International Journal of Recent Technology and Engineering (IJRTE)
ISSN: 2277-3878 (Online), Volume-8, Issue-1, May 2019

Characterizing CSFB Performance in Cellular Networks

N.C. Eli-Chukwu

Abstract: The performance of a cellular network is centered on her ability to perform circuit and packet switch services. Improvements in these services has led to evolution of cellular network up to the 4th generation that is designed for IP and packet service. This paper presents and analyzes mobile phone behaviour and network performance of circuit services using the Circuit Switch Fall Back (CSFB) approach in LTE from various LTE cells. The goals of our study were to extend our understanding of mobile phone behaviour during CSFB by characterizing a cellular network and understand legacy fall-back preference of the mobile phone. LTE enabled mobile phones during circuit switch services falls back more on the UMTS network without much consideration on the radio environment as the UMTS has a mean fall back probability 0.77 and average fall back time of 1.56ms as against the GSM which was 0.23 and 1.86ms. The result shows that it will be difficult for the UE to successfully fall-back from a distance away from the cell and the UE power consumption rate will be very high.

Index Terms*: *Circuit Switch Fall-Back (CSFB), circuit switch, Universal Mobile Telecommunication System (UMTS).

I. INTRODUCTION

The rate of penetration and acceptability of mobile network since the advent cellular network in Nigeria in 2001 has been on the increase. From the available statistics, over 66.4% of Nigeria population owns a cellular phone [1,2,3]. Presently, the number of active network subscribers is directly proportional to the population of the country and as such changed the entire activities of the people [3]. It has reduced the risk and cost of traveling a long distance to speak with relatives and also a good business driver. Of its numerous advantages, serving as a tool for effective communication greatly exceeds its other uses. In fact, the quest to make voice calls led to the development of cellular network as GSM network is plagued with the consistent poor data transfer rate that led to the introduction of enhanced data rates in GSM evolution (EDGE) [4,5]. The theoretical maximum speed is 473kbps for 8 timeslots but could drop as low as 135kbps in order to reserve spectrum resources. Increasing request for higher data rates with less latency gave birth to the UMTS/WCDMA network. The services provided by the UMTS network are classified into four. It includes conventional services (voice and video calls and online games), streaming services (sending and receiving multimedia photos), background service (e-mails and SMS exchange and downloading attachments from mail) and interactive services (internet browsing and subscriber's database) [6, 7. With an improvement in service accessibility and speech quality during a voice call, the limited data transfer rates in UMTS led to evolved high-speed packet access (e-HSPA) with a theoretical data transfer rate of 42Mbps which still cannot efficiently stream videos without degraded quality. In a bid to improve subscribers' satisfaction in data service, the LTE was introduced. Since its introduction in 2004, LTE was projected as the future of effective and seamless flow of data transmission [8,9]. By 2017 in Nigeria, the sale of LTE smartphones rose by 70% which underlines the unending importance of LTE network performance. LTE network connectivity is really important for all kinds of business be it small, medium and large enterprise as LTE phones provide a higher data rate above 50mbps, lesser latency at a flexible frequency with a high spectral efficiency. Since LTE has such high data rates, it is gaining massive popularity not only amongst network operators but subscribers from all works of life. LTE changes the process of moving data to an internet protocol system. It moves large amount of packets of data and streamlines the service. Cooperate organizations such as banks have integrated cellular technology into banking operations such as mobile banking app, while shopping malls, ICT labs, hospitals, examination bodies, and educational institutions require peak data rates with short round trip time to function effectively. More recently, the internet of things is a machine type communication that uses LTE is been deployed in various homes and offices which further outlines the emphatic importance of LTE data performance. In Nigeria, voice over LTE (VoLTE) has not been deployed and as such, smartphone user camp on LTE for data transfer services and either GSM or UMTS during a voice call. Asides the performance metrics, [9] LTE is also designed to reduce installation and maintenance cost, reduce power consumption rate, promotes compatibility with existing technologies that ensures seamless inter radio access technology (IRAT) events between systems.

