Optimization of Network Performance in Wireless Communication Networks.

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ABSTRACT

In today's world of Wireless Communication Technology (WCT), the key challenges is in the area of improved coverage, Quality of Service (QoS), and Channel capacity. This paper aims to optimize network performance by developing a pilot study which was conducted in south-eastern Nigeria, Maiduguri, on the performance of GSM network. Data were collected and analyzed. The key parameters necessary for optimization were enhanced to improve performance. Simulations were carried out to assess various parameters and recommendations were made on how to improve on the efficiency of the wireless communication network.

(**Keywords**: wireless network, CDMA, TDMA, call drop, QoS, quality of service, channel capacity, optimization)

INTRODUCTION

The technology of wireless mobile communications with duplex transmission is one of the fastest expanding in the world. The foundation for a widespread commercial deployment of wireless mobile communications was laid with the standardization of the first generation cellular mobile radio systems in the 1980s. [1]

Parallel to the TDMA based second generation standards, the IS-95 was developed in the USA, employing Code Division Multiple Access (CDMA) with Direct Sequence (DS) spectrum spreading, combined with FDMA. The origin of CDMA goes back to the beginnings of spread spectrum communications in the first half of the 20th Century. CDMA is one of the most promising medium access technologies for next generation cellular networks. The primary application of spread spectrum communications was in the development of secure digital communication systems for military use. Since the second half of the 20th Century, spread spectrum communications became of great interest also for commercial applications, including mobile multi-user communications. Spread spectrum signals are characterized by their use of bandwidth, which is much greater than the minimum necessary bandwidth for data transmission [15].

The spectrum spreading is achieved by using a spreading code that is Independent of the a-synchronized replica of the spreading code to de-spread the received signal allowing recovery of the message. The large redundancy inherent in spread spectrum signals is required to overcome interference caused by the nature of the channel, by intentional disturbances, and by multiple accesses of various users. The exploitation of the spread spectrum technique to enable multiple users a simultaneous access to the channel is called CDMA [3, 4, 5].

Beginning with CDMA-One this technology is developed towards 3G technologies and cdma2000 1x is now one of the IMT-2000 3G standards. The CDMA2000 standards are implemented in two phases. In the first phase, the CDMA2000 still adopts the spread spectrum rate of CDMA-One (i.e., 1 × 1.2288Mbps). A single carrier occupies 1.25MHz bandwidth. It adopts DS spread spectrum technology (DS-CDMA). The cdma2000 system in the first phase is also called CDMA2000 1x. In the second phase, the spread spectrum rate is 3 × /6 × /9 × /12 × 1.2288 Mbps, respectively, occupies 5/10/12/15 MHz bandwidth. It adopts multi carrier modulation technology (MC-CDMA). The CDMA2000 system in the second phase is also called cdma2000 3X.

In addition, the 1xEVDO Rev A, which serves as an enhanced standard supplemental to IS2000, supports data transmission up to 3.1Mbps in a bandwidth of 1.25 MHz [6, 7, 8].

All CDMA users occupy the same frequency at the same time; the frequency and the time are not unique for each user. In CDMA Coding is used to distinguish between users. The interference of CDMA comes mainly from nearby users. CDMA physical layer Consist of two channels of 1.25 MHz-wide, one from Base Station (BS) to Mobile Station (MS) called Forward Link or Down Link and the other from Mobile Station to Base Station called Reverse Link or Up Link [9, 10, 11].

Each channel is made unique by mathematical codes. Code channels in the Forward Link are; Pilot, Synchronous, Paging, Forward Traffic Channels. Code channels in the Reverse Link are; Access, Reverse Traffic Channels [12, 13].

CDMA uses spread spectrum concept and takes benefit from the process gain to increase the number of users per frequency band. There are 8 band classes stipulated in the IS-2000 for the working frequency band of the cdma2000 [14, 15].

Recently, there has been an increase in demand for wide-band services such as video-phones and videoconferencing over wireless networks. As a result, networks are fast evolving from voice only networks to multi-service networks supporting a heterogeneous mix of services with varying traffic characteristics. Improved bandwidth allocation is a key requirement for the viability of next generation cellular networks. The challenge comes from efficiently supporting a broad spectrum of services with different Quality of Service (QoS) requirements and traffic characteristics. This thesis provides an accurate network performance optimization model allowing for system level performance in terms of capacity, coverage and quality of service [16, 17].

CDMA offers some unique features such as soft handoff and the quelling of fast fading through the use of diversity reception, equalization, interleaving and RAKE receivers. A unique feature of CDMA is the universal frequency reuse factor which allows for mobiles to soft handoff between cells. Traditional cellular systems require a break in communication with its current base station prior to making a new connection with the new base station. For analytical purposes, a soft handoff region and normal region is usually defined. Mobile stations in the soft handoff region can be power controlled by two or more base stations, while mobile stations in the normal region are power controlled by the base station in the current cell.

During the process of soft handoff, the base stations initially and independently decode the signal that they receive from the mobile station. The base stations then send the information to the mobile switching centre which favors the base station that receives the highest signal strength. On the forward link, the mobile station aggregates the signals from various base stations.

Performance is enhanced when the mobile station combines all the different multipath signals to strengthen the received signals. Figure 1 shows a typical CDMA network with soft handoff and normal region.

