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IMPROVING THE SIGNAL RECEPTION OF 4G NETWORK IN KOGI STATE USING AN INTELLIGENT BEAM FORMING ALGORITHM

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Abstract

This study presents improving the signal reception in 4G network using an intelligent beam forming algorithm. The study was embarked on to address the limited signal strength issues recorded in many localities all over the world due to technical challenges attitude to 4G network like congestion, overload, fading, loss etc. To solve this, characterization was performed at the Omala 4G cell and the result showed that areas which are 150m away from the cell suffer poor signal strength. To solve this problem, beam forming algorithm was developed and deployed on the 4G cell using Matlab. The result when simulated showed that the quality of service was improved from -102dBm averagely in the characterized to -90dBm which is an 11.7% improvement in service quality and presented good signal strength according to the Nigerian Communication Commission Standard (NCC) for 4G network.

Keywords: Beam forming, signal reception, quality of service, 4G cell, Matlab

I. INTRODUCTION

The internet has improved the way we access and transmit data and information around the world, then the advancement of the internet technology from 1G to 4G LTE networks has further enhanced the speed, reliability, and capacity of what can be done with data over the around the world through the internet. 4G is short for Fourth (4th) Generation Technology.4G Technology is basically the extension in the 3G technology with more bandwidth and services offers in the 3G. But at this time nobody exactly knows the true 4G definition. The expectation for the 4G technology is basically the high-quality audio/video streaming over end-to-end Internet Protocol. If the Internet Protocol (IP) multimedia sub-system movement achieves what it going to do, nothing of this possibly will matter (Bhavesh, 2018).

The 4G network was developed to improve user experience and make accessibility of information over the internet faster and more reliable but the development and application of this technology is faced with common challenges which includes; i) Security and Privacy, ii) Quality of Service (QoS) and iii) Complex Architecture etc., (Hassan, 2010;

Saman and Muhammad, 2010; Hadji, 2010). But the most common and challenging of them all is the quality-of-service challenge due to how it can be affected by user density and location proximity. Therefore, optimizing the performance of 4G network can be effective by solving this QoS challenge.

There are various algorithms that can be applied to enhance the QoS of 4G wireless networks some of the techniques are i) Whale Optimization algorithm, ii) Genetic Algorithm iii) Beamforming Algorithm, iv) Artificial Neural Network (ANN) etc., and some of these algorithms has proved to be effective in improving the rate of optimization of the delivery quality overtime but has their limitations.

According to Qi et al., (2019) Beamforming algorithm is an array of signal processing algorithm with an antenna in an area of wireless communication which is aimed at effectively estimating the signal of interest (SOI) in the presence of noise and interference employing in the array of antennas which are located at different spatial positions according to some specific geometry. Beamforming algorithm can be subdivided into two main groups, fixed beamforming and adaptive beamforming. In fixed beamforming, the interference is mitigated but not suppressed, while in adaptive antenna beamforming, it requires the adoption of signal processing algorithm in order to steer the main love towards the desired direction and to suppress the undesired sources, which in turn leads to optimal performance of the network.

This paper will adopt the adaptive beamforming algorithm approach for the optimization of the 4G LTE network QoS because of its ability to adjust the antenna according to the network strength so as to provide effective and reliable network coverage to the users. To this end, systematic review was conducted to discuss the previous works on quality of service in 4G as shown in table 1;

Table 1: LITERATURE REVIEW

Author	**Topic**	**Work Done**	**Research Gap/ Limitations**
Tchao et al. (2018)	Performance Evaluation of a Deployed 4G LTE Network	Presented the performance of the newly deployed 4G LTE network in the 2600 MHz band operating under varied MIMO antenna configuration.	40Mbps throughput achieved which can be improved
Subuh et al. (2020)	Optimization of 4G LTE (Long Term Evolution) Network Coverage Area in Sub Urban	Optimization of the coverage area of 4G LTE network by using the physical tuning method to adjust the antenna tilt, azimuth antenna power.	Increased the Signal Interference Noise Ratio (SINR) from 4.87% to 10.16%

