International Journal of Advanced Research in Physical Science (IJARPS)
Volume 1, Issue 6, October 2014, PP 44-55
ISSN 2349-7874 (Print) & ISSN 2349-7882 (Online)
www.arcjournals.org

Maximising Coverage and Capacity with QOS Guarantee in GSM Network by Means of Cell Cluster Optimization

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Abstract: *Monitoring, performance evaluation and optimization exercise after service rollout is to correct the expected errors in network planning and to achieve benefits such as improved network capacity, enhanced coverage and quality of service. This paper exposes the cell cluster performance evaluation and optimization carried out on a commercial GSM (Global System for Mobile Communication) network operating at Onitsha and environs, Anambra State, south-East Nigeria. The performances of the network was analysed using specific key performance indicators (KPIs) such signal coverage rate, coverage reliability, TCH congestion rate, carried traffic, throughput capacity, RxQual, and SQI before and the optimisation exercise. The results show that after optimization process, the network coverage, capacity and quality-based KPIs were greatly improved.*

Keywords: *Cell cluster optimisation, Network capacity, Network capacity, Service quality.*

1. INTRODUCTION

The wireless cellular network services are growing fast and are coupled with an ever increasing high bit rates and multimedia applications that inevitably translate into demands for better coverage and capacity of the networks to guarantee Quality of Services (QoS) to end users. The global wireless cellular subscriptions stand at 6.8 billion users in 2013 with global penetration rate of 96%; 128% penetration rate in developed countries and 89% in the developing countries [1]. According to ERRICSSON Mobility Report [2], total mobile subscriptions are expected to grow from 6.8 billion in first quarter, 2014 to 9.2 billion by the end of 2019. Also, in this report, global mobile broadband subscriptions are predicted to reach 7.6 billion by 2019 and will gain an increasing share of the total mobile subscriptions over time, with GSM/EDGE subscriptions-only represent the largest share of the mobile subscriptions. In developing markets, GSM/EDGE will continue to represent a large share of total mobile subscriptions. This is because new, less affluent users in developing markets will likely choose a low-cost mobile phone and subscription. In addition, it takes time for the installed base of phones to be upgraded. GSM/EDGE networks will also continue to be important in complementing WCDMA/HSPA and LTE coverage in all markets [2].

Currently, the tremendous growth and subscription of wireless cellular network services is forcing network operators worldwide to redesign and optimize their network from time to time. This is to enable them to handle the ever increasing traffic demand while considering the possibility of reducing network deployment costs. Also, since the availability of radio bandwidth is limited, the available radio frequency (RF) spectrum has to be used efficiently and effectively to address its coverage and capacity needs.

Therefore, to effectively cater for subscribers' demand, the radio network optimization approach must be geared towards maximizing the coverage and capacity need with guaranteed Quality of Service (QoS).

In this work, a commercial GSM telecom service provider operating in South-East Nigeria is used as a case study and the focus is geared towards evaluating the performance of the mobile cellular radio network in terms of coverage, capacity and quality, before and after cell cluster optimization exercise. For commercial reasons, I am advised not to disclose the targets GSM telecom operator's name. Thus, the selected operator or GSM service provider will hence forth be referred to as Operator A in this paper.

2. Problem Statement

Operator A is one independent, middle range communication company that has been providing wireless mobile service from more than14 years. It is one of nation's leading Telecommunication Company which was lunched with a reputation of providing good and efficient service. Specifically, Operator A launched GSM mobile services in May, 1999 for the first time in Nigeria. The operator's network is expanded all over the country and it covers almost all the major cities as well as suburban and rural areas. The customers' rate of subscription to this Operator A telecom network is almost greater than a double every year. With the increase of the subscriber base, customers' complain has also increased. Frequent call drop, poor network coverage and unsatisfactory customer care support are the common issues faced by the subscribers (e.g. see our previous work in [3] for a similar report). As a result, customer's dissatisfaction is increasing and complains against the network are also increasing, which in turn leads to low customers loyalty and high churn rate. In fact, presently, Operator A is having a public pressure to fulfill the demand of a prepaid mobile which is popular throughout the country. Generally, in the following cases, a communication network should be optimized:

- The network quality decreased seriously and there are many complaints from subscribers.
- New network or expansion on existing network.
- An event occurs suddenly which affects the network performance seriously.
- The number of subscribers increased and affects the network performance gradually.

However, how to carry out a proper network optimization to improve the end users satisfaction rate with the good service quality is the real challenge.

3. Background Concept of Investigated KPIs in the Study

The three leading elements of any mobile network are capacity, quality and coverage. Consequently, during network optimisation, the main goal to achieve is to maximise coverage and capacity while meeting the QoS as illustrated in figure 1.