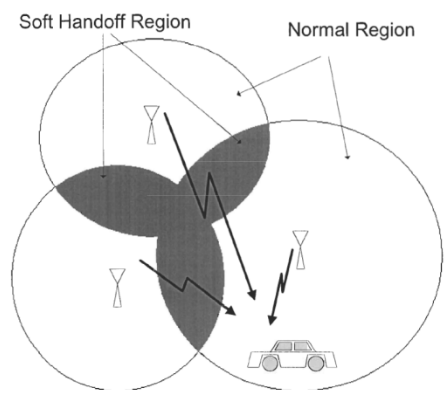


Figure 1: CDMA Network Coverage Specifying the Handoff and Normal Regions.[23]

OBJECTIVE

Cellular network operators must periodically optimize their networks to accommodate traffic growth and performance degradation. Optimization action after service rollout is to correct the expected errors in network planning and the benefits like improved network capacity, enhanced coverage and quality of service. The basic objectives of this research are to ensure that the radio parameters are maintained at their standard thresholds after the optimization of the network to enhance the network performance. These are validated by the results obtained during the various models and techniques adopted to assess the network performance.

The cdma2000 system in the second phase is also called cdma2000 3X. In addition, the 1xEVDO Rev A, which serves as an enhanced standard supplemental to IS2000, supports data transmission up to 3.1 Mbps in a bandwidth of 1.25 MHz [24].

Network Topology

Figure 2 shows the major architecture of a cdma2000 1x network.

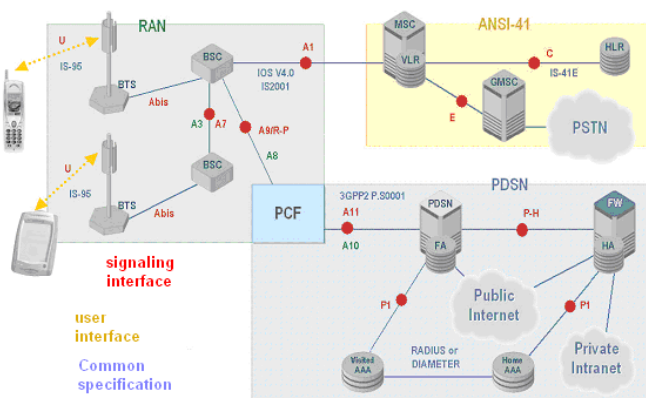


Figure 2: cdma2000 1x Network Topology.[33]

Radio Access Network (RAN)

The Radio Access Network is the mobile subscriber's entry point for communicating either data or voice content. It consists of:

- The air link
- The cell site tower/antenna and the cable connection to the Base Station Transceiver via Um interface.
- The Base Station Transceiver Subsystem (BTS)
- The interface or the communication path between the BTS and the Base station controller (BSC) is the Abis.
- The Base Station Controller (BSC)

The RAN has a number of responsibilities that impact the networks delivery of packet services in particular. The RAN must map the mobile client identifier reference to a unique link layer identifier used to communicate with the PDSN, validate the mobile station for access service, and maintain the established transmission links. The main parts are the BTS and the BSC.

CDMA Spread-Spectrum Concept

Traditional technologies attempt to send the signal into the minimum required bandwidth as quickly as possible. Direct-Sequence Spread spectrum systems merge their input data with a fast spreading sequence and transmit a wideband signal. The spreading sequence is independently regenerated at the receiver side and mixed with incoming wideband signal to recover the original data [18, 19, 23]. This principle is shown in Figure 3.

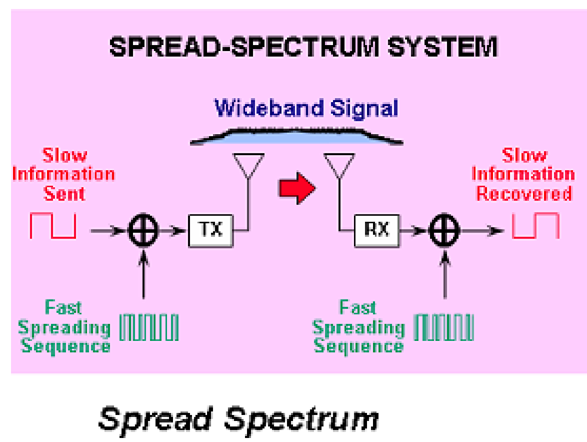


Figure 3: Spread Spectrum Concept.[20]

Processing Gain: If a signal is deliberately transmitted using more RF bandwidth than required, it is easier to detect at the receiver.

Processing gain= W (spectrum wide)/R(Bit Rate)….**(1)**

Spectrum wide is 1.25 MHz and Bit Rate can be 8kbit for half rate or 13kbit for full rate.

The Processing Gain has big influence on numbers of user's per bandwidth. CDMA can support 22 to 32 voice users per one spectrum [20, 21].

CDMA Codes Channel

CDMA channels aggregate of three different spreading sequences to create unique channels. This is explained in Figure 4.

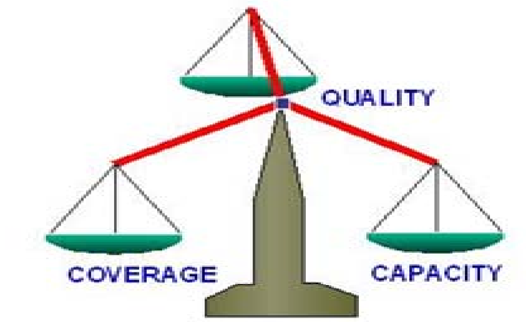


Figure 4: The Main Factors in Network Optimization[7]

Walsh Code: the fist spreading sequence is Walsh Code. There are 64 Walsh Code sequence each Walsh Code consist of 64 chips (chip is a binary of 0' and 1' digit). Each Walsh Code is Orthogonal to all other Walsh Code; it will be easy to recognize the particular Walsh Code at other side if you know the two same-length binary strings are Orthogonal if the result of XOR them has the same numbers of 0s as 1s [23].

Short PN Code: the second spreading sequence is Short PN codes. There are two PN sequence code I and Q each of them has 32,768 chips. Each Short PN Sequence is special Orthogonal to a copy of itself [22, 24].

Long PN Code: the third spread sequence is Long PN code. Each mobile station uses a unique Long Code Sequence generated by applying a mask [25, 26]. Based on its 32-bit ESN, to the 42-bit Long Code generator which was synchronized with CDMA system during the mobile station initialization.