Egena (2017)	Planning and Optimization of 4G/5G Mobile Networks and Beyond	Application of Collaborative Resource Allocation Algorithm (CRAA) and Memetic-Bee-Swam Stile Location-Allocation Algorithm (MBSSLAA) to solve the problem of efficient resource management for users and network coverage problem to improve the Quality-of-Service (QOS) while keeping the cost of deployment low in a network	CRAA achieved an improvement of 30% in the network which can be improved using beamforming algorithm
Lei (2013)	Performance Engineering of Mobile Broadband - Capacity Analysis, Cellular Network Optimization, and Design of In-Building Solutions	Analysis the fundamental capacity, resource planning and range optimization of broadband cellular networks, which will be adopted to build solutions based on distributed antenna systems. It also proposed mathematical model approach to optimize the system	Beamforming model can be integrated into the system for improved optimization
Fadli et al. (2019)	Optimization In Quality of Service for LTE Network Using Bandwidth Expansion	Analyzes the Quality of Service (QoS) using Key Performance Indicators (KPI) for LTE networks in order to optimize the network and solve congestion problems of LTE networks	Improved Can be improved with adaptive beamforming
Abdoulaye (2015)	Optimization and Self-Optimization in LTE-Advanced Networks	Considered self-optimization to address the specific problems related to the performance of the two network densification strategies with small cells and Active Antenna Systems (AASs)	Can be improved with adaptive beamforming

II. MATERIALS AND METHODS

This section presents the materials and method adopted for achieving a highly optimized LTE network performance.

a. Materials

The materials used for this research are listed below;

- Laptop
- Multi connector port
- Data cable, 2dBi antenna,
- Glo Modem
- Excel software, etc
- Gionee android signal strength meter
- Netspot software
- Glo Simcard, etc.

b. Characterization

This section characterized the GLO 4G cell located at Omala, Ogudu; Kogi State. The characterization was conducted using drive test method in communication setup was configured and installed on a vehicle and drove around the cell starting 150m away and data recorded every 30 minute for 12 hours. The setup constituted the laptop, modem, SIM card, android phone, Gionee android meter, Netspot software and car. The Netspot software installed on the laptop and connected to the spectrum analyzer which recorded signal at 960MHz modulating frequency and antenna was used to record the signal strength of the area. The Gionee software installed on the android phone was also used to confirm the signal strength recorded for reliability. The models considered for the measurement of the signal strength and pass loss were Alor et al. (2014) and the result presented in figure 1.

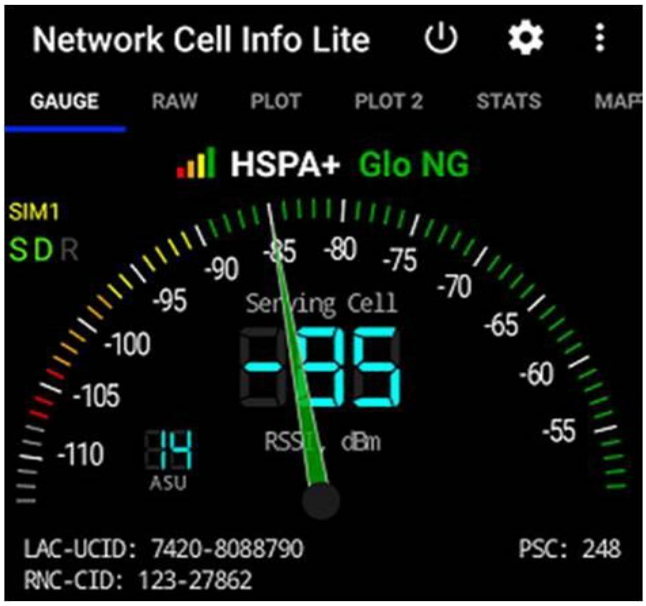

Figure 1: The 4G antenna and the monitoring software app interfece

The figure 1 presented the monitoring software interface which collected the necessary signal strenght required for the study at various times and reported in table 1;