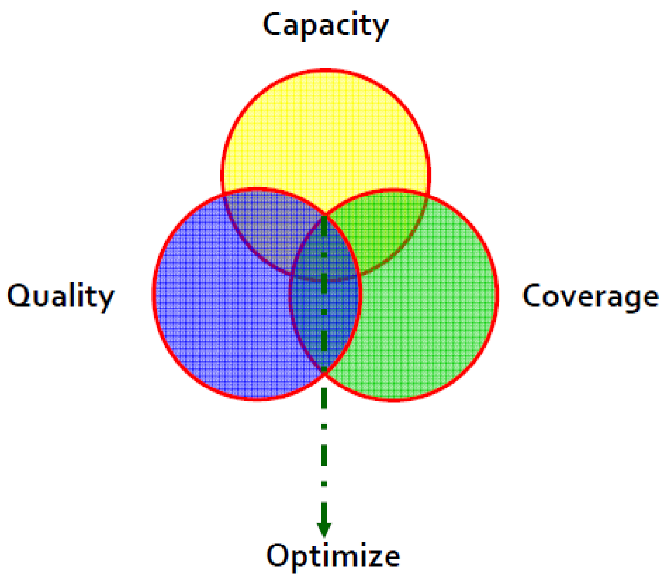

Figure 1. *Concept of network optimisation [7]*

4. Coverage-Based KPI'S

Coverage is simply the distance that a wireless network can transmit data at a given data rate subject to the regulations in its frequency band and the standard under which it operates. Coverage analysis gives an estimation of the resources needed to provide service in the deployment coverage area with the given system parameters. The coverage area of a cell is denoted as the area where the received broadcast channel (BCCH) power does not fall under the receiver sensitivity of the mobiles. The receiver sensitivity is given by the minimum signal level where GSM technology is still able to operate and the coverage threshold has to be well defined to exceed the required quality criteria. Coverage in GSM network stands for the geographical area covered by the network from which mobile is accessible to the network.

In this paper, my focus is on the following coverage-based KPIs:

- **Signal Coverage Rate**

Technically, coverage performance is measured with the parameter Received Signal Level (RxLev) with units in dBm. The availability of service coverage for drive test is defined that a network must achieve a minimum of -95dBm of signal strength. Performance is based on the percentage of calls that have the minimum signal strength required [4]. Signal coverage rate is computed by [5]:

$$Coverage\ rate = \frac{No\ of\ samples\ having\ signal\ strength \geq -95dBm}{Total\ samples}\ x\ 100 \qquad (1)$$

- **Service Coverage Reliability**

A minimum coverage quality within a cell is achieved when the received signal power has a certain level in at least 90%-95% of the coverage area. This coverage quality parameter is often referred to as the coverage reliability. The probability that the received signal power will exceed a certain value can be calculated from the cumulative density function.

5. CAPACITY-BASED KPI'S

The capacity of a given network is measured in terms of the subscribers or the traffic load that it can handle. The capacity of a cell gives the number of users or simultaneous calls (in the case of speech service) the links can handle. Here, the number of calls is independent of the coverage and can be controlled by the number of carriers the operator allocates to the cell. Hence, carrier assignment is a key parameter for efficient GSM network design and has to be handled carefully to ensure that the base station can cope with the offered traffic on its whole service area. GSM is worldwide standard allows users of different operators to connect and to shares the services simultaneously. The capacity of a cell/cluster can be studied by running reports on the following KPIs which includes: Carried traffic, Throughput capacity, TCH congestion and blocking, SDDCH congestion and blocking, etc. In this paper, the focus is on following:

- **Traffic Channel (TCH) Congestion**

Traffic channel (TCH) congestion is one of the most important performance indicators in GSM networks. Congestion is defined as failure to establish connection between caller and receiver after a call attempt has been made even when service coverage is good. The minimization of TCH congestion corresponds to the maximization of the number of subscribers that can be served. This leads to increase network capacity since many subscribers as possible should be able to access the network without service denial due to resource availability. A reduction in traffic congestion indicates that radio network resources are available to cater for more users and this automatically translate to increase in the network capacity since many subscribers as possible should be able to access the network without service denial due to resource availability.

- **Carried Traffic**

A suitable measure of traffic capacity is the carried traffic. The carried traffic gives the average established number of calls in the system. From its name, the carried traffic reflects the proportion of calls that is handled by the system (not blocked). The relationship between the carried traffic and the blocking ratio (i.e., the number of blocked calls to the total number of carried calls) is given by the following expression:

$$\text{Carried traffic} = \text{Offered traffic} \times (1 - \text{Blocking ratio}) \qquad (2)$$

- **Throughput Capacity**

Another major performance indicator that is evident to customers is throughput. Throughput data reflects the effective network capacity. Throughput is the rate at which data is expected or received over a period of time. Simply, it is the data rate achieved against expectations.

6. QUALITY-BASED KPIS

In any operational communication network, QoS is one of the important concerns from both customers and providers point of view. It is a measurable set of parameters that define the level of service that a service provider can be accountable. In the ITU-T Recommendation E.800 [6], QoS is defined as the collective effect of service performance, which determines the degree of satisfaction of a user of the service. QoS can also be defined as the capability of the cellular network providers to provide a satisfactory service to end users. The quality of a radio network can be evaluated by examining the KPIs such as: Signal quality (RX QUAL), Speech quality index (SQI), Dropped call ratio (SDCCH and TCH), MS and BTS power levels, etc. In this paper, the focus is centered on following:

- **Signal quality (RxQual)**

RxQual performance is defined as quality of voice transmission while subscribers are using their mobile phones. Excellent signal quality performance would guarantee no missing words or “ping pong” sound. Technically, this parameter is a measurement of Bit Error Rate (BER) of the signal received by subscribers. Bit Error Rate is then converted to a value ranging from 0 to 7 as shown in table 1. In TEMS tools, the RxQual values are calculated in the same way as values reported in the measurement report sent on the uplink channel to the GSM network.