Recognize Forward Code Channels: A mobile station is surrounded by base stations, all of them transmitting on the same CDMA frequency. Each sector in each base station is transmitting a CDMA forward traffic channel containing up to 64 distinct forward code channels. A mobile station must be able to discriminate between different sectors of different base stations and listen to only one set of code channels. I and Q Short PN Sequences (or Short PN Codes) are unique and defined for the purpose of identifying sectors of different base stations. These Short PN Sequences can be used in 512 different ways in a CDMA system. Each forward Channels with unique Short PN has 64 Walsh Codes used to identify the channels from the base station. Each Forward Link Channels has his unique Walsh Code. Figure 5 shows the forward channels.

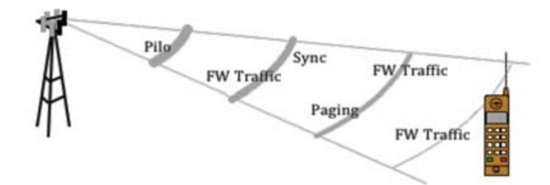


Figure 5: Forward Code Channels **[9]**

Area of Study (Test Bed)

Following the need for the coverage of Maiduguri City in Nigeria, 16 BTS sites were built by Visafone, with the intention of creating a good CDMA 1x network in the city. The BTS configurations are S1/1/1; with frequency point of 419 in the 800MHz band. The 16 BTS sites are connected to the Kano BSC, which is one of the nine BSC locations of Visafone, via a 16E1 capacity fibre link.

The list of the on-air sites, their co-ordinates and configurations are listed in Table 1.

Table 1: List of On-Air Sites.

BTS Name	Longitude	Latitude	BTS Configuration
MAD001	13.1572	11.8606	S1/1/1
MAD002	13.16081	11.84746	S1/1/1
MAD003	13.14328	11.8492	S1/1/1
MAD005	13.12693	11.8593	S1/1/1
MAD006	13.16807	11.8358	S1/1/1
MAD007	13.14624	11.8242	S1/1/1
MAD008	13.13578	11.8128	S1/1/1
MAD009	13.14646	11.8029	S1/1/1
MAD010	13.15882	11.8149	S1/1/1
MAD011	13.17486	11.81326	S/1/1/1
MAD012	13.19302	11.8088	S1/1/1
MAD013	13.17873	11.8611	S1/1/1
MAD014	13.08002	11.8354	S1/1/1
MAD015	13.09693	11.8253	S1/1/1
MAD016	13.11675	11.8155	S1/1/1
MAD017	13.18319	11.8419	S1/1/1

Table 2: List of On-Air Sites.

	Area Coverage Probability
	Indoor
Urban	90%
Suburban	85%

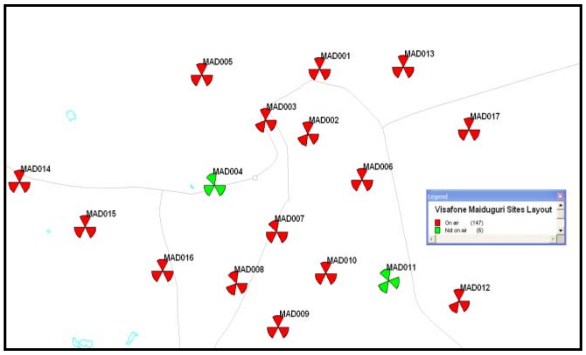


Figure 6: BTS Layout of Maiduguri City.

Propagation Loss Formula

Okumura-Hata Model

Lb=69.55+26.16log$f$–13.82loghb–a(hm)+(44.9-6.55log hb)(logd) **(2)**

Formula explanation:

1. The unit of d is km,
2. The unit of f is MHz;
3. A (*hm*) is the basic mean value of propagation loss for the urban area; hb and hm, in meters, are the effective heights of the base station and mobile station antennas.

Calculation of the base station antenna effective height hb: Suppose the height of the base station antenna from the ground is hs, the base station ground height above sea level is hg, the mobile station ground height above sea level is hd, then the effective height of the base station antenna is:

$$hb = hs + hg - hd \quad (3)$$

Modifying factors for suburbs:

$$K_{mr} = -2\log_{10}^{2}\left[\frac{f}{28}\right] - 5.4$$

Modifying factors for the countryside:

$$K_r = -\log_{10}^{2}\left[\frac{f}{28}\right] - 2.39\log_{10}^{2} f + 9.17\log_{10} f - 23.17 \quad \textbf{(4)}$$

L =Lb +K various environment [20] **(5)**

Plan Values for Network in Maiduguri

Voice services Model: The Table 3 shows the values for voice services traffic model.

Table 3: Voice Services Traffic Model

Blocking Rate	Voice Active Factor	Soft Handoff Ratio
2%	0.4	20%

Data Services Model: The Table 4 shows the values for data services traffic model.

Table 4: Data Services Traffic Model.

Data service subscribers distribution	High-end subscribers	15%
	Middle subscribers	25%
	Low-end subscribers	60%
Data service model parameters	PPP Session Time(s)	350
	PPP Session Duty Ratio	10%
Data Service Active Factor		1

Data Access Rate: The Table 5 shows the data access rate grade.

Table 5: Data Access Rate Grade.

Grade of Data Rate (kbps)	Data Rate (kbps)	Statistics Proportion			Average (kbps)
		Low-end	Middle	High-end	
9.6	9.6	100%	25%	5%	Low-end 9.60
9.6+9.6	19.2	0%	40%	5%	
9.6+19.2	28.3	0%	18%	20%	Middle 26.11
9.6+38.4	48	0%	12%	25%	
9.6+76.8	86.4	0%	4%	30%	High-end 69.60
9.6+153.6	163.2	0%	1%	15%	

Subscribers Distribution: We suppose that the subscribers in the coverage area are uniformly distributed.