Table 1: Data collected of the QOS

Time (min)	Signal strenght (dBm)	Time (min)	Signal strenght (dBm)
00:00	-104	07:00	-104
00:30	-106	07:30	-100
01:00	-107	08:00	-98
01:30	-109	08:30	-97
02:00	-108	09:00	-98
02: 30	-108	09: 30	-93
03:00	-107	10:00	-94
04:00	-106	10:30	-96
04:30	-104	11:00	-94
05:00	-108	11:30	-93
05: 30	-109	12: 00	-94
06:00	-108	Average	-102
06:30	-103		

The table 1 presented the performance of the ell characterized using the drive test method and the result was analyzed using the NCC standard for QOS in table 2;

Table 2: NCC criteria for signal strength in 4G Cell

Signal strength	Excellent	Good	fair	Poor	Dead zone
3G (dBm)	-70	-70 -85	-86 -100	-101 -109	-110
4G / LTE (dBm)	-85 -90	-91 -105	-106 -110	-111 -119	-120

From the standard presented in table 2, the performance of the 4G network after 150m is averagely -102dBm which is poor quality of service and needs optimization. To achieve this, beam forming algorithm was developed as shown in the next section.

c. Development of the Beam forming Algorithm

The purpose of the beam forming in this paper is to generate multiple beams towards desired users to ensure better data reception service and also to mitigate interference via the adjustment of beam forming weights. To develop the beam forming algorithm, a reference signal and multiple antenna elements were required. The antenna elements were used to collect signal received which were defined by their amplitudes and phase coefficient, then they were multiplied with a weight coefficient function (w) and used to adjust the weights and amplitudes of time series input signal. The summation of the output is given as the array output y(k) as the beam forming algorithm presented in (Chizhik, 2007). This output was made adaptive using Least Square Algorithm (LSA) to optimize the response and achieve desired output with improve the signal amplitude. y(k) is filtered to minimize error G(k) using LSA which computes the difference between the array output and the desired signal d(n). The mathematical model of the beam forming is presented using the model as (Chizhik, 2007);

$$y(k) = y(y2) - (w1, w2, \ldots . w(n))G\,(x1, x2 \ldots . xn(k)) \quad 1.0$$

Where $w = [w1, w2, w(n)]$ and $xn = [x1(n), x2(n), xk(n)]$; G is the reference signal of receiver, Y(n) is the sum of coefficient, X(n) is received signal from antenna, w is weight coefficient is output. The architectural model of the beam former is presented in figure 2;