Table 1. *BER to RXQual Conversion*

Rx Qual.	Bit Error Rate (BER)
0	BER < 0.2%
1	0.2 % < BER < 0.4%
2	0.4 % < BER < 0.8%
3	0.8 % < BER < 1.6%
4	1.6 % < BER < 3.2%
5	3.2 % < BER < 6.4%
6	6.4 % < BER < 12.8%
7	12.8 % < BER

- **Speech Quality Index Performance**

Speech Quality Index (SQI) expresses the degree of voice distortion caused by the GSM radio link transmission, and it is calculated by weighting a number of radio link parameters including Bit Error Rate (BER), Frame Error Rate (FER), handing over, Discontinuous Transmission (DTX) and speech coding mode (speech codec), etc. It is specific only to the TEMS family of drive testing/field testing tools. SQI aims to provide a reasonable estimate of the voice quality, as perceived by a human ear.

7. METHODOLOGY

Optimization process can be seen as a very involving process as a large number of variable are available for tuning impacting different aspect of the network performance. The process involves the use of various methods to maximize the system performance by optimally configuring the network and utilizing its resources. To simplify this process, a step by step method is required. The optimization method adopted for this research is cluster optimization and it involves testing multiple base stations in a single cluster and the performance of good relationship between the BTS. The Cluster optimization process is summarised in the figure 2 and the details are presented as follows:

1. Initial Drive test:
2. Drive test analysis
3. Change proposal made

4. Changes Implemented
5. Verification of changes implemented by carrying out another Drive test Step
6. Do the analysis of the new drive test.
7. Any positive change? If yes make a cluster report of the whole are /if no, go back to step III
8. Cluster report of the whole region.
9. Step IX. Move to next cluster area

Network optimisation process is initiated by collecting and analyzing data from drive testing on selected routes and also data from networks nodes by using customized tools which include a Vehicle, Global Positioning System, and Laptop equipped with TEMS software and MapInfo, Sony Ericsson TEMS pocket Mobile Phone, Dongle, Data Card, Compass and Inverter.

Initial test drives is conducted when an installed base station have been completed to determine the initial data of a BTS and also to demonstrate the feasibility of a network level. The initial drive test is a part of data collection exercise that carried out on pre-defined routes in pre-defined cities using the above standard drive test tools and at network level. The Drive test routes and the cities was discussed and agreed before the start of the task.

The result from the initial drive testing is used as the reference level for verification of the performance of the radio network.

After collection, the log-file was analyzed. Possible problems are identified within the network. Proper optimisation proposals are then made to improve the network performance.

Implementation of proposals involves tuning the engineering antenna parameters such as the antenna height or tilt, performing parameter audit or simply changing transceivers within one or two base transceiver stations within the network of operation.

After implementing the recommended changes, another post drive test exercise is performed to ascertain the effect of the changes in the network parameters. Post drive testing is carried out under similar traffic conditions as before, route, weekday and time of the day for the tests similar to those of the pre drive tests. The same set of drive test routes, as used in the initial drive testing, is also used for the post drive Testing. The post drive test cluster report will include the same reports as the initial drive Test.

After each optimization exercise, the Key Performance Indicators (KPIs) obtained are analyse and checked against the desired threshold.

In this paper, we specifically engaged the three leading elements of any mobile network which are capacity, quality and coverage. This in turn allowed us to determine the general network performance. This exercise took place after some key problems such as poor transmission line performance, reduced power output, cell coverage degradation, coverage hole, over shooting, cell imbalance, poorly connected feeders, increased interference and among others were identified across the studied GSM cell clusters. The following recommendations were proposed and implemented on the network to maximised coverage and capacity with QoS guarantee across the three investigated cell clusters:

- Addition of missing adjacent cells in each cell cluster
- antenna azimuth and tilt changes
- BTS Equipment/Filter change
- Re–tuning of interfered frequencies
- Adjustment accessibility parameters
- power parameters changes
- Increase the reuse distance between the co-frequency and adjacent frequencies.