Revised Manuscript Received on 30 May 2019.
***** Correspondence Author
N.C. Eli-Chukwu*, Department of Electrical & Electronics Engineering, Alex Ekwueme Federal University Ndufu-Alike, Ebonyi, Nigeria.

II. RELATED WORK

Voice calls continues to be the major plague of the LTE network as telecommunication operators and vendors has given resolving it a priority target.

Service providers use the UMTS and GSM as back-up for the LTE since the LTE network is affected by limited distance resulting from its higher bandwidth and it takes a relatively longer time to build and LTE site. The back-up layers are used to cover the areas where LTE has little or no coverage [10]. If the UE is camped on LTE, during voice calls, the UE performs a circuit-switched fall back (CSFB) to either the UMTS or GSM network. There are possibilities of the introduction of IP Multimedia Subsystem (IMS) to cater for LTE voice calls in the nearest future [11]. The system design of the LTE uses internet protocol and as such efficiently performs packet service functions within the confines of the network. This has led to various research and proposals of other methods by which the LTE system can effectively perform other telecommunication services apart from packet service. One method that was greatly considered and largely deployed is the use of circuit-switched fall back (CSFB) to manage voice call activities in LTE system. The major challenge in using the CSFB to manage calls is longer call setup time which may even be doubled if the CSFB registration, authentication and fall back happens on a different mobile switching center (MSC) [12]. An LTE network that is actively on air can give a data download throughput up to 100mbps which greatly underlines her performs in packet service. But the network falls short of the primary or basic task of a cellular network which is to make voice calls independently. This will have a negative impact on the service providers as voice calls remains their major source of revenue. To mitigate this ugly scenario, the circuit-switched fall back was introduced to allow UEs on LTE to make voice calls by falling back to either 3G or 2G [13]. Telecommunication service providers are upgrading their networks by deploying LTE particularly in urban areas. This will make their system to accommodate the co-existence of GSM, UMTS and LTE networks. During voice calls on LTE, the service provider may consider voice over LTE (VoLTE), voice over internet protocol (VoIP) or the circuit-switched fall back. A UE that is camped on LTE falls back to either the UMTS or the GSM during voice calls and halt any packet service in session until the voice call ends before it returns back to the LTE [14]. LTE technology uses IP service which ensures that data bits are packet-encrypted. The end-to-end connection between the UE and the core is packet-oriented. This makes voice calls in this system really tasking and led to the integration of circuit-switched fall back (CSFB) to the system. Although there are other methods that can be used to make voice calls in LTE such as the VoLTE and VoIP, cost and transmission path gives CSFB an edge [15]. There are two major ways of making voice calls in the LTE network: the voice over LTE (VoLTE) and the circuit-switched fall back (CSFB). There is a negative impact when the UE moves from 4G ↔ 3G during CSFB and cell reselection. This could lead to ping-pong that will affect the 4G network performance to a tune of 90% as subscribers will be promptly knocked out of the network without prior knowledge [16]. There has been a persistent yearn for voice call continuity between various network technologies. This was obvious in the introduction of UMTS as the mobile could seamless move from 2G ↔ 3G during voice calls. This is a challenge in the LTE but it uses the circuit-switched fall back (CSFB) to manage voice calls. But there are varying call setup time between the LTE CSFB and UMTS networks. [17]. Cellular network activities are broadly classified into circuit and packet switch services. There should be an operational relationship between radio access technologies when deploying LTE network as it has limited voice service capabilities. The circuit-switched fall back serves as a link between the LTE and UMTS or GSM [18]. In installing LTE, the VoLTE and the CSFB are both deployed to manage circuit-switched services. VoLTE uses internet protocol multimedia subsystem to support the fall back process from 4G to 3G or 2G. Service providers tends to compare the performance of the VoLTE and CSFB to ascertain subscriber's preference, challenges of the deployed techniques and proffer solutions [19].

