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Improving Long Term Evolution Network Signal Quality Using Resource Block Allocation

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Abstract

With every passing day, the importance and number of people that uses data services experiences a geometrical growth. From product survey and testing, marketing and advertisement of products, online sales and purchase of products, execution of employee training and development programs, multimedia conferencing, advance research programs and the likes, the use of Long Term Evolution (LTE) technology has no limit. But all these afore-mentioned merits are marred by poor network signal quality which is an integral part in measuring the network Quality of Service (QoS). To improve the network signal quality using block call allocation, data traffic sessions (drive test) were conducted in Port-Harcourt cluster for the existing LTE networks daily for twelve (12) weeks using a pre-defined test route. Result showed a network signal quality improvement of 13.02% and 25.87% for 1 and 2 units rise in the allocated Resource Blocks (RBs) respectively.

Keywords

LTE, QoS, Data Traffic Sessions, Network Signal Quality, Resource Blocks

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1. Introduction

With every passing day, the importance and number of people that uses data services experiences a geometrical growth. From product survey and testing, marketing and advertisement of products, online sales and purchase of products, execution of employee training and development programs, multimedia conferencing, advance research programs and the likes, people appreciate and yarn for faster data service with optimum reception of images and videos that were transferred. The introduction of Long Term Evolution (LTE) is to serve as an improvement on the performance of Wideband Code Division Multiple Access (WCDMA) in terms of speed and quality. With this high expectation of subscribers of the LTE technology, the design, planning, deployment of equipment and its overall service should curtail congestion, possess small response time with good quality. Figure 1 shows the areas in telecommunication that LTE should perform well. The paper focuses on improving the quality of the LTE network as it could be the backbone of data activities.

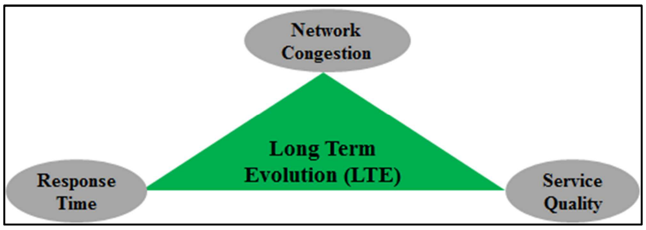

Figure 1. LTE performance areas.

2. Related Work

The main technical features of LTE are its performance in terms of peak bit rate and average cell throughput, among

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others. LTE entails a great technological improvement as compared with the WCDMA [1]. The most popular mobile application is the video streaming in the application of multimedia. The above task is achievable by means of developing the LTE (Long Term Evolution) in the world of mobile. With low latency and high data rates in the applications of multimedia the effective services is provided by the LTE technology features [2]. This technological improvement can be affected by various antenna parameters on the downlink performance. Cell coverage and capacity in different macro-cellular network scenarios for various combinations of antenna parameter configurations determines the Signal to Interference Noise Ratio (SINR) performance and cell throughput [3]. During radio resources allocation, transmitters may cause significant amount of interference to the cellular network. Such interference can be avoided or reduced if the radio resources are allocated intelligently with the coordination from the eNodeB [4]. The four basic Radio Resource Management (RRM) measurements in Long Term Evolution (LTE) system are Channel Quality Indicator (CQI), Reference Signal Received Power (RSRP), Reference Signal Received Quality (RSRQ), and Carrier Received Signal Strength Indicator (RSSI). A measurement of channel quality represented by Signal to Interference plus Noise Ratio (SINR) is used for link adaptation along with packet scheduling, whereas RSRP and RSRQ are needed for making handover decision during intra-eUTRAN (evolved Universal Terrestrial Random Access Network) handover in LTE [5]. The performance of an LTE network can be measured considering the head of line delay, probability of packet loss and the delay threshold for different types of data [6]. The overall network performance can also be measured in terms of mobility. A self-optimizing algorithm tunes the handover parameters of the LTE system to diminish negative effects such as service drops [7]. With higher mobility, the various network performance parameters like signal to interference to noise ratio, throughput, received signal strength indicator etc. get affected [8]. There are two kinds of handover algorithms that adjust the handover (HO) parameters of LTE (Long-Term Evolution) eNodeB (evolved NodeB) to improve the overall network performance and diminish negative effects [9]. During data traffic session, parameters tend to fade as the UE gets to areas of poor or limited coverage. The signal coverage and capacity of the system are improved through antenna tilting [10]. With the radio capacity and expected output, the usage of LTE technology will definitely be affected by congestion. Hence, the challenge of scheduling user transmissions on the downlink system should be addressed. Embedding a multiuser scheduler with Proportional Fairness (PF) can be used to effectively schedule resource among User Equipment (UE). Numerical results show that the PF scheduler provides a superior fairness performance with a modest loss in throughput, as long as the user average SINRs are fairly uniform. A suboptimal PF scheduler can also be considered, as it has a much lower complexity at the cost of some throughput degradation [11]. One of the challenges to be handled by LTE is the quality of transmitted signals. A gain control scheme/strategy maximizes SINR and reduces the transmit power [12]. The User Equipment (UE) reports Channel Quality Indicator (CQI) values depending on a linear mapping function from effective Signal to Noise Ratio (SNR). The reported CQI value gives a corresponding Modulation and Coding Scheme (MCS) and data throughput [13]. With the ever-growing subscriber database of the technology, LTE is currently being upgraded with the aim of doubling the capacity over High-Speed Packet Access (HSPA). It is sensitive to inter-cell interference and as such the power control becomes decisive to provide the required SINR, while controlling at the same time the interference caused by neighbouring cells [14]. Signal quality and strength, temporal and network operator factors are all essential in modelling the performance of an LTE system [15].