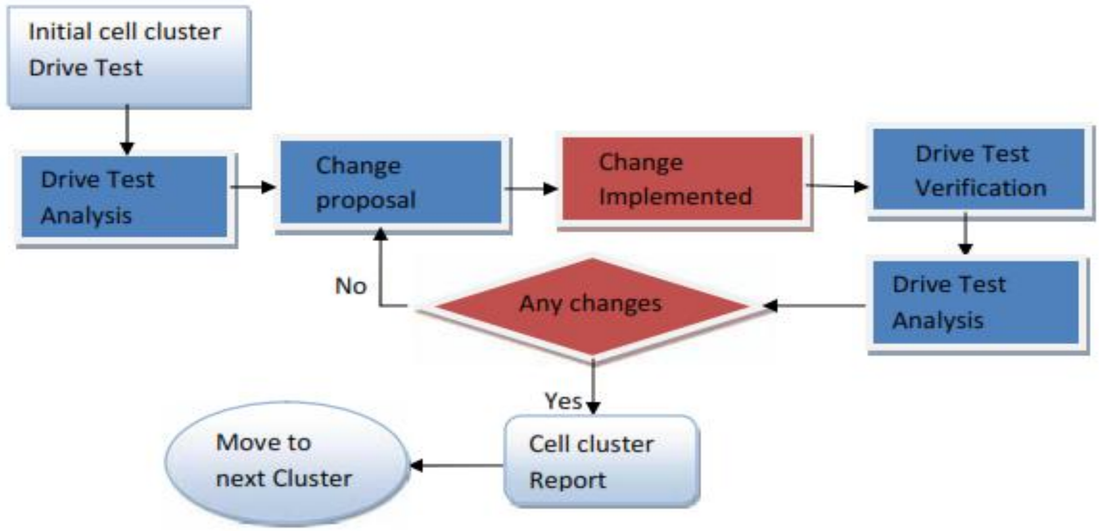

Figure 2. *Network Optimization flowchart.*

8. THE INVESTIGATED ENVIRONMENTS

This study was carried out with the need to enhanced end user satisfaction as desired by one of the leading cellular network service providers in South East, Nigeria. The operator recently engaged one of the equipment vendors in the country for BTS swapping across so some selected cities in Asaba Area, South East Nigeria. To carry out the swap drive test experiment, the study area was divided into three clusters. Each cluster has 26-40 sites on Air.

9. RESULTS AND DISCUSSION

The performances of the network in terms of signal coverage rate, coverage reliability, TCH congestion rate, carried traffic, throughput capacity, RxQual, SQI and handover success rate for the investigated cell clusters are as shown figures 3-15. As summarised in table 2-4, the results show that the network coverage, capacity and quality-based KPIs were greatly improved after optimization process.

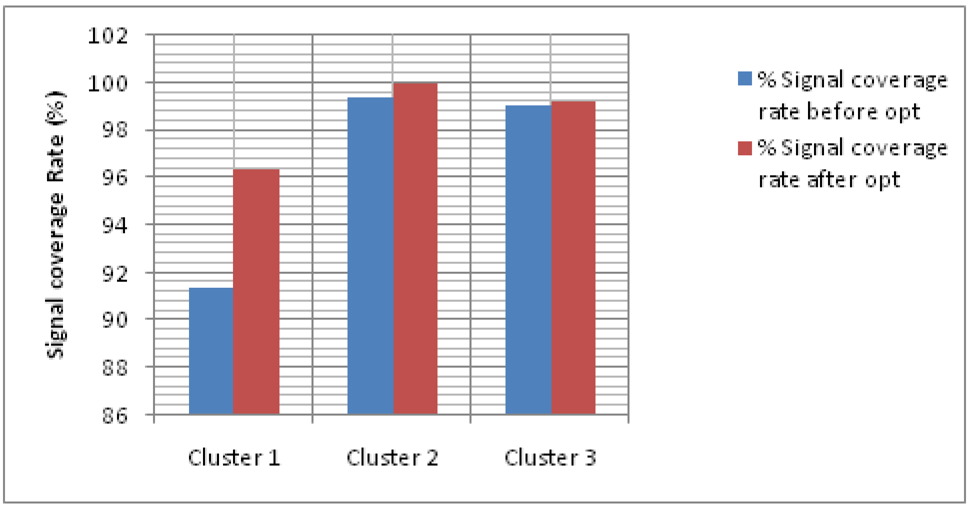

Figure 3. *Signal coverage performance before and after optimization in cluster 1-3*

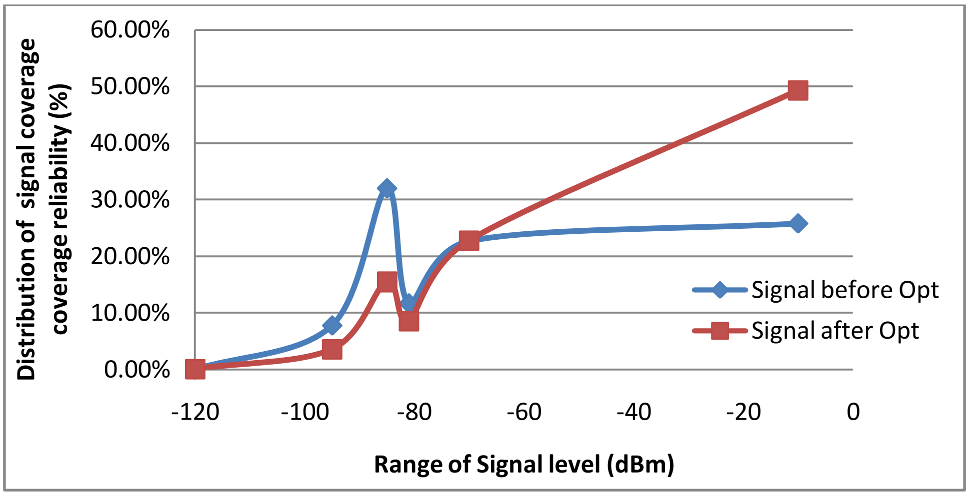

Figure 4. *Signal coverage reliability before and after optimisatiom in cluster 1*

