface*, 4(6):1.

Popovski, P., Trillingsgaard, K. F., Simeone, O., and Durisi, G. (2018). 5G wireless network slicing for eMBB, URLLC, and mMTC: A communication-theoretic view. *IEEE Access*, 6:55765–55779.

Shafi, M., Molisch, A. F., Smith, P. J., Haustein, T., Zhu, P., De Silva, P., Tufvesson, F., Benjebbour, A., and Wunder, G. (2017). 5G: A tutorial overview of standards, trials, challenges, deployment, and practice. *IEEE Journal on Selected Areas in Communications*, 35(6):1201–1221.