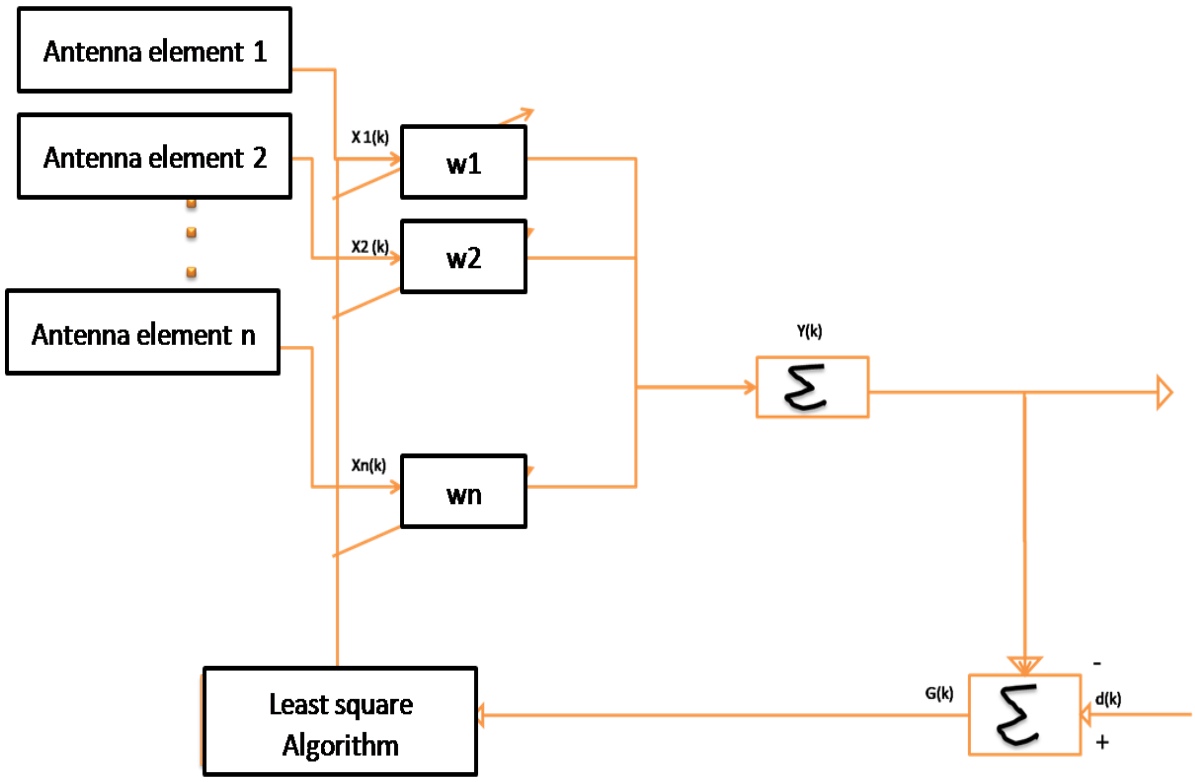

Figure 2: The structure of the beam forming algorithm

From the structure in figure 2, the input from the antenna elements (wn) are collected and then multiplied with a coefficient function xn to get the beam form output as y(k). This output signal was equalized using feedback process which uses least square algorithm to compare the signal with a reference signal and produced the desired received signal as d(n). The least square algorithm is presented in figure 3, while the pseudopodia are presented as;

The Pseudo code for the beam forming algorithm

1. *Start*
2. *Collect received signal (xn) from antenna element*
3. *Define reference signal from receiver as (G)*
4. *Get the weight coefficient function as wn*
5. *Sum the coefficients as y(n)*
6. *Compare y(n) and G(n) using least mean square algorithm*
7. *Get the designed output as the d(k)*
8. *Return*
9. *Stop*