The aim of this paper is to model signal quality performance in LTE and propose parameter adjustment on parameters that influences signal quality.

3. Research Procedure

The research aims at improving signal quality in LTE using mathematical models. The network is studied to understand various signal quality parameters, their impact on the network and various parameter adjustments to improve the overall signal quality.

3.1. Data Collection of Signal Quality Parameters

A telecommunication data collection technic called drive test was used to collect LTE data from three (3) operators in Nigeria as shown in Figure 2.

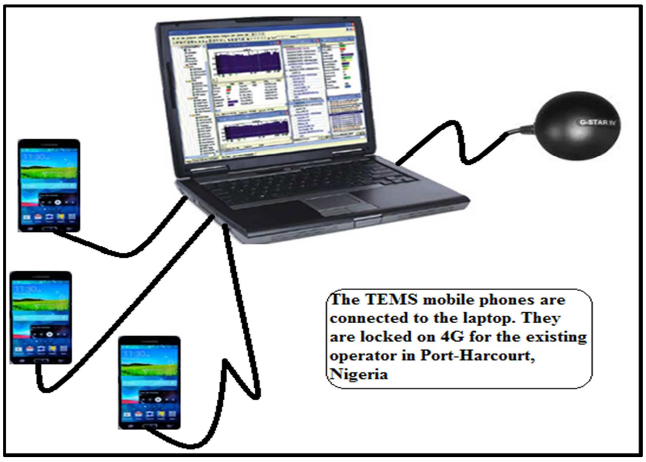

Figure 2. LTE drive test setup.

The drive test setup uses Testing Equipment for Mobile System (TEMS) software version 16.0.3, 3 TEMS phones (Samsung S5), a Global Positioning Service (GPS) and a power inverter. Files of equal sizes were downloaded from a dedicated server while the car goes through the defined routes. The test route covers the urban areas in Port-Harcourt, Nigeria and it was for a period of 12 weeks.

3.1.1. Signal Quality Parameters

In LTE, the Reference Signal Received Quality (RSRQ) is the parameter used by the system to report the quality of the transmitted or received signal. The RSRQ is an important parameter for measuring a cell, site and an entire network (LTE) performance as it helps the User Equipment (UE) to perform functions such as cell reselection and handover.

$$RSRQ = \frac{RB_{All} * RSRP}{RSSI} \tag{1}$$

$$RB_{All} = Number\_of\_resource\_blocks\_allocated$$

The process of reporting transmitted signal quality in LTE goes through some mathematical process and as such, some parameters combine to give the signal quality. These parameters are:

RSRP

The Reference Signal Receive Power (RSRP) is the linear average of reference signal power (in dB) across the specified bandwidth. As Rx-level and RSCP denotes the signal coverage of GSM and WCDMA respectively, the RSRP is her equivalent in LTE. The quality of any signal can be measured only when signals are transmitted and signals are only transmitted when there is network coverage.