Assumptions on radio environment: Two environments: urban, and suburban with penetration loss of, 20dB, and 15dB respectively. Shadow fading margin is calculated with 8dB of standard deviation, and then the shadow fading margins in different environment are shown in Table 6.

Table 6: Subscribers Distribution.

Situation	Urban
Area Coverage Probability	90%
Marginal Coverage Probability	75%
Shadow fading Margin (dB)	5.5

Body loss is 0 dB for voice service since fixed terminals are used. Assumptions on BTS: Maximal transmission powers of fixed terminal and base stations are 250mW (23.98dBm) and 20W (43.01dBm) respectively. CDMA2000-1X reverse link channels includes a pilot channel (R_PICH), a fundamental channel (R_FCH) and an optional supplemental channel (R_SCH). The power allocations to these channels are set according to the values recommended by IS-2000 standard, and shown in Table 7.

Table 7: Channels Power Allocation.

R_SCH Data Rate (kbps)	Vioce	9.6	19.2	38.4	76.8	153.6
Max R_FCH TX Power (dBm)	21.55	19.17	20.50	21.29	21.91	22.35
TX Power Ratio of R_FCH to R_PICH (dB)	4	3.75	3.625	2.375	1.125	-0.75
Max R_PICH TX Power (dBm)	17.55	15.42	14.25	13.79	12.91	11.85
TX Power Ratio of R_SCH to R_PICH (dB)	--	3.75	6.25	7.5	9	10.5
Max R_SCH TX Power (dBm)	--	19.17	20.50	21.29	21.91	22.35

BTS **receiver noise figure** is 3.2dB and mobile station receiver noise figure is 8dB.

Noise rise = 10 * log10 (1/(1-loading)) **(6)**

i.e. 3.01 dB for 50% reverse load.

Table 8: BTS Antenna Height and Feeder Cable Loss Values.

Item	urban
Antenna height (m)	20
Feeder lenth (m)	30
7/8Feeder cable loss(dB/100m)	2.7
5/4Feeder cable loss(dB/100m)	1.9
1/2 jumper loss(dB/100m)	7.6

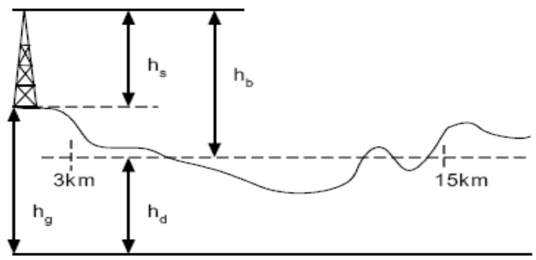


Figure 7: Calculation of the Base Station Effective Height.

Table 9 shows the Eb/Nt thresholds in different conditions.

Table 9: Eb/Nt Thresholds in Different Conditions.

Eb/Nt (dB)	FER 1%	FER 5%	FER 5%	FER 5%	FER 5%	FER 5%
	Voice 9.6 kbps	Data 9.6 kbps	Data 19.2 kbps	Data 38.4 kbps	Data 76.8 kbps	Data 153.6 kbps
0km/h	3.5	2.17	1.91	1.71	1.65	1.65

Table 10 shows the network quality requirements.

Table 10: Network Quality Requirement.

Voice FER Target	1%
Data FER Target	1%(R-FCH), 5%(R-SCH)

Coverage and Capacity Requirements

According to network requirements, the total number of subscribers to be considered in network planning is 4,800,000 about 4,400,000 subscribers are in the urban area, and about 400,000 subscribers are in suburban areas.

Site Coverage Radius

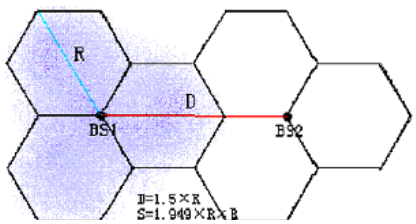


Figure 8: Site Coverage Radius[18].

Figure 8 displays the method to estimate the area of 3-sector directional site. We assume that the cell's coverage shape is a hexagon.

For directional site: S = 1.949×R×R **(7)**

Where, S is coverage area of one site; R is the site coverage radius.

Forward Link Budget

Based on the condition above and using Huawei "CDMA2000 Radio Netplan Estimate Tool" Table 10 shows propagation loss of a FWT for voice and data services for various types of areas.

Table 11: Forward Propagation Loss.

Terminal Type	Urban (Indoor)		Suburban (Indoor)		Rural (Outdoor)	
	Voice	Data	Voice	Data	Voice	Data
FWT (indoor antenna)	137.07	132.32	142.07	137.32	150.27	145.52

Reverse Link Budget:

To calculate reverse link capacity, we use the method presented in [1, 2] and assume an isolated cell with k_u statistically identical users being independently power controlled. Signals from all users in the cell arrive at the BS with equal strength, so the average noise and interference power I_{0W} at the BS is:

$$I_0W = \sum_{i=1}^{K_u} E_b R + N_0 W \quad \textbf{(8)}$$

Where, I_0 is interference density, N_o is thermally noise density, W is the spread spectrum bandwidth, R is the data rate, and E_b is bit energy.