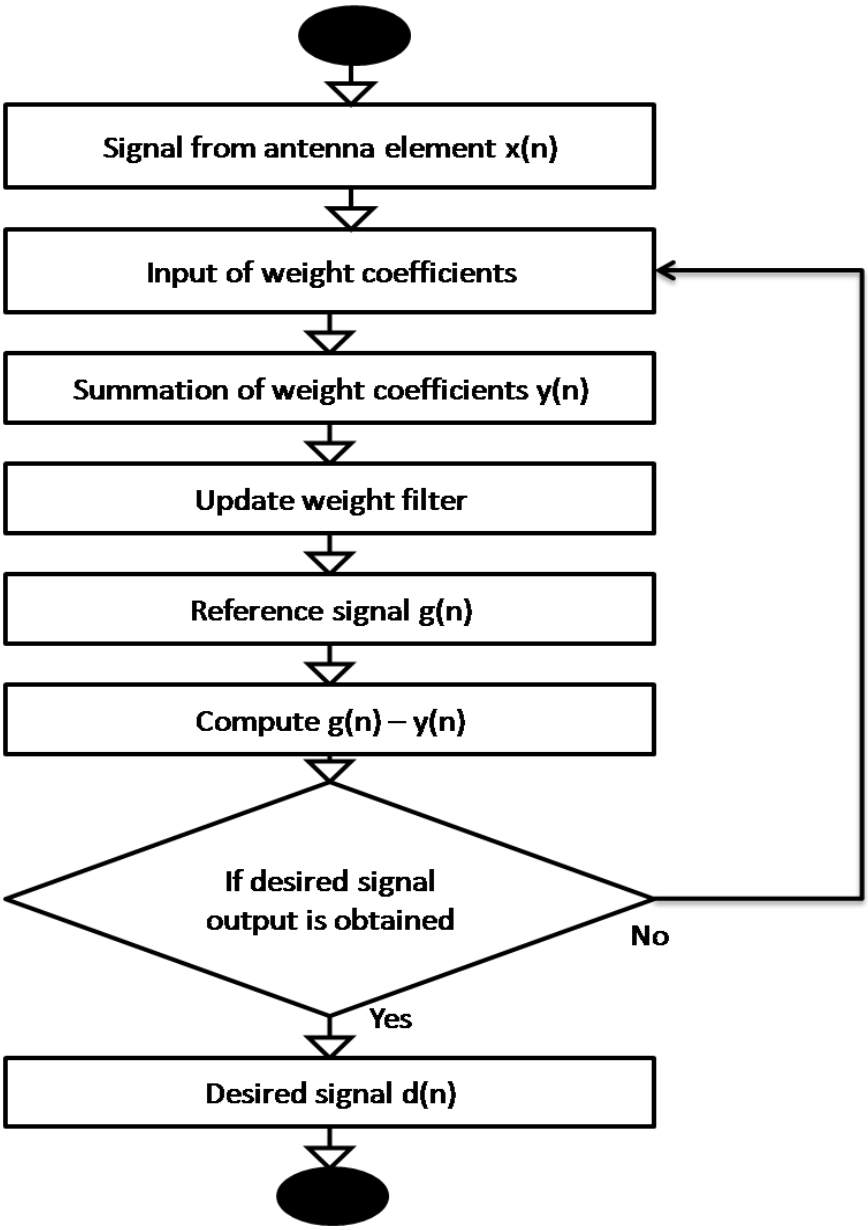

Figure 3: the least square algorithm

III. IMPLEMENTATION AND RESULTS

This section presented the implementation of the developed algorithm on the 4G network using signal processing toolbox, LTE toolbox, communication toolbox and MATLAB environment. To achieve this, the algorithm used to configure the 4G network and simulated at a frequency of 960MHz, distance of 150m, and gain of 2dBm while the results are presented as in figure 4;