$$\text{From eqn. 1, } RSRP = \frac{RSRQ * RSSI}{RB_{All}} \tag{2}$$

SINR

When signals are transmitted, the quality of the signal upon reception tends to fade or degrade. This could be as a result of interference (channels or cells) or noise in the tested area. The Signal-to-Interference Noise Ratio is the ratio of measured usable signal power to the summation of the average interference power from the other channels or cells and the background noise.

$$SINR = 10\log(\lambda * N_S) + RSRQ \tag{3}$$

$$N_S = 12\text{subscribers/Resource Block (RB)}$$

$$\lambda = \alpha * \beta^{-1}$$

$$\alpha = \text{Reference\_signal and}$$

$$\beta = Physical\_Downlink\_Shared\_Channel(PDSCH)$$

$$\text{Hence, } SINR = 10\log(12\lambda) + RSRQ \tag{4}$$

SNR

The Signal-to-Noise Ratio is a KPI that compares the desired signal to the level of background noise in the system.

$$SNR = RSRQ(\lambda * N_S) \tag{5}$$

RSSI

The Received Signal Strength Indicator is the entire received power including the wanted power from the serving cell as well as all co-channel power and other sources of noise.

$$\text{From eqn. 1, } RSSI = \frac{RB_{All} * RSRP}{RSRQ} \tag{6}$$

Resource Block (RB)

This is the smallest unit of resource that is allocated to a user during traffic session. During traffic session, the UE requests for RBs based on the data service it wants to perform.

Let C_{BW} =Channel Bandwidth,

$N_{SC/u}$ =Number of Subcarrier/User

F_{SC} =Frequency of Subcarrier and

RB_{Rq} =Number of Resource Block Requested

$$RB_{Rq} = \frac{C_{BW}}{N_{SC/u} * F_{SC}} \tag{7}$$

3.1.2. Data Collection Result

The required signal quality parameters were extracted from the drive test log-files using TEMS Discovery. The average for each week was taken for twelve (12) weeks and summarized in Table 1 below:

Table 1. Signal quality parameter performance.

WK	OPERATOR A					OPERATOR B					OPERATOR C				
	RSRP	RS SNR	RSSI	Number of Allocated PRBs	RSRQ	RSRP	RS SNR	RSSI	Number of Allocated PRBs	RSRQ	RSRP	RS SNR	RSSI	Number of Allocated PRBs	RSRQ
1	-99.1	6.0	-64.1	-9.1	-14.1	-94.1	5.7	-60.9	-8.7	-13.4	-96.8	5.9	-62.7	-8.9	-13.8
2	-97.3	4.3	-61.9	-9.0	-14.1	-92.5	4.1	-58.8	-8.5	-13.4	-95.1	4.2	-60.5	-8.8	-13.8
3	-99.6	9.2	-65.5	-8.7	-13.3	-94.6	8.7	-62.2	-8.3	-12.6	-97.3	9.0	-64.0	-8.5	-13.0
4	-96.0	8.9	-65.1	-7.4	-11.0	-91.2	8.4	-61.8	-7.1	-10.4	-93.8	8.7	-63.6	-7.3	-10.7
5	-91.7	9.2	-60.8	-7.0	-10.5	-87.1	8.8	-57.8	-6.6	-10.0	-89.6	9.0	-59.4	-6.8	-10.3
6	-98.0	2.5	-64.7	-8.2	-12.4	-93.1	2.4	-61.5	-7.8	-11.8	-95.7	2.5	-63.2	-8.0	-12.1
7	-96.9	6.2	-62.6	-8.8	-13.6	-92.1	5.9	-59.5	-8.3	-12.9	-94.7	6.1	-61.1	-8.6	-13.3