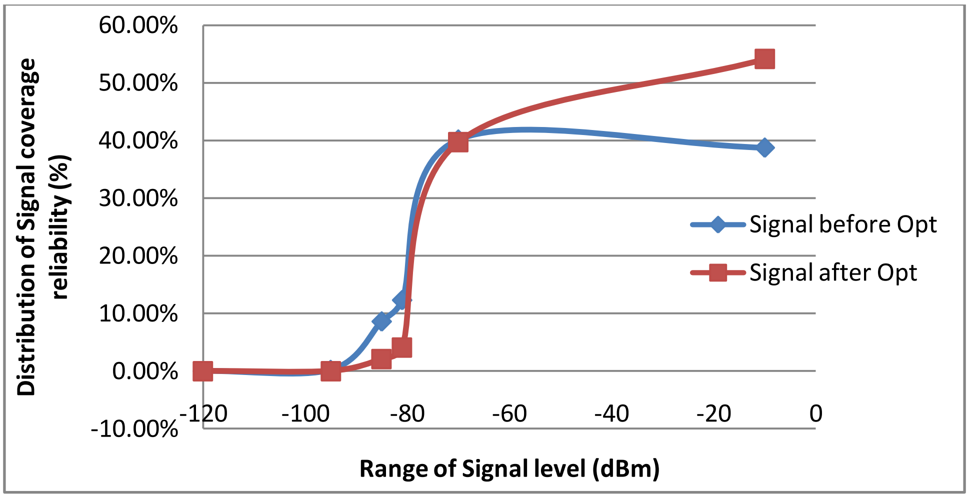

Figure 5. *Signal coverage reliability before and after optimization in cluster 2*

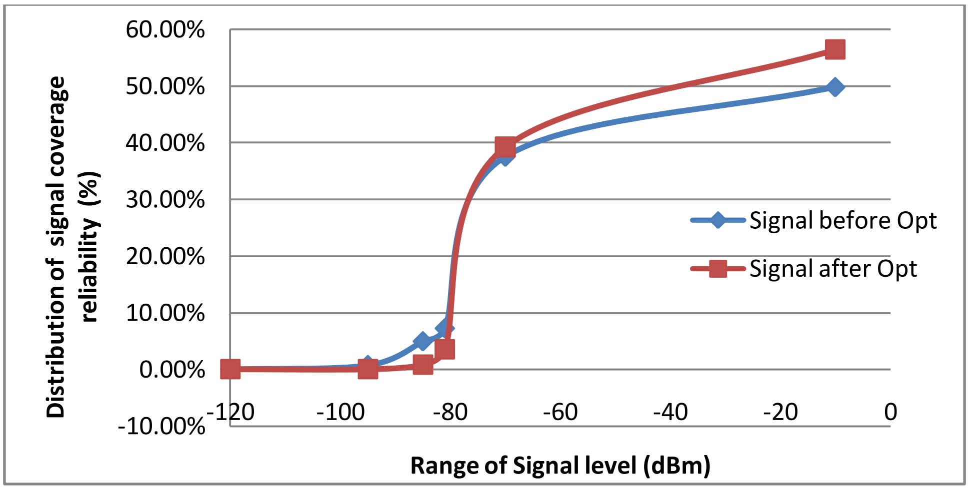

Figure 6. *Signal coverage reliability before and after optimization in cluster 3*