To maintain system stability, we limit the rise-over-thermal ratio $\frac{I_o W}{N_o W}$ to a particular outage level ρ:

$$\frac{Io}{No} < \rho \quad \textbf{(9)}$$

Combining Equations 8 and 9, we obtain:

$$\sum_{i=1}^{k_u} E_b R = (I_o - N_o)W < I_o W(1-\frac{1}{\rho}) \quad \textbf{(10)}$$

Since $E_b = E_c.\frac{W}{R} where E_c$ represents chip energy, we have:

$$\sum_{i=1}^{K_u} \frac{E_c}{I_o} < 1 - \frac{1}{\rho} \equiv K_o^{'} \quad \textbf{(11)}$$

When the condition in Equation 11 is not satisfied, the system is considered to be in outage. Therefore, the probability of outage, P_{out}, is:

$$Pout = \Pr\left\{ \sum_{i=1}^{k\ (1+f)} \frac{E_c}{I_0} > K_o^{'} \right\} \quad \textbf{(12)}$$

A Poisson process is a good model for the aggregate traffic of a large number of similar and independent users. Thus, we assume that calls from the entire population in the cell arrive according to a Poisson process with a total average arrival rate of λ calls/second. Call service-times are exponentially distributed with average call duration of $\frac{1}{\mu}$ seconds. To determine the occupancy distribution and the profitability of blocked calls, we use the "lost call held" (LCH) model, which assumes that unserved users repeat their call attempts immediately and remain in the system as typical for mobile communication systems. From this model, the number of active calls in a cell k_u is a Poisson random variable with distribution.

$$P_{k_u} = \frac{(\lambda/\mu)^{K_u}}{k_u} e^{-\lambda/\mu} \quad \textbf{(13)}$$

$$k_u = 0,1,2....$$

However, the level of interference power at a given base station is caused not only by users in the cell, but also by users in surrounding cells controlled by other base stations. Assuming uniform loading of all cells, interference from users of surrounding cells increases the interference at the base station under analysis by a fraction f of the interference from the desired cell's users. If users of surrounding cells are also power controlled and thus have similarly distributed (E_c / I_o), the average interference power due to users of surrounding cells can be modeled as $f.k_u$ additional users, where k_u is the average number of active users per cell. Modifying the results to include the effects of other cell interference, we have:

$$P_{out} = \Pr\left\{\sum_{i=1}^{k(1+f)} \frac{E_c}{I_o} > K_0^{'}\right\} = \Pr\left\{\sum_{i=1}^{k_u^{'}} \frac{E_c}{I_o} > k_o^{'}\right\} \quad \textbf{(14)}$$

Where,

$$k_u^{'} = k(1+f)$$

Continuing with the probability of outage, we may define the random variable of interest $Z^{'}$ as the sum of the signals of users in the cell (including the effects of other-cells users).

$$Z^{'} \equiv \sum_{i=1}^{k_u} E_c / I_o \quad \textbf{(15)}$$

The outage probability can now be expressed as:

$$p_{out} = \Pr\{Z^{'} > K_o^{'}\} \quad \textbf{(16)}$$

Due to inaccuracies in power control loops, the received E_c/I_o of the R-PICH of a particular user is log-normally distributed with a standard deviation of 1.dB to 2.5 dB. Since the strength of the R-FCH is specified as an offset from the R-PICH, the total received E_c/I_o from a user varies as a function of the data rate. Assuming users exhibit similar data rate characteristics, the received E_c/I_o from different users in the sector may be modeled as independent and identically distributed (IID) random variables. Unfortunately, it is not easy to obtain the exact analytical derivation of the sum of these IID random variables, the desired random variable $Z^{'}$.

Thus, for ease of computation, we can invoke the Central Limit Theorem to approximate $Z^{'}$ as a Gaussian random variable. While a stricter upper limit can be obtained by numerically computing the Chernoff bound, simulations run, shows that the Gaussian approximation underestimates this limit by at most 1%, so it is used here for convenience.

Since $Z^{'}$ is the sum of $k_u^{'}$ random variables where $k_u^{'}$ is itself a random variable. The mean and variance are given by:

$$E\{Z^{'}\} = E\{k_u^{'}\}E\{E_c/I_o\} = \left(\lambda/\mu\right)(1+f).E\{E_c/I_o\} \quad \textbf{(17)}$$

$$Var\{Z^{'}\} = E\{k_u^{'}\}Var\{E_c/I_o\} + Var\{k_u^{'}\}\left[E\{E_c/I_o\}\right]^2 \quad \textbf{(18)}$$

Furthermore, since $k_u^{'}$ is a poisson random variable,

$$E\{k_u^{'}\} = Var\{k_u^{'}\} = \left(\lambda/\mu\right).(1+f) \quad \textbf{(19)}$$

so that

$$Var\{Z'\} = \left(\lambda/\mu\right).(1+f).\left[E\left(Ec/Io\right)\right]^2 \quad \textbf{(20)}$$

Thus, the normal approximation for probability of outage can be written:

$$P_{out} = Q\left[\frac{K_u' - \{Z'\}}{\sqrt{Var\{Z'\}}}\right] \quad \textbf{(21)}$$

$$Var\{Z'\}$$

Where $E[Z']$ is given by Equation 17.

The Erlang capacity of the system is measured by the average traffic load corresponding to the number of active users causing blocking with the designated blocking probability, which in the above analysis, corresponds to the value of λ/μ.

RESULTS AND DATA ANALYSIS

In this section, we examined the collated data for the study. The data was collated through the drive test, before and after the network optimization exercise .These were processed with the drive test tool, Dingli Panorama and the output was produced in the form of distribution charts and maps and subsequently analyzed to lay credence to the set objectives of the study. This result was compared with the simulation output produced by the simulation software, Tems cell Planner. These outputs of the examined network optimization metrics include, Ec/Io, Rx level, Tx level, FFER, Call drop, PN Plot, Short call statistics.

<u>Analysis</u>

The diagrams in Figures 9, 10, 11, and 12 show coverage by Ec/Io in Maiduguri city before and after optimization was carried out in the network. Areas **A** and **B** had poor coverage due to GPS antenna tracking.