III. OVERVIEW OF CSFB

LTE is an all-IP network purely for PS services that has little or no circuit switch capabilities. To perform voice call in LTE, telecommunication service providers could either deploy VoLTE, VoWiFi or CSFB. Due to the cost of implementation, the CSFB is used in LTE to perform voice calls. When a UE camped on LTE initiates a voice call, the UE falls back to either UMTS or the GSM network depending on the configured fall back criteria. The call process (call attempt → call setup → call established → call end) is completed in the preferred network it falls back on before the UE is returned back to the LTE network if it is still within the LTE coverage area. The network interface that permits CSFB in the system architecture is the SGs interface.

A. *CSFB Architecture*

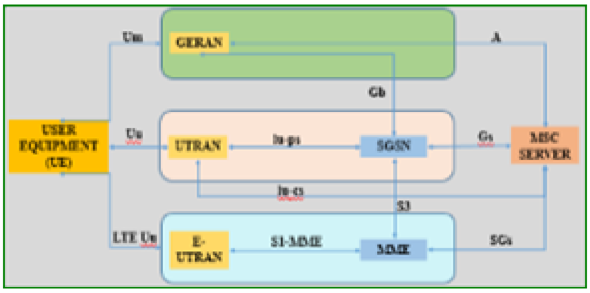


Fig. 1: CSFB Architecture

The CSFB architecture comprises the GSM EDGE radio access network (GERAN), UMTS terrestrial radio access network (UTRAN) and Evolved UTRAN (EUTRAN). The UE falls back to the legacy network (GERAN/UTRAN) during call initiation. The CS fall back function is implemented by reusing the SGs interface between the MME and the MSC server. The SGs interface is similar to the Gs interface between the Serving GPRS Support Node (SGSN) and the Mobile Switching Centre (MSC).

B. *CSFB Class*

Based on the capabilities of UEs and networks, five (5) fall back classes are available for an eNodeB to perform CSFB:

- Cell Change Order (CCO): After receiving a CS Fall back request, the eNodeB sends the UE a Mobility from EUTRA command message that contains a target GERAN cell, instructing the UE to access the cell. The UE must acquire synchronization with the cell and read system information about the cell before it can access the cell to initiate a CS service.

• CCO with Network Assisted Cell Change (NACC): If CCO/NACC is enabled, the RIM procedure is started during CCO from E-UTRAN to GERAN. The eNodeB acquires system information about the target cell and delivers it to the UE. The UE accesses the target cell to initiate a CS service with no need to read the system information, reducing the delay.
• PS Redirection: After receiving a CS Fall back Indicator, an RRC connection release message that displays the frequency details of the target cell UTRAN is sent to the UE by the eNodeB. Based on the received frequency information, the UE searches for a UTRAN cell, reads the system information of the UTRAN cell, and initiates initial access and CS s service setup.
• Flash CSFB: After receiving a CS Fall Back Indicator, an RRC connection release message that displays the frequency details of the target cell UTRAN is sent to the UE by the eNodeB as well as the information about multiple cells on the frequency. Based on the received frequency information, the UE searches for a UTRAN cell. As the UE has obtained the system information about the target cell, the UE directly initiates initial access and CS service set up in the target cell, reducing voice delay.
• PS Handover: The UE is handed over to the UTRAN through a PS handover procedure between the eNodeB and the UTRAN. After the handover, the UE initiates CS service set up in the target cell.

IV. METHOD OF NETWORK CHARACTERIZATION

The method of network characterization is the statics network test. It is an experimental method used to collect on-the-spot radio performance of a cell. The UE is kept between 0.3km and 0.4km away from each cell. The experimental setup as shown in Fig. 2 uses a Testing Equipment for Mobile System (TEMS) software license (V16.3) installed on the laptop, a TEMS LTE enabled phone, a GPS and a power inverter. Five (5) voice calls were made for 120secs on the MTNN network by the mobile phone on each cell often (10) randomly selected LTE sites in Victoria Island, Lagos, Nigeria.

Fig. 2: Test Experimental Setup

The TEMS phone was not locked on any technology to allow Inter-Radio Access Technology (IRAT) handover.

V. NETWORK CSFB RESULT

After performing the test under each cell, the time takes the call to fall back, the mean signal coverage, mean signal quality and the number of RAN fallback is extracted from the log-files using TEMS Discovery 10 and presented as shown in Table 1a and b.

