Research Article

Handoff and Drop Call Probability: A Case Study of Nigeria's Global System for Mobile Communications (GSM) Sector

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Abstract: This paper investigates the quality of service of GSM networks in Nigeria using the call drop rate and the call handover success rate as the key performance indicators. In the analysis, we have utilized the Erlang B probability formula, which highlights the service quality at any given moment on the number of channels available at that time. The parameters of the four main GSM services in Nigeria were analyzed with the help of data obtained from the Nigerian Communications Commission. The results show that the operators are not performing well with regard to these metrics; therefore, ways to increase not just the performance of the metrics but also the performance of the whole network are suggested. The analysis shows that GSM services in Nigeria are currently unreliable. Cell splitting, sectoring, and efficient resource management are highlighted as the possible means of maximizing the networks' quality of service when implemented. This implementation would lead to soft handover in the network; thus, creating a more robust telecommunication system.
Keywords: handover/hand-off, drop call rate, efficient resource management, sectoring, cell splitting.

INTRODUCTION

Telephone handsets enable us to communicate in real time with persons who are far away from us. When one makes a call using a handset, it is routed from a Base Station (BS) through another BS until the call is received by another person. This continuation of an active call is a major quality of the service parameter in telecommunication. Any time someone loses a connection to a BS, the call is dropped. Therefore, if either the caller or the called person is moving, there is a need for his Mobile Station (MS) to remain connected to a BS in order to maintain the communication. However, each BS has a defined area of coverage, so if either of them moves out of the coverage region of his or her BS, the call is handed over to another BS. This process is referred to as handoff (or handover).

Handoff poses serious challenges to the Nigerian telecommunications sector. The number of global system for mobile communication (GSM) subscribers in Nigeria has continued to grow since its launch in the country in 2001. The number of subscriber grew from 1.57 million in 2002 to 18.56 million in 2005, then to 81.08 million in 2010 [1]. According to the Nigerian Communications Commission (NCC), the current number of active GSM subscribers in Nigeria is 132 million [2]. However, the service qualities provided by the GSM operators in Nigeria have remained abysmal. Basically, every subscriber to the country's

GSM networks is affected. In order to enforce better service quality, the Nigerian Communication Commission (NCC), the country's highest GSM regulator, set a benchmark for the key performance indicators (KPIs). The KPIs are metrics for measuring the quality of service of the GSM networks. Some of the KPIs are the call setup success rate (CSSR), call drop rate (CDR), call handover success rate (CHSR), call completion ratio (CCR), and call setup time among others.

Two of these KPIs, the call drop rate - the rate of calls not completed successfully - and the call handover success rate - the rate of successful handovers - are the worst performing metrics in Nigeria. Furthermore, two kinds of handoff occur in GSM networks: the soft handoff and the hard hand off. When the communication channel is first released before a new channel is acquired by the MS, the on-going call is lost, and hard handoff is said to occur. This handoff usually occurs when the BSs are located far apart or occupied (no available channel in the BS). The time lag causes the loss of on-going calls and/or the blocking of incoming calls. Call losses due to handoff are rampant and harm the Nigeria telecommunication sector. Research by [3] on the quality of GSM KPIs in Nigeria confirmed that the call drop rate is among the worst performing metric in the country. They conducted their research by distributing questionnaires to the six

regions of Nigeria. Moreover, [4] in their drive time test in Abuja, the Federal Capital Territory, substantiates the claim of [3]. According to [4], most of the operators are yet to meet the NCC target for the two critical KPIs, - the CSSR and the CHSR. The CSSR of Glo is the best among the operators [3], but its CSSR is still below the NCC threshold [4]. These papers observe that the high value of CSSR indicates that the GSM networks - which are considered in the study - are highly congested. In fact, the QoS issues will persist according to [4] because teledensity is forecast to grow.

Therefore, this research will focus on ways to enhance the CDR and CHSR in Nigeria GSM services. We will analyze the latest call drop and handoff data obtained from the NCC, and explore possible ways to improve the overall service quality of the system. Soft handoffs rarely result in call loss because the connected BSs smoothly switch the call to the new channel before the connection to the source BS is broken. Hence, this research will also seek to discover a robust method to achieve soft handover in our telecommunication systems.