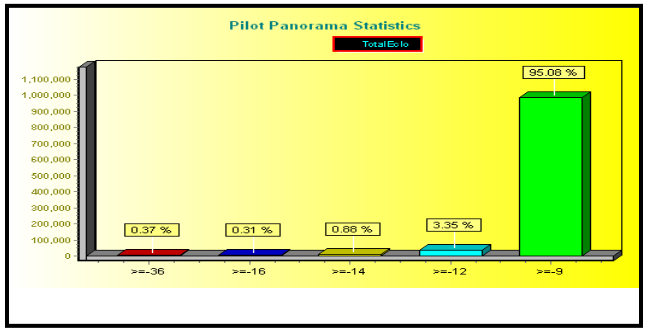
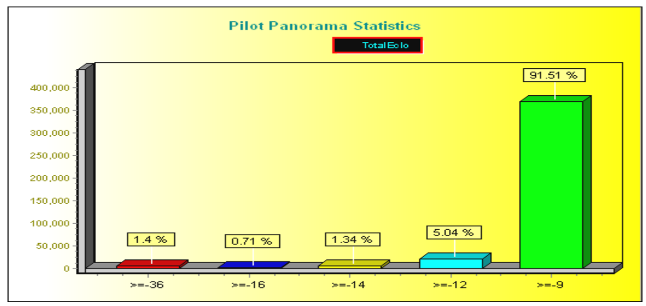


Figure 9: Ec/Io Distribution Chart before Optimization.



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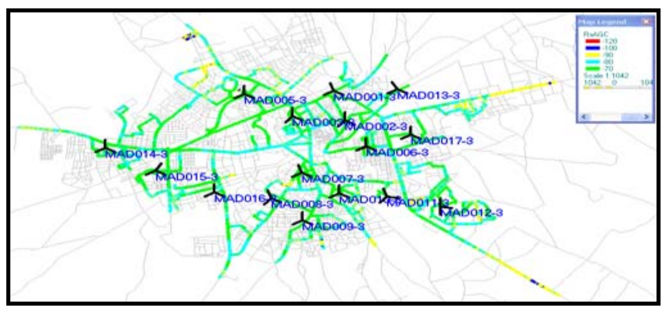

Figure 11: Total Ec/Io Distribution Map before Optimization.

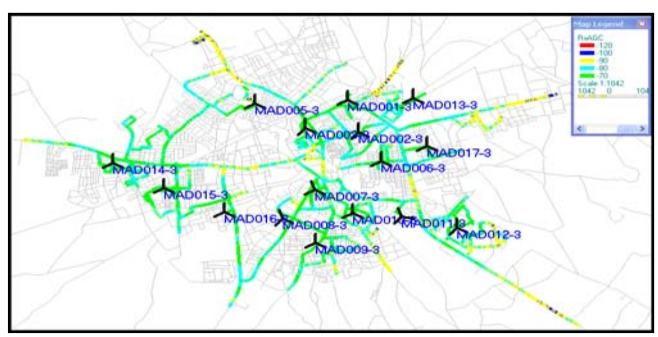

Figure 12: Total Ec/Io Distribution Map after Optimization.

EC/IO COVERAGE

Problem of **MAD0016** and **MAD002** coupled with some sites with RSSI problems. However, after optimization, all these snags were cleared and the city has excellent Ec/Io coverage. Affected areas, **A and B** have improved compared to their previous states.

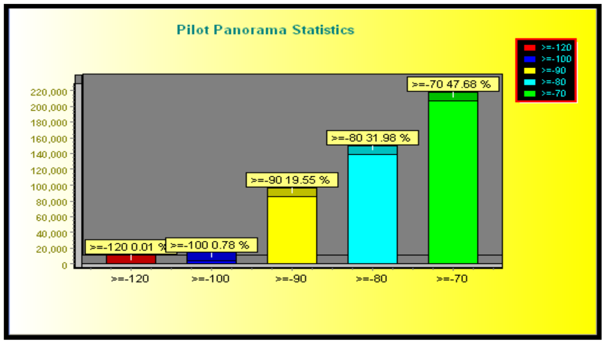

Figure 13: Ec/Io Distribution Chart after Optimization.

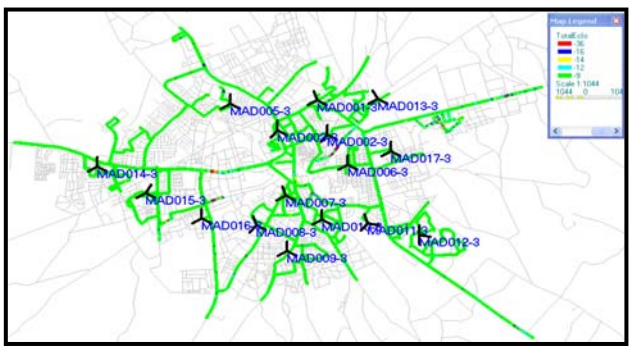

Figure 14: Max Ec/Io Distribution Map before Optimization

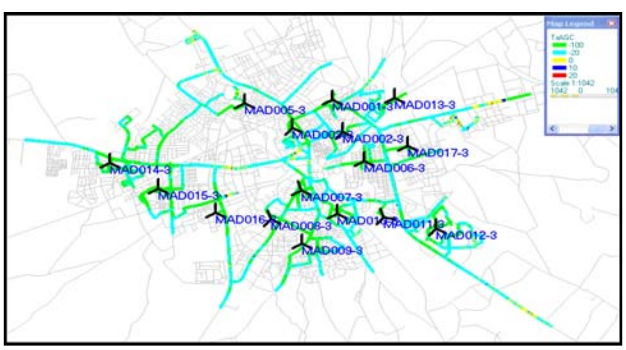

Figure 15: FFER Distribution Map after Optimization.