WK	OPERATOR A					OPERATOR B					OPERATOR C				
	RSRP	**RS SNR**	**RSSI**	**Number of Allocated PRBs**	**RSRQ**	**RSRP**	**RS SNR**	**RSSI**	**Number of Allocated PRBs**	**RSRQ**	**RSRP**	**RS SNR**	**RSSI**	**Number of Allocated PRBs**	**RSRQ**
8	-96.3	5.7	-65.3	-9.4	-13.9	-91.5	5.5	-62.0	-8.9	-13.2	-94.1	5.6	-63.8	-9.2	-13.6
9	-107.8	9.3	-63.5	-7.5	-12.8	-102.5	8.9	-60.3	-7.2	-12.2	-105.4	9.1	-62.0	-7.4	-12.5
10	-88.5	14.4	-58.1	-6.4	-9.8	-84.1	13.7	-55.2	-6.1	-9.3	-86.5	14.0	-56.8	-6.3	-9.6
11	-93.3	10.0	-62.7	-6.8	-10.2	-88.6	9.5	-59.6	-6.5	-9.7	-91.1	9.8	-61.3	-6.7	-9.9
12	-102.3	9.2	-72.6	-7.0	-9.9	-97.2	8.8	-69.0	-6.7	-9.4	-100.0	9.0	-70.9	-6.9	-9.7

From the data collection result in table 1 above, it is obvious that the signal quality of the operators in the tested area falls short in performance which led to longer latency and low data throughput. Although the signal coverage (RSRP) and signal strength (RSSI) negatively affected the signal quality, in this research, interest is in the physical resource block and how it affects the signal quality. Figures 3, 4, 5 and 6 shows the relationship between the various radio quality parameters and the network signal quality.

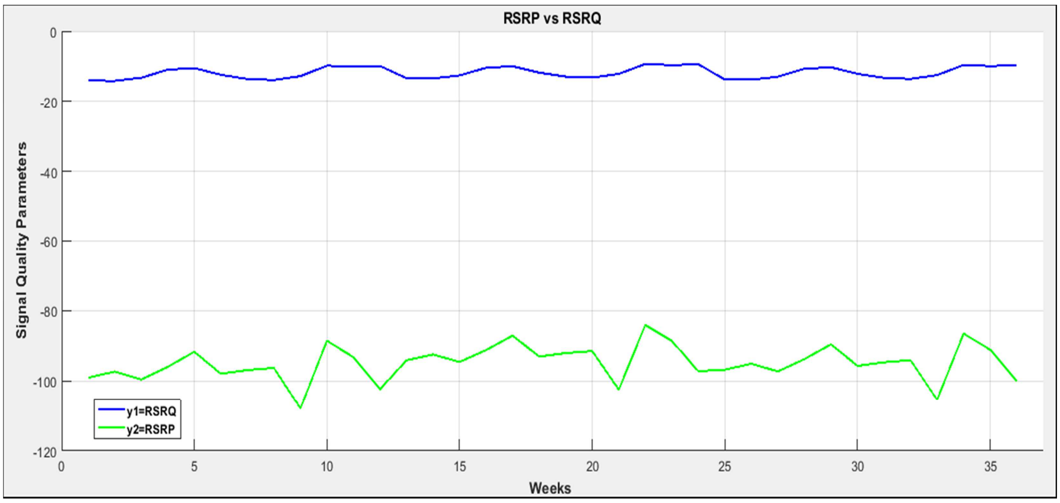

Figure 3. Radio quality parameter (RSRP) and Signal quality (RSRQ) performance chart.

The mean signal quality and referenced signal receive power during the test period was -11.83 and -94.87 respectively. The RSRP has a very weak relationship of 0.183 with the overall system transmitted quality. Hence, eqn. 8 estimates the signal quality given the Signal Quality Parameter (SQP) where e_i 's are the errors.