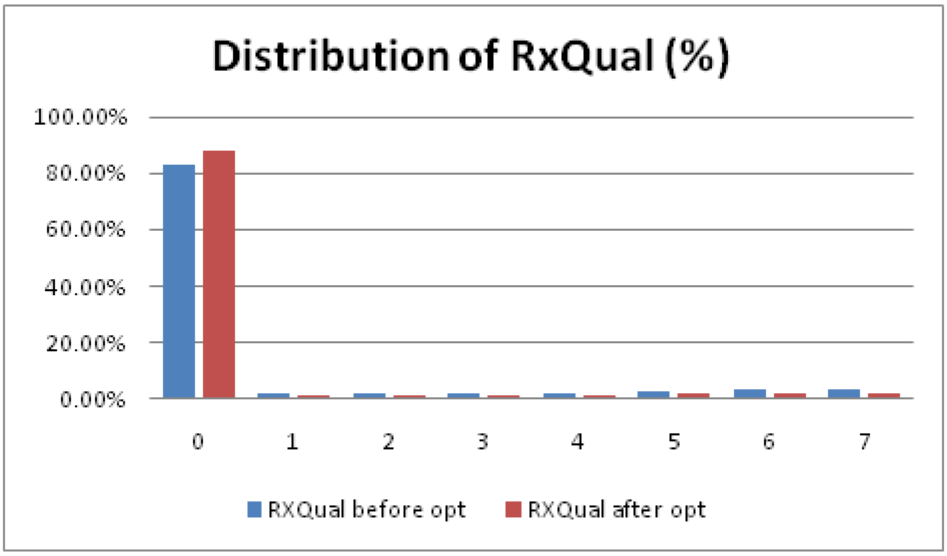

Figure 7. *Signal level quality before and after optimization in cluster 1*

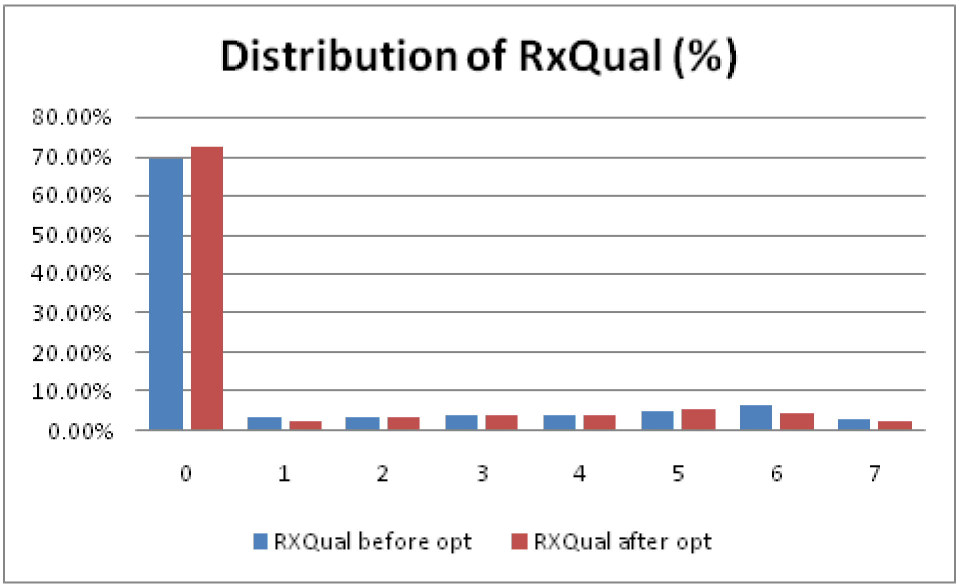

Figure 8. *Signal level quality before and after optimization in cluster 2*

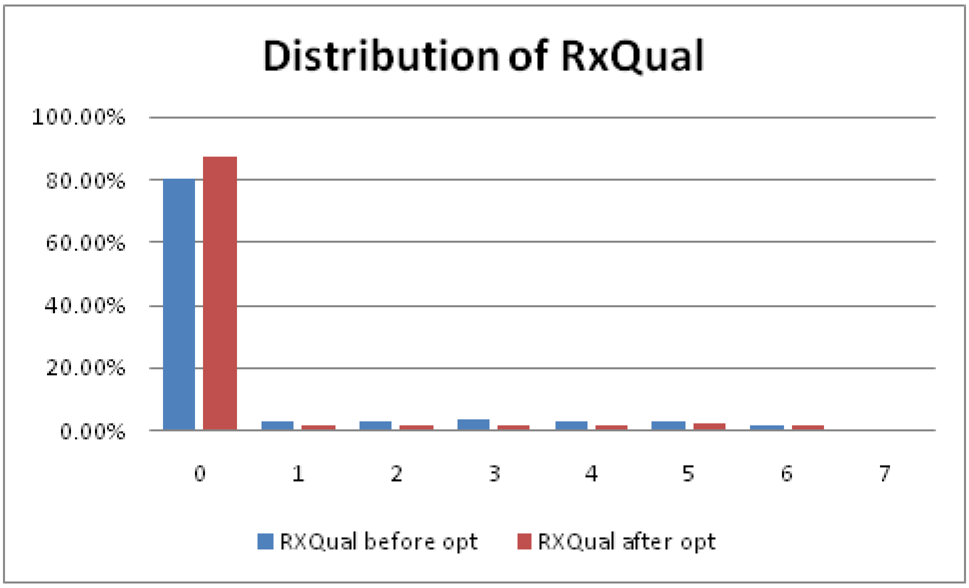

Figure 9. *Signal level quality before and after optimization in cluster 3*

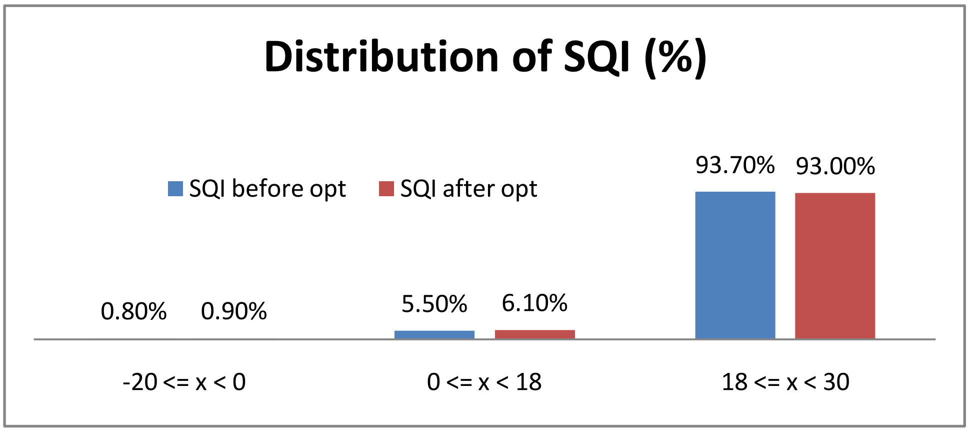

Figure 10. *Speech quality performance before and after optimisatiom in cluster 1*

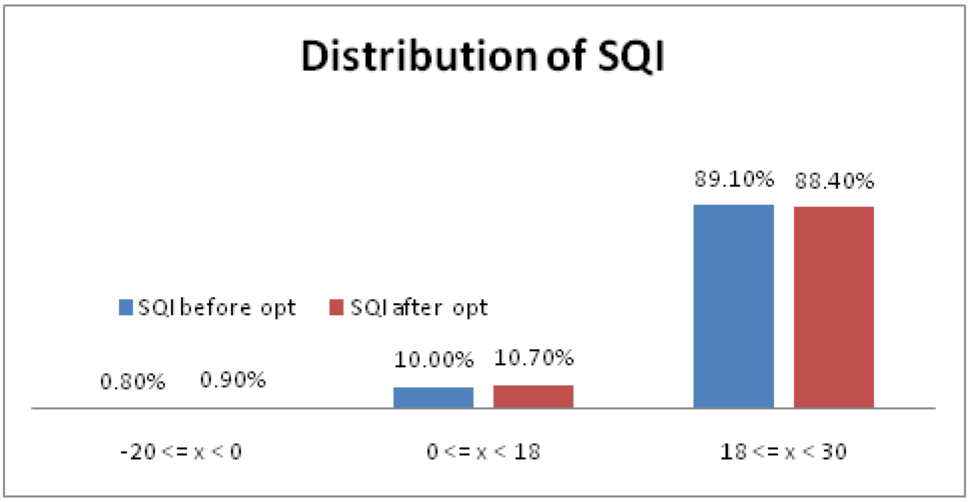

Figure 11. *Speech quality performance before and after optimisatiom in cluster 2*