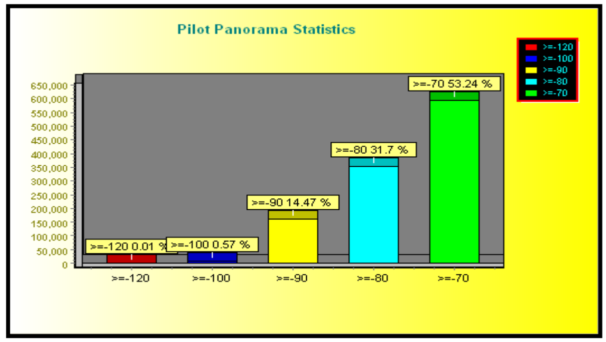

Figure 16: Rx Level Distribution Chart after Optimization.

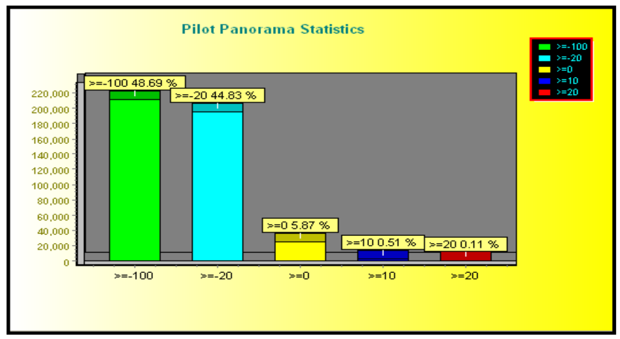

Figure 17: Tx Level Distribution Chart before Optimization.

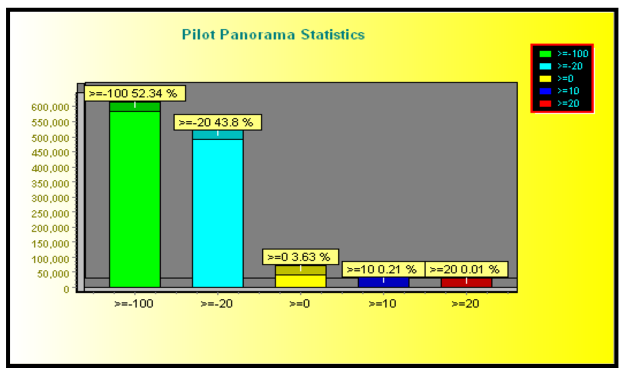

Figure 18: Tx Level Distribution Chart after Optimization.

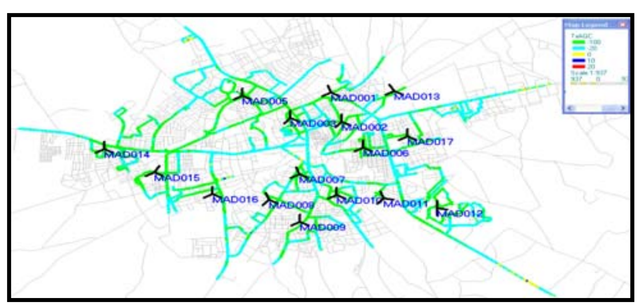

Figure 19: Rx Level Distribution Map before Optimization.

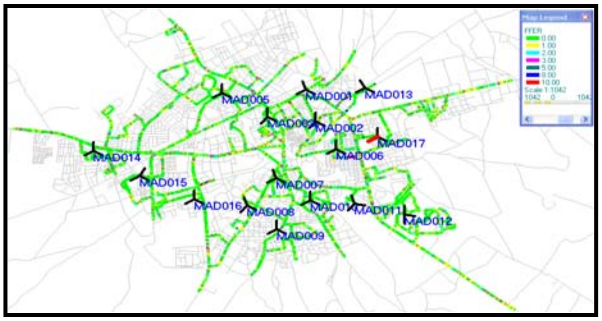

Figure 20: Rx Level Distribution Map after Optimization.

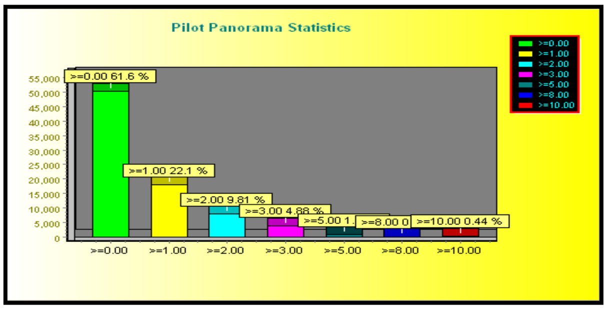

Figure 21: Tx Level Distribution Chart after Optimization.

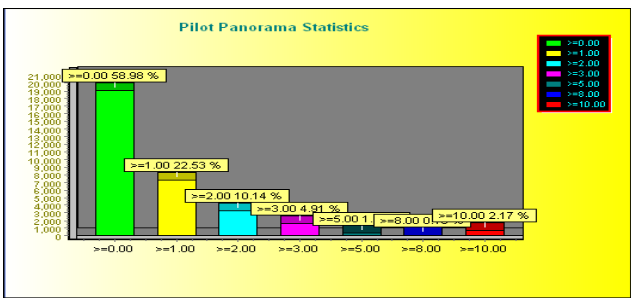

Figure 22: FFER Distribution Histogram after Optimization.

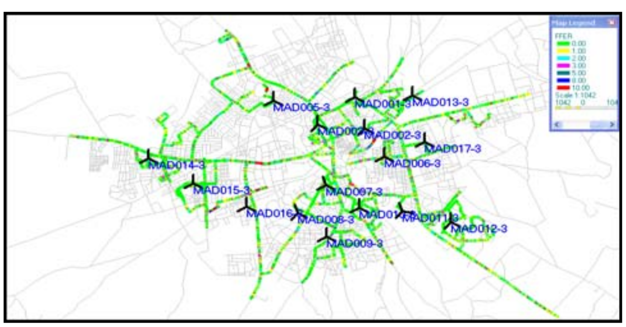

Figure 23: Tx Level Distribution Map after Optimization.