Table 1a. Network Characterization Result (LTE – GSM)

SITE	Cells	GERAN RADIO			
		Mean Coverage (dBm)	Mean Quality	Number of CSFB	Mean Time (ms)
A	1	-55.68	0.02	1	1.25
	2	-60.31	0.01	2	1.26
	3	-58.82	0	1	1.43
B	1	-53.68	0.01	2	2.25
	2	-56.92	0	1	2.01
	3	-58.77	0.01	1	1.26
C	1	-56.92	0	1	2.04
	2	-57.8	0.01	1	1.24
	3	-56.92	0	1	1.99
D	1	-53.21	0.01	1	2.23
	2	-56.92	0	1	2.01
	3	-54.54	0.01	1	2.22
E	1	-56.92	0	1	2
	2	-56.92	0	1	1.97
	3	-53.58	0.01	2	1.22
F	1	-54.22	0.01	2	1.32
	2	-55.83	0	1	2.05
	3	-59.36	0.01	1	2.31
G	1	-53.74	0.01	1	1.34
	2	-57.97	0.01	1	1.65
	3	-55.09	0.01	1	1.35
H	1	-52.73	0.01	1	1.98
	2	-58.02	0	1	2.24
	3	-54.12	0.01	2	2.35
I	1	-59.33	0.01	1	1.88
	2	-58.38	0.01	1	2.33
	3	-53.92	0	1	2.02
J	1	-56.24	0.02	1	2.32
	2	-60.91	0.01	1	2.32
	3	-57.84	0	1	1.96

Table 1b. Network Characterization Result (LTE – GSM)

SITE	Cells	UTRAN RADIO			
		Mean Coverage (dBm)	Mean Quality	Number of CSFB	Mean Time (ms)
A	1	-65.75	-7.5	4	1.25
	2	-64.98	-7	3	1.233
	3	-67.41	-6.4	4	2.227
B	1	-68.86	-7.8	3	1.238

	2	-66.83	-6	4	2.208
	3	-67.76	-6.2	4	1.226
C	1	-61.21	-5.6	4	1.196
	2	-62.52	-6.6	4	1.222
	3	-63.33	-5.7	4	2.201
D	1	-65.73	-5.2	4	1.186
	2	-59.95	-4.6	4	1.185
	3	-60.01	-5.1	4	1.198
E	1	-58.41	-5.2	4	2.157
	2	-65.23	-6.2	4	1.212
	3	-62.11	-5.7	3	1.205
F	1	-68.17	-7.41	3	1.89
	2	-66.16	-5.7	4	0.92
	3	-67.08	-5.89	4	1.9
G	1	-65.07	-4.94	4	1.94
	2	-59.35	-4.37	4	1.95
	3	-59.41	-4.85	4	1.93
H	1	-57.83	-4.94	4	0.97
	2	-64.58	-5.89	4	1.92
	3	-61.49	-5.42	3	1.93
I	1	-60.6	-5.32	4	1.93
	2	-61.89	-6.27	4	1.91
	3	-62.7	-5.42	4	0.93
J	1	-65.09	-7.13	4	1.88
	2	-64.33	-6.65	4	1.9
	3	-66.74	-6.08	4	0.9

Findings and Implication

A total of 150 calls were attempted on the LTE network and 115 fell back to the UMTS network. The UMTS has a mean fall back probability 0.77 and average fall back time of 1.56ms. The graph in Fig. 3 compares the mean fall back coverage of UMTS and the GSM. Although the GSM has a better signal coverage of -56.52dBm during fall back, calls and SMS services tend to fall more on the UMTS network. This is as a result of the network design and configurations. With the UMTS preferred over the GSM when performing CSFB, the process of falling back successfully will be difficult at a certain distance from the serving cell. Also, the rate of power consumption will be relatively high and draining the UE during fall back. Research should be geared towards optimizing UE power consumption as LTE is deployed in urban areas where there are existing UMTS sites.