RESEARCH METHODOLOGY

Dropped calls, especially during handover, are common in GSM services in Nigeria and in many other developing countries. Call drops and handover losses are generally due to inadequate radio resources. To maximize the coverage areas of BSs such that handover and drop call probabilities are reduced to a minimum, the implementation of cell splitting, sectoring, and efficient handover management is required.

Cell splitting, sectoring, and efficient resource management, if properly implemented, could help to reduce premature call losses due to handover. To achieve this reduction, the coverage area of each cell is first redesigned (split) to accommodate micro-cells and pico-cells. Ironically, cell splitting increases the rate of handoff. However, since the coverage areas of the various cells now overlap, the resulting handoff is usually a smooth one and does not lead to the loss of an on-going call(s). Sectoring entails that the omni-directional antennas, which are installed by various operators, be replaced with several sector antennas. Sectoring uses directional antennas to further control the interference and frequency reuse of channels [5]. Sector antennas produce beams of stronger intensity than omni-directional antennas; hence, sectoring greatly improves network coverage. Moreover, a certain number of channels should always be reserved to manage handover [6]. An in-depth analysis of how cell splitting, sectoring, and efficient handoff management increases radio resources was presented. We also proved by using the Erlang B probability formula, that the number of call losses decreases with an increase in radio resources.

In addition, we analyzed the latest drop call and handoff data obtained from the NCC, and explored ways to improve the overall service quality of the system. We further compared the service quality of various GSM operators in Nigeria with respect to the investigated KPIs.

PROBABILITY ANALYSIS

The Erlang B formula for loss probability is used to estimate the relationship between call losses and the number of available channels [7], [8]. This relationship (the Erlang B formula) is given in the equation (1) below:

$$B = \frac{\frac{A^N}{N!}}{\sum_{k=0}^{N} \frac{A^k}{k!}} \qquad (1)$$

Where B = Loss probability, A = offered traffic intensity in Erlang, and N = available number of channels. Equation (1) signifies that an increase in the number of channels leads to a decrease in drop call probability.

Furthermore, the drop call probability is given as [7], [9]:

$$P(Y = n) = \frac{(v_d t)^n}{n!} e^{-v_d t}, \quad n \geq 0$$

$$(2)$$

Where V_d is the drop call rate, t is the call duration, Y is a random variable that counts the number of drops, and n is the confirmed call dropped. This is a Poisson Probability function with a discrete variable, which counts the number of dropped calls [7].

Moreover, the number of dropped calls is calculated from the relation [7]:

$$\text{Drop call rate} = \frac{Number\ of\ dropped\ calls}{Number\ of\ call\ attempts} \qquad (3)$$

The application of the above formula (equations 1, 2, and 3) in probability analysis as carried out in various literature [7], [8], [9] shows that drop call probability decreases with an increasing number of channels; thus supporting the fact that cell splitting and sectoring will greatly improve handoff in GSM.

RESULTS

The bar graph in Figure 1 shows the DCR of the major GSM operators in Nigeria. The two operators that overshoot the benchmark in Figure 1 constitute over 64.5% of the subscribers as can be seen in Table 1. The total DCR for the four telecommunication operators is 3.79%; thus, almost 4 out of every 100 calls made in

Nigeria are likely to be prematurely terminated. The only two operators that met the target set by NCC, Airtel and Etisalat (EMTS limited), have the lowest number of subscribers. The operators in red ink in the summary table (Table 1) are no longer active; therefore, they are not included in the total calculations.

Despite its high DCR, Table 1 indicates that Globacom limited has continued to attract more subscribers; it grew by 3.56% between the second quarter and the third quarter of 2013, and it more than doubled this rate between the last quarter of 2013 and the first quarter of 2014. This growth might be attributed to their fast but cheap data plans. However, MTN, which has the highest DCR of 1.21 as illustrated in Figure 1, lost a good number of its potential customers between the last quarter of 2013 and the first quarter of 2014, perhaps because of the implementation of the Mobile Number Portability in Nigeria. Most of its disaffected customers that were afraid of losing their business phone numbers should they stop using their MTN SIM card, now port to other competing networks.