$$RSRQ = \beta_0 + (\beta_1 * SQP) + 1/n(\sum_{i=1}^{n} e_i) \quad (8)$$

$$RSRQ = 1.352 + (0.139 * RSRP) \quad (9)$$

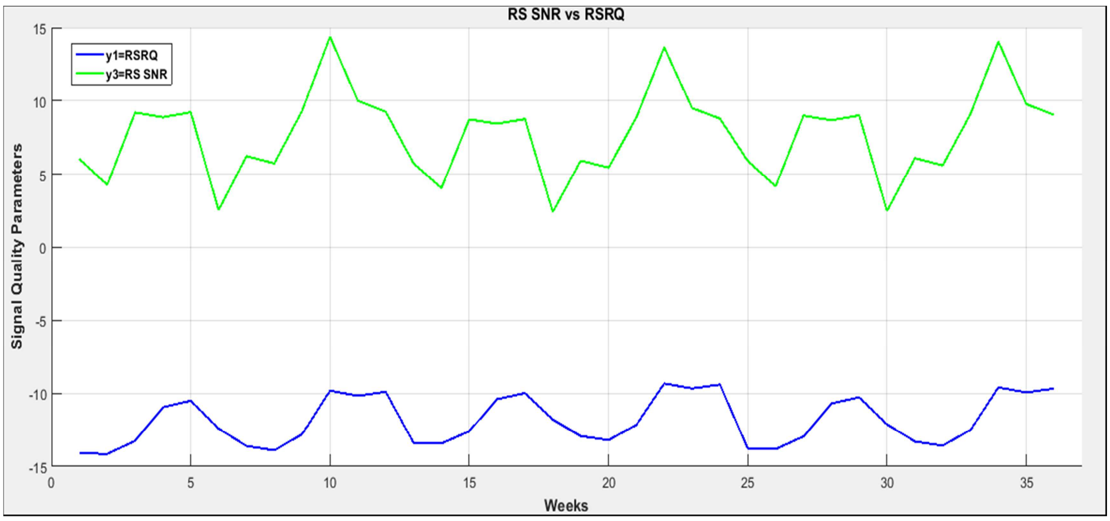

Figure 4. Radio quality parameter (RS SNR) and Signal quality (RSRQ) performance chart.

The mean signal quality and referenced signal signal-to-noise ratio during the test period was -11.83 and 7.73 respectively. There is a positive relationship of 0.464 between the RS SNR the overall system transmitted quality. Such that any form of improvement on RS SNR value improves the system's quality performance. Using eqn. 8,

$$RSRQ = -14.793 + (0.383 * RS\ SNR) \quad (10)$$

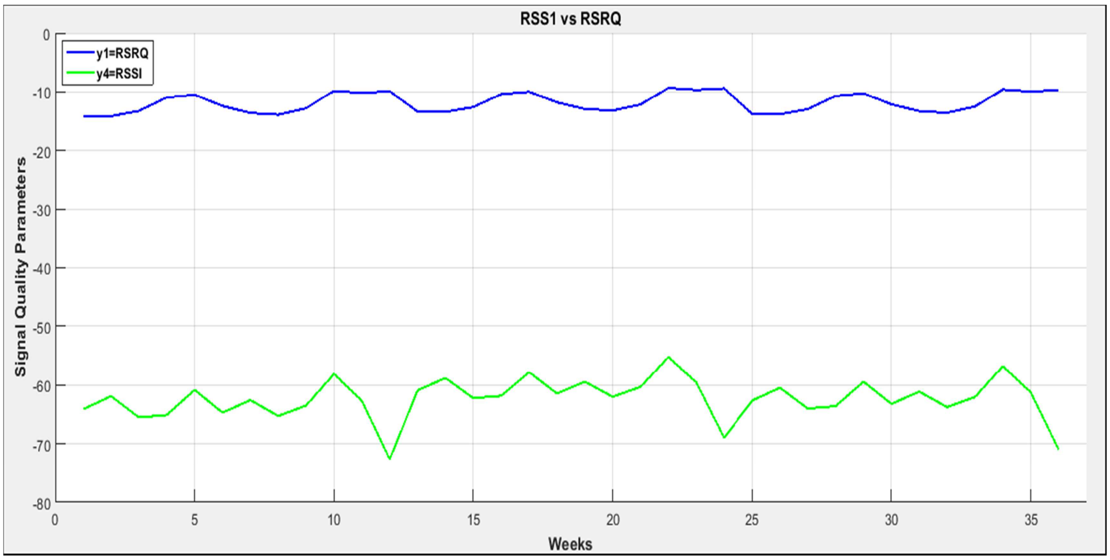

Figure 5. Radio quality parameter (RSSI) and Signal quality (RSRQ) performance chart.