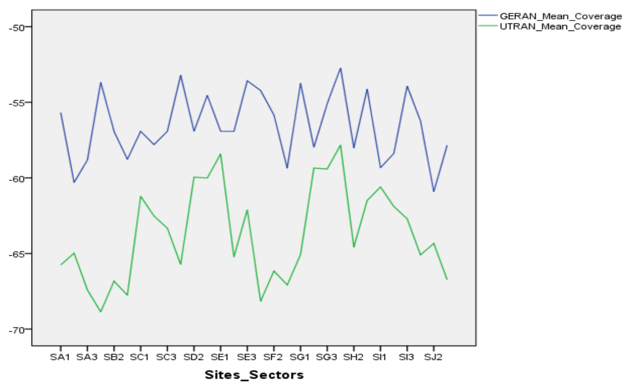


Fig. 3: Fall Back mean coverage comparison chart

The chart in Fig. 4 displays the comparison of fall back mean time of both GSM and UMTS. Initiated calls in LTE falls back faster to the UMTS network than the GSM. It takes an average of 1.56ms and 1.86ms for calls to fall back to UMTS and GSM respectively.

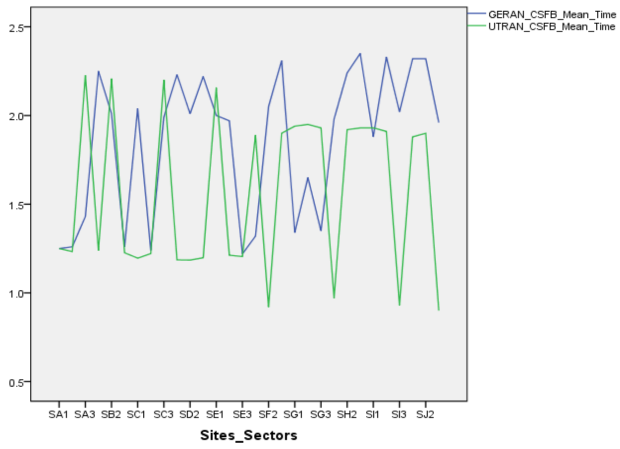


Fig. 4: Fall Back mean time comparison chart

With the above results, cellular network installation, upgrade, and operations follow a gradual and systematic approach. LTE network is an upgrade of the UMTS network as it would be a technical anomaly upgrading from GSM to LTE.

VI. CONCLUSION

In this research work, we characterized Circuit Switch Fall Back (CSFB) of the LTE network in Lagos metropolis, Nigeria. By studying and analyzing dataset collected through drive test from ten (10) different sites, there is LTE network preference in performing CSFB. Circuit switch services fall back more to the UMTS if it has a good signal coverage that may not be better than the GSM coverage.

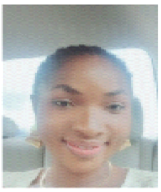
Looking at the importance of CSFB in cellular network activities, the research will be taken a step further by considering reducing CSFB time through a better cell reselection pattern and criteria and optimizing User Equipment (UE) power consumption as LTE is deployed in urban areas where there are existing UMTS sites.

REFERENCES

1. World Bank "World Development Indicators: Nigeria", World Bank Databank, [Online]. Available: http://data.worldbank.org/country/Nigeria.
2. Nigerian Communications Commission (NCC), "Industry statistics data bank", [Online]. Available: www.ncc.gov.ng/index.php?option=com_content&view=category&id=65&Itemid=67
3. Research ICT Africa (RIA), Household and Small Business Access & Usage Survey, RIA Survey Methodology Brief, [Online]. Available: www.researchictafrica.net/publications/Research_ICT_Africa_Policy_Briefs/2012_ Stork_-_ICT_Survey_Methodology.pdf
4. K. Zangi, A. Furuskar, and M. Hook, "EDGE: Enhanced Data Rates for Global Evolution of GSM and IS-136", Proc. Multi-Dimensional Mobile Commun. 1998.
5. ETSI TS 03 64 V5.1.0 (1997-11), "Digital Cellular Telecommunications system (Phase 2+); General Packet Radio Service (GPRS); Overall Description of the GPRS Radio Interface; Stage 2 (GSM 03.64, v. 5.1.0).
6. 3GPP TS 23.107, "QoS Concept and Architecture (Release 6)", 2002.
7. 3GPP TS 23.207, "End-to-End QoS Concept and Architecture"
8. A. Damnjanovic, J. Montojo, Y. Wei, T. Ji, T. Luo, M. Vajapeyam, T. Yoo, O. Song, D. Malladi, "A survey on 3GPP heterogeneous networks", IEEE Wireless Communication, Volume: 18, Issue: 3, pp: 10 – 21, 2011