Table 1: Summary of GSM subscribers in Nigeria [10]

| OPERATORS	Jun-13	Sept-13	Dec-13	Mar-14	Q2-Q3	Q3-Q4	Q4-Q1
MTN Nigeria Communication	55,238,430	55,596,025	56,766,085	57,224,316	0.65	2.10	0.81
Globacom Limited	25,019,862	24,129,183	25,933,867	23,416,867	(3.56)	7.48	(9.71)
Airtel	21,591,904	22,726,698	24,847,567	25,521,046	5.26	9.33	2.71
M-Tel Limited	258,520	258,520	258,520	258,520	-	-	-
EMTS Limited	15,303,647	15,759,810	17,035,276	18,722,613	2.98	8.09	9.90
Sub-Total (GSM)	117,153,843	118,211,716	124,582,795	124,884,842	0.90	5.39	0.24
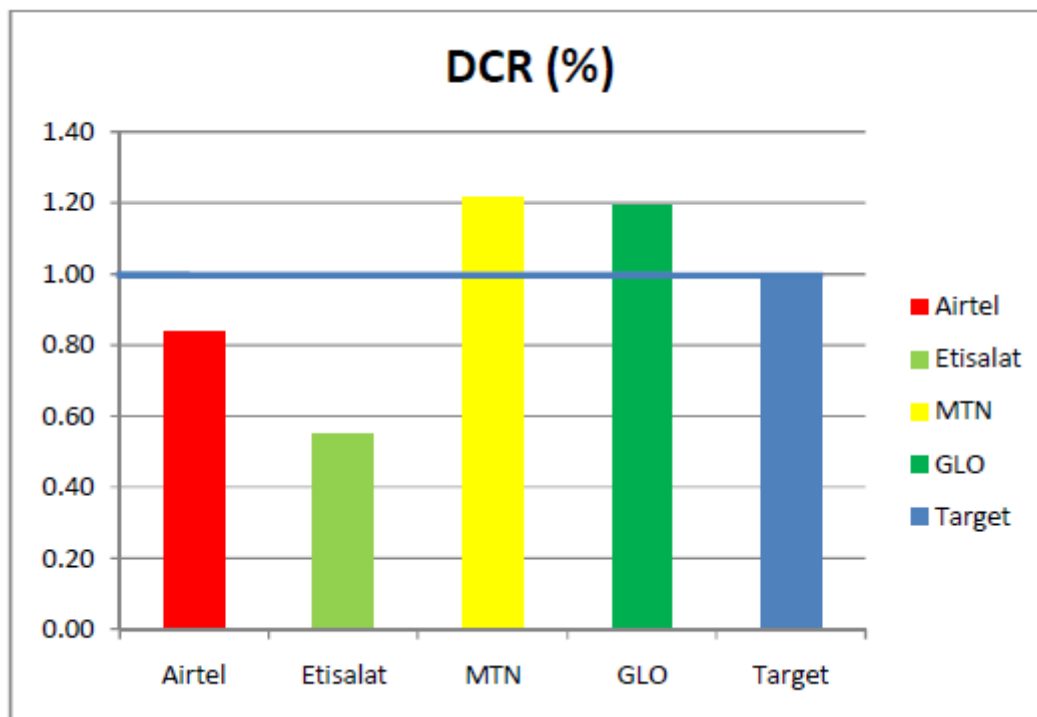
Figure 1: Nigeria Telecoms Drop Call Rate (January, 2014) [11]

DISCUSSION

In this paper, we discussed how cell splitting, sectoring, and efficient resource management could help in the reduction of call losses due to handoff. Moreover, we analyzed the call drop and handoff data of GSM subscribers in Nigeria, and then we illustrated with the Erlang B formula the necessity of CDR at a given time on the number of the available channels at that time.

The data presented in the result section clearly indicates that the service quality (with respect to dropped calls) of GSM operators in Nigeria is inadequate. In other words, the telecoms are far from

providing a reliable service in Nigeria; thus, further enhancement is urgently needed. Four percent of all the calls across the country's GSM networks get prematurely lost. This translates to hundreds of thousands of call losses on daily basis, bearing in mind that over one hundred million active GSM lines exist in the country.

It can be concluded that the service quality of current GSM networks in Nigeria is inadequate and unreliable. Much needs to be done to ensure that Nigerians enjoy better GSM service. NCC should regularly inspect these GSM networks and ensure that the operators comply with the standards. The operators should build more base stations to meet the demand of their increasing subscribers. In fact, cell splitting, sectoring, and efficient network management should always be implemented in order to surmount this obstacle. When these recommendations are implemented, the GSM network accessibility in the country will improve, and the highly congested networks that callers currently experience will be minimized; thus, increasing the QoS and the overall performance of the GSM operation in the country.

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