The mean signal quality and referenced signal strength indicator during the test period was -11.83 and -62.36 respectively. There is no relationship between the RSSI and the overall system transmitted quality.

$$RSRQ = -10.833 + (0.016 * RSSI) \quad (11)$$

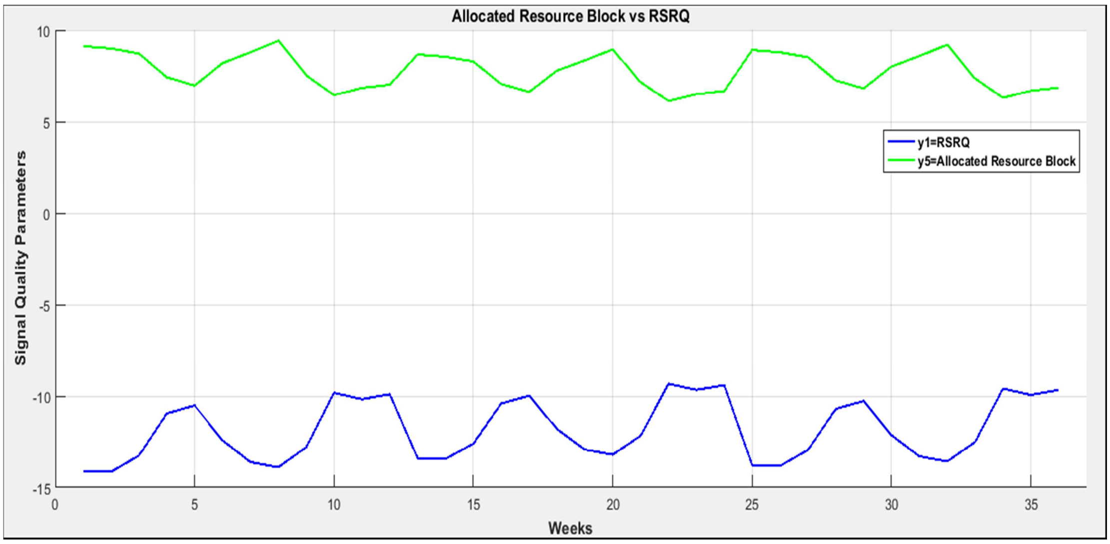

Figure 6. Radio quality parameter (Allocated Resource Blocks) and Signal quality (RSRQ) performance chart.

The mean signal quality and allocated resource block during the test period was -11.83 and -8 respectively. There is a very strong relationship of 0.911 between the allocated resource blocks and the overall system transmitted quality. An increase in the allocated resource block will improve the network signal quality.

$$RSRQ = -3.467 + (1.602 * PRBs_{all(i)}) \quad (12)$$

3.2. Research Target

LTE channel bandwidth is ≥ 3MHz and applying eqn. 7, the least requested physical resource block is 15RBs. From the drive test log-files and parameters extracted, the signal quality of the considered operator in the first two weeks particularly operator A requires optimization. The research aims at improving network signal quality through the allocation of resource blocks.

4. Result and Analysis

The drive test log-files show some degree of relationship between the signal quality and the allocated resource blocks. When there is an increase in the number of allocated resource block, the reported signal quality from the UE improves. Figures 7 and 8 shows the signal quality performance when the allocated resource block is increased by 1 and 2 units respectively with the same radio environment from the log-file collected and discussed in section 3.1