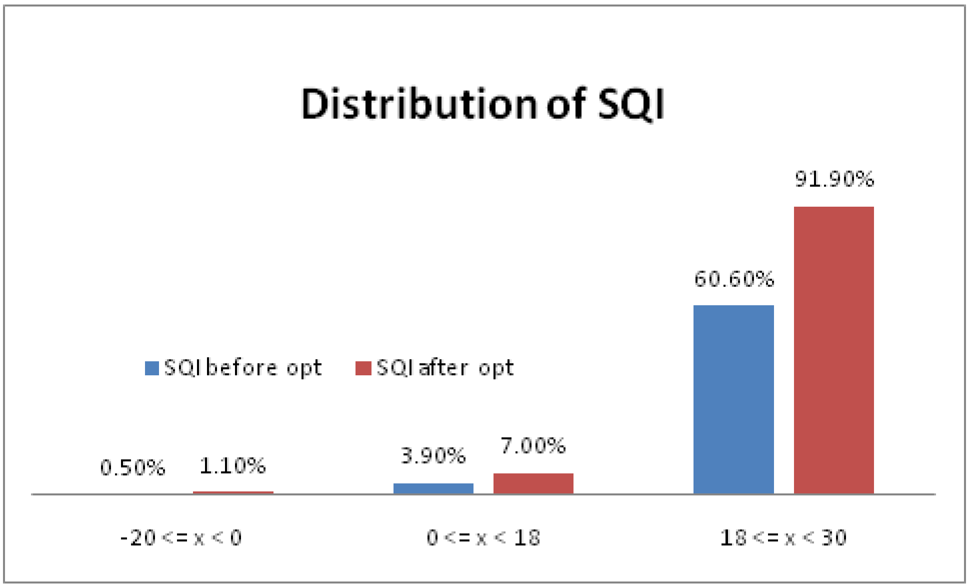

Figure 12. *Speech quality performance before and after optimization in cluster 3*

Figure 13. *Network capacity performance with Carried traffic before and after optimization in cluster 1-3*