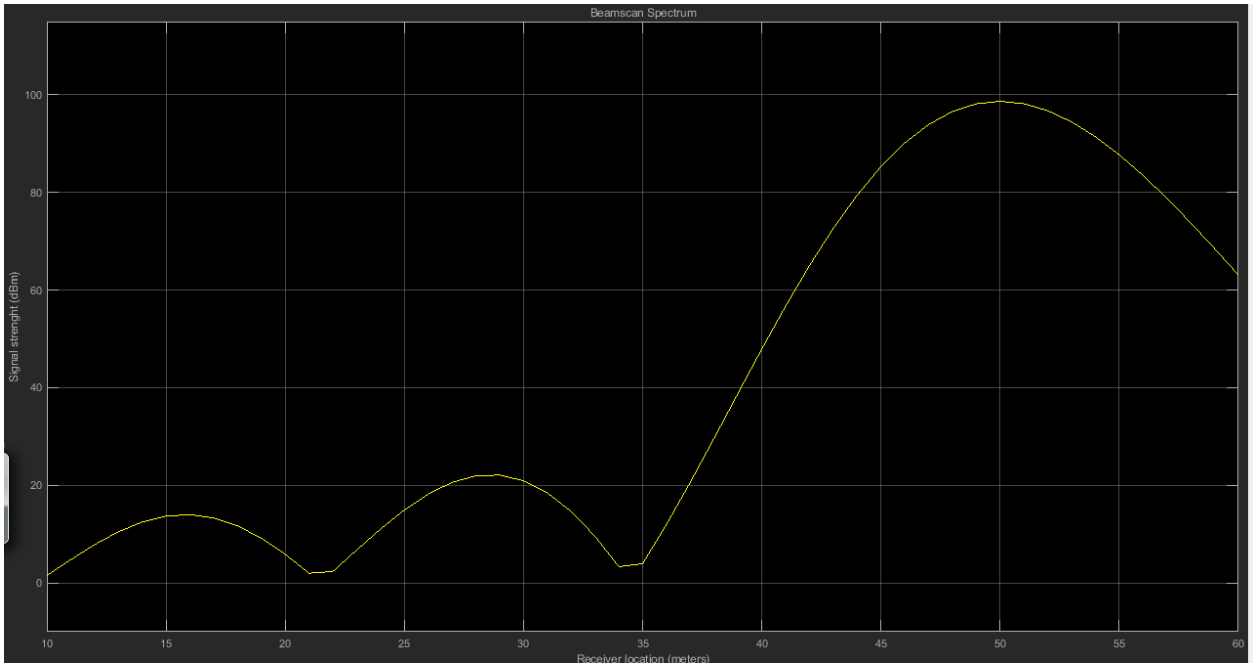

Figure 4: The signal strength at 4G network.

The figure 4 presented the performance of the simulated 4G cell and the result showed that the signal strength is -97dBm. The implication of the result showed that the beam forming algorithm was able to ensure that 4G antenna has a better signal strength than the conventional -105dBm recorded when measured in the characterization without beam forming algorithm. The algorithm was integrated on the 4G cell and evaluated and the results are presented in table 3;

TABLE 3: Performance Of The 4G with Beam forming

Time (min)	Signal strenght (dBm)	Time (min)	Signal strenght (dBm)
00:00	-91	07:00	-88
00:30	-89	07:30	-91
01:00	-89	08:00	-89
01:30	-91	08:30	-89
02:00	-90	09:00	-91
02: 30	-91	09: 30	-90
03:00	-91	10:00	-91
04:00	-87	10:30	-91
04:30	-97	11:00	-87
05:00	-88	11:30	-97
05: 30	-91	12: 00	-88
06:00	-88	Average	-91
06:30	-98		

The table 3 presented the performance of the 4G antenna when deployed with the developed 4G algorithm and measured. The result showed that the average signal strength of the 4G cell is -88 which are good compared to the conventional -95dBm recorded earlier which is only but a fair network performance. The overall performance analysis of the cell was presented as shown below for other locations.

Comparative Analysis

This section begins by colleting the data of the characterized 4G station antenna and analysis size by side with the new result recorded at Omala L.G.A respectively as presented in table 4:

Table 4: Comparative Data from Omala L.G.A with Beamforming algorithm

Time (min)	Signal strenght with Beamforming	Signal strenght without Beamforming
00:00	-91	-104
00:30	-89	-106
01:00	-89	-107
01:30	-91	-109
02:00	-90	-108
02: 30	-91	-108
03:00	-91	-107
04:00	-87	-106
04:30	-97	-104
05:00	-88	-108
05: 30	-91	-109
06:00	-88	-108
06:30	-98	-103
07:00	-88	-104
07:30	-91	-100
08:00	-89	-98
08:30	-89	-97
09:00	-91	-98
09: 30	-90	-93
10:00	-91	-94
10:30	-91	-96
11:00	-87	-94
11:30	-97	-93
12: 00	-88	-94
Average	-98	-109

The result in table 4 presented the comparative performance of the 4G cell when deployed with the beamformaining algorithm developed and also without beamforming as in the characterized. From the result, it was observed that the worst signal strength without beam forming is -109dBm while with Beam forming is -98dBm. The percentage increase in performance with the beamforming algorithm is 11.7%.

IV. CONCLUSION

This paper has successfully investigated the performance of the 4G cell located at the Ogudu L.G.A in Kogi state and find out that the quality of service is not reliable. To address this problem adaptive beam forming algorithm was developed and installed on the cell for optimization using Simulink.

V. CONTRIBUTION TO KNOWLEDGE

Beam forming algorthm was developed with LSA and used to optimze the quality of signal reception in 4G network.

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