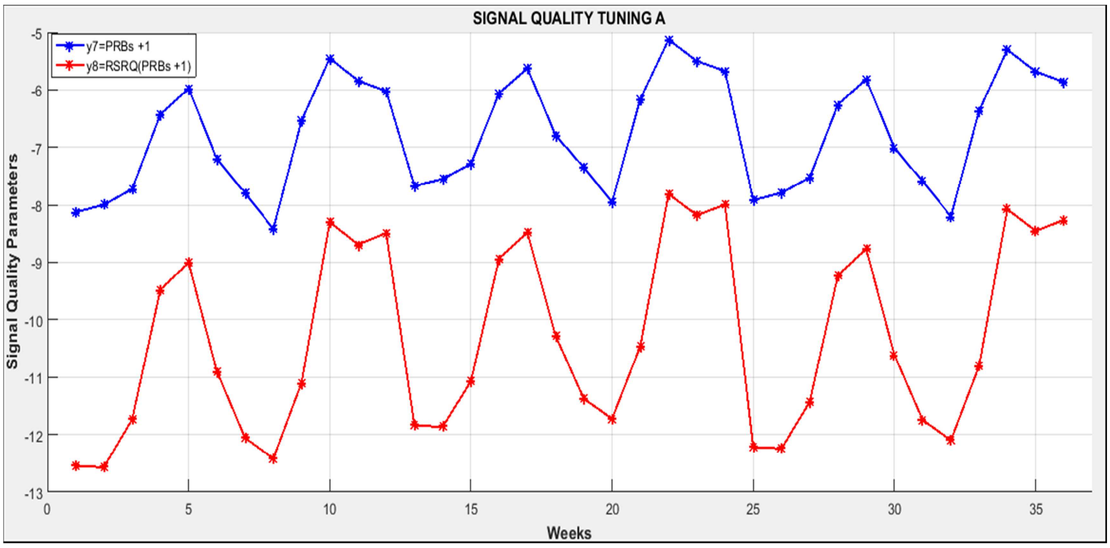

Figure 7. Signal quality parameter performance chart.

$$RSRQ_{Tunning\ A} = -0.665 + (1.423 * PRBs_{all}) \quad (13)$$

A unit increase in the allocated resource block gives a mean signal quality of -10.29.

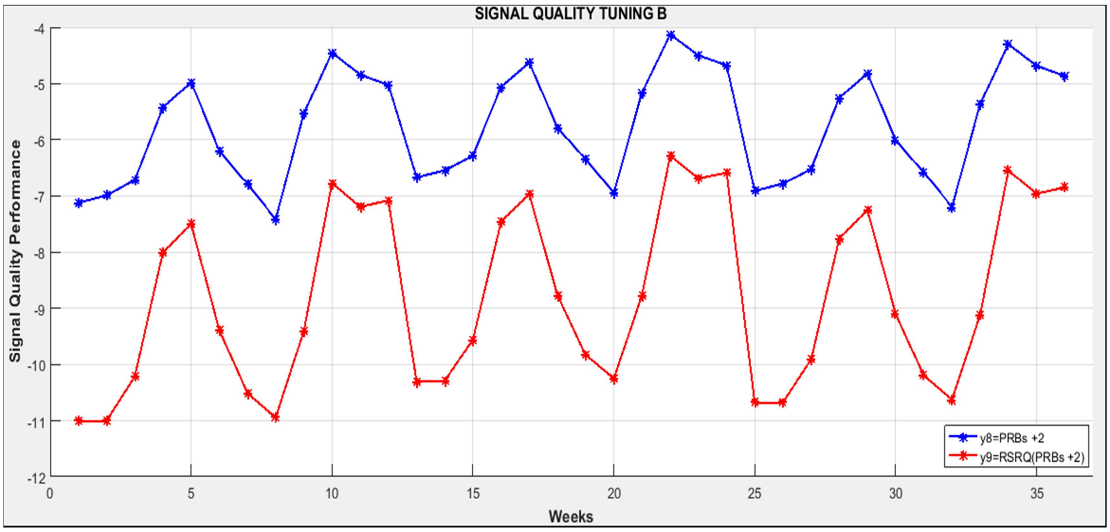

Figure 8. Signal quality parameter performance chart.

$$RSRQ_{Tunning\ B} = -0.628 + (1.413 * PRBs_{all}) \quad (14)$$

Increasing the allocated resource block by 2 units gives a mean signal quality of -8.77.

With the above, it is conclusive to say that an increase in the allocated resource block size will lead to an improved network signal quality. From the test performed and discussed in section 3.1, the maximum allocated resource block is 9 and with an increase of 2 units, the proposed allocated resource block is 11 < 15 the available resource block.

5. Conclusion

In the Nigerian telecommunication industry, LTE (4G) technology is the latest deployment in some urban areas to cushion the effect of low data throughput during data traffic sessions resulting from poor network signal quality. The research considered the importance of resource blocks allocation during data traffic sessions as it affects the network signal quality performance. Result showed a network signal quality improvement of 13.02% and 25.87% for 1 and 2 units rise in the allocated resource blocks respectively.

Hence, designing a more robust resource block scheduling algorithm or allocation technique should be considered in future research.

Competing Interests

The authors declare that they have no competing interests.

Original Manuscript

The authors declare that the manuscript is original and the data contained herein are authentic

The authors assure that all data used for the manuscript are properly acknowledged and the manuscripts is only submitted to this journal.

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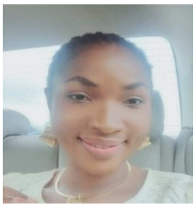
Biography



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