9. Y. Wang, C. Chuang, "Efficient eNB deployment strategy for heterogeneous cells in 4G LTE systems" Computing Network, Volume: 79, pp: 297–312, 2015
10. A. Hussein, A. Luay, "LTE Fall-Back Optimization using the Decision Tree", IEEE 8th Annual Ubiquitous Computing, Electronics and Mobile Communication Conference (UEMCON), DOI: 10.1109/UEMCON.2017.8248974, 2017.
11. J. Bautista, S, Sawhney, M. Shukair, I. Singh, "Performance of CSFB from LTE to UMTS", IEEE Communications Magazine, Volume 51, Issue 9, pp: 136 – 143, 2013
12. A. Elbayoumy, S. Al-Ashry, "The New Scheme for CSFB Improvement in LTE", IEEE 12th International Computer Engineering Conference (ICENCO), Cairo, Egpyt, December 28 – 29, 2016
13. V. Paisal, "Seamless voice over LTE, IEEE 4th International Conference on Internet Multimedia Services Architecture and Application", Bangalore, India, December 15 – 17, 2010
14. R. Liou, Y. Lin, Y. Sung, P. Liu, "Performance of CS Fall-Back for Long Term Evolution Mobile Network", IEEE Transactions on Vehicular Technology. Volume: 63, Issue: 8, 2014
15. A. Teković, I. Pešut, Z. Morić, "Voice Service in an LTE Network-CSFB", IEEE Proceedings ELMAR, Zadar, Croatia, September 25 – 27, 2013
16. G. Tu, C. Li, C. Peng, S. Lu, "How voice call technology poses security threats in 4G LTE networks" IEEE Conference on Communications and Network Security (CNS), Florence, Italy, September 28 – 30, 2015
17. L. Bhebhe, M. Heiskanen, "Performance of Circuit Switched Fall Back & single radio voice call continuity from TD-LTE to UMTS", IEEE 22nd International Conference on Software, Telecommunications and Computer Networks (SoftCOM), Split, Croatia, September 17 – 19, 2014.
18. G. Tu, C. Li, C. Peng, S. Lu, "How voice calls affect data in operational LTE networks", 19TH Annual International Conference on Mobile Computing and Networking, Florida, USA, September 30 – October 4, 2013
19. A. Elnashar, M. El-Saidny, M. Mahmoud, "Practical Performance Analyses of Circuit-Switched Fall-Back and Voice Over LTE" IEEE Transactions on Vehicular Technology, Volume 66, Issue 2, pp: 1748 – 1759, 2017
20. [20] R. Ren-Huang Liou, Y. Lin, Y. Sung, P. Liu, C. Wietfeld, "Performance of CS Fall-Back for Long Term Evolution Mobile Network "IEEE Transactions on Vehicular Technology. Volume 63, Issue 8, pp: 3977 – 3984, 2014

AUTHORS PROFILE



Engr. Ngozi Clara Eli-Chukwu received a Bachelor of Engineering (B. ENG) degree in Electrical and Electronics in 2003 and a Masters of Engineering (M.ENG) in Communication Systems Engineering in 2008 from Enugu State University of Science and Technology Nigeria. She has a Post Graduate Diploma (PGD) degree in Project Management in 2015 from University of Liverpool, London. She is a lecturer at Alex Ekwueme Federal University, Ndufu-Alike, Ikwo, Ebonyi State, Nigeria. Her current research interest includes: Internet of Thing, cognitive communication, QoS, wireless sensor networks.