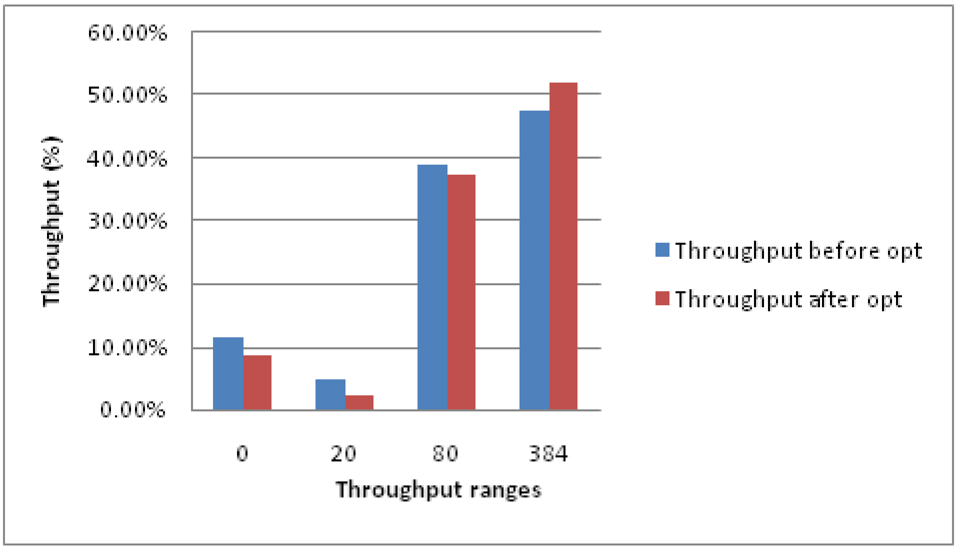

Figure 14. *Throughput performance before and after optimization in cluster 1*

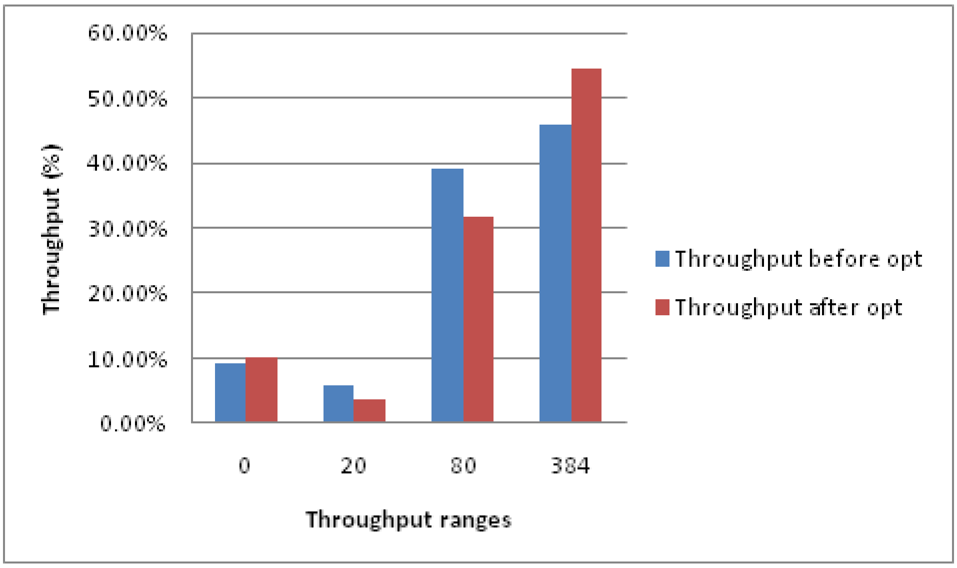

Figure 15. *Throughput performance before and after optimisatiom in cluster 2*

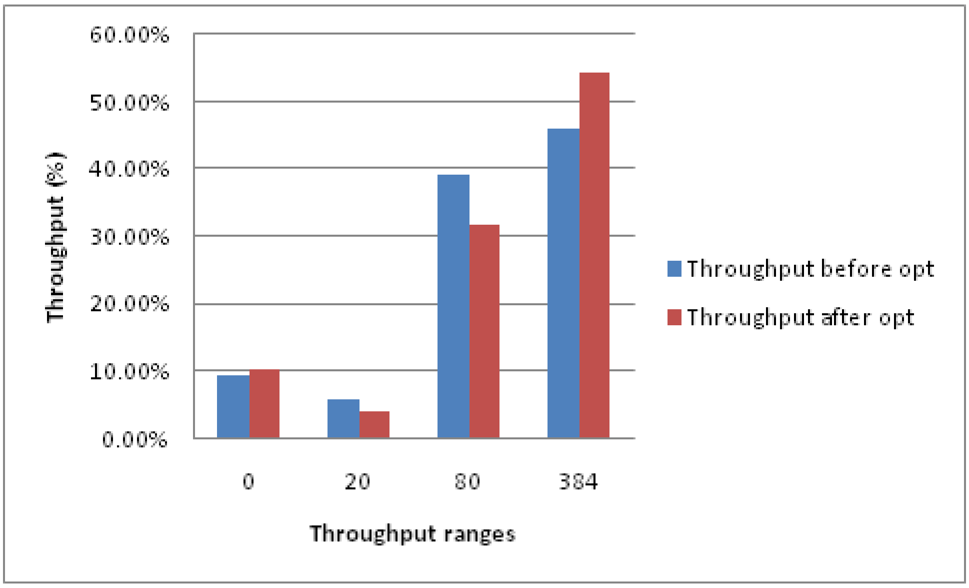

Figure 16. *Throughput performance before and after optimisatiom in cluster 3*

Table 2. *Network coverage, capacity and quality before and after optimisatiom in cluster 1*

Category	Indicators	Pre drive test	Post drive test
Coverage	**Rx Signal coverage rate > -(95dbm)**	91.38%	96.34%
	Coverage reliability	92.20%	96.30%
Capacity	**Traffic Congestion**	8.33%	0.00%
	Carried Traffic	82	103
	Layer Throughput	73.74kbits/s	77.07kbits/s
Quality	**RxQual_sub <5**	87.40%	93.70%
	Rx Signal coverage rate > -(95dbm)	91.38%	96.34%

Table 3. *Network coverage, capacity and quality before and after optimization in cluster 2*

Category	Indicators	Pre drive test	Post drive test
Coverage	**Rx Signal coverage rate > -(95dbm)**	99.41%	99.95%
	Coverage reliability	99.70%	100.00%
Capacity	**Traffic Congestion**	5.88%	0.00%
	Carried Traffic	99	104
	Layer Throughput	87.54kbits/s	102.65kbits/s
Quality	**RxQual_sub <5**	81.20%	83.00%
	Rx Signal coverage rate > -(95dbm)	81.35%	89.70%

Table 4. *Network coverage, capacity and quality before and after optimisatiom in cluster* 3

Category	Indicators	Pre drive test	Post drive test
Coverage	**Rx Signal coverage rate > -(95dbm)**	99.04%	99.21%
	Coverage reliability	99.40%	100.00%
Capacity	**Traffic Congestion**	6.25%	0.00%
	Carried Traffic	87	105
	Layer Throughput	85.06kbits/s	92.38kbits/s
Quality	**RxQual_sub <5**	9.30%	8.80%
	Rx Signal coverage rate > -(95dbm)	92.98%	96.99%

10. CONCLUSION

The optimization process is a long term process that requires the study of the network situation and the provision of solutions to weak features sorted out first, without a hasty implementation, to attain a desirable network performance threshold. In this paper, we present the results of network performance evaluation and optimisation of a GSM network on cell cluster-basis, in Asaba region, South East Nigeria. We employ a specific key performance indicators such signal coverage rate, coverage reliability, TCH congestion rate, carried traffic, throughput capacity, RxQual, and SQI to examine overall performance of the GSM network. This in turn allowed us to determine the end user satisfaction rate and the general network performance. The results show that after optimization process, the network coverage, capacity and quality-based key performance indicators were greatly improved.

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