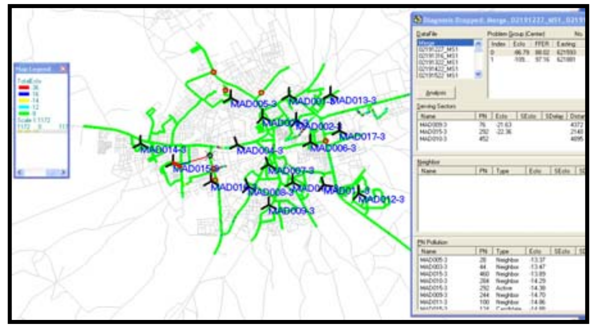

Figure 24: FFER Distribution Map before Optimization.

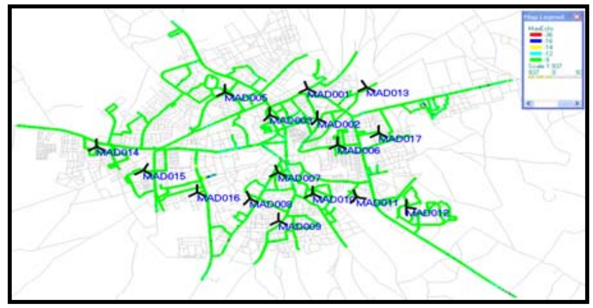

Figure 25: Call Drops (Long Call) before Optimization.

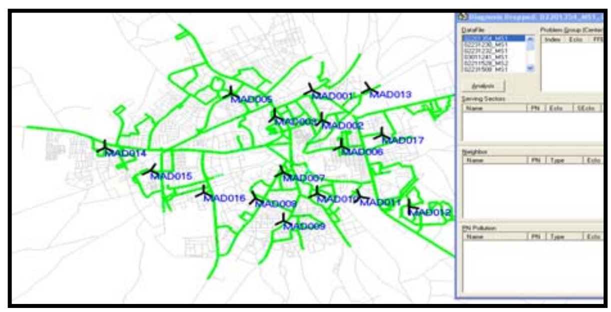

Figure 26: Call Drops (Long Call) after Optimization.

Analysis

As shown in Figure 16, areas **A**, **B**, **C**, and **D** had poor coverage. But after optimization, Rx Level has improved in the affected areas, **A**, **B**, **C** and **D** compared to the previous RX Levels.

As shown by statistics in Figure 13, Total Ec/Io greater than -9dB was **91.51%,** before optimization. However, after optimization, as shown in Figure 14, the value came to **95.08%**, which is a remarkable improvement over the previous value for the network.

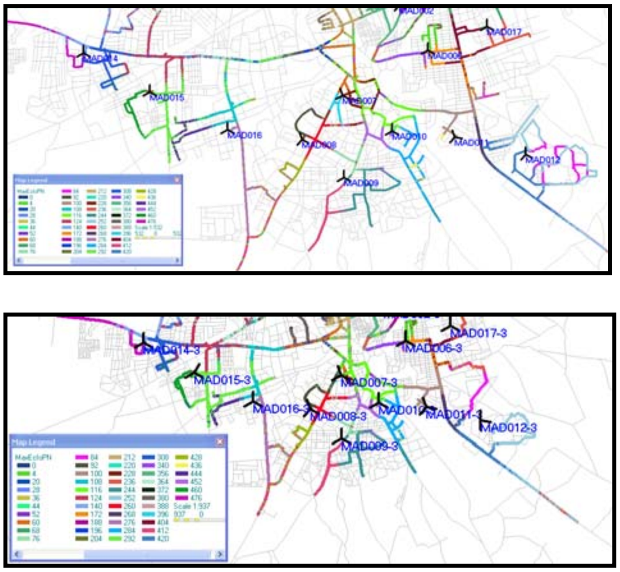

Figure 27: PN Plot for Maiduguri Sites after Optimization.

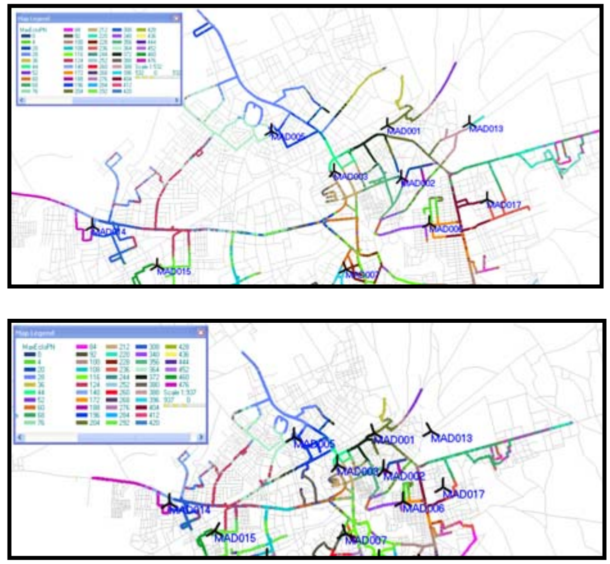

Figure 30: PN Plot for Maiduguri Sites before Optimization.

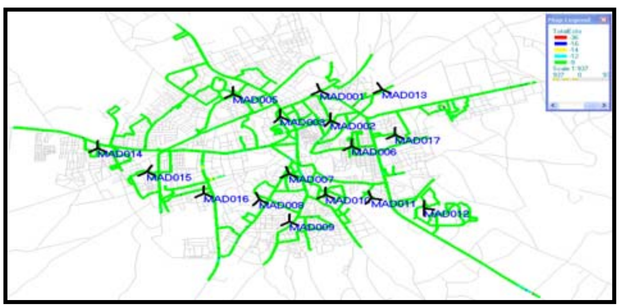

Figure 28: Max Ec/Io Distribution Map before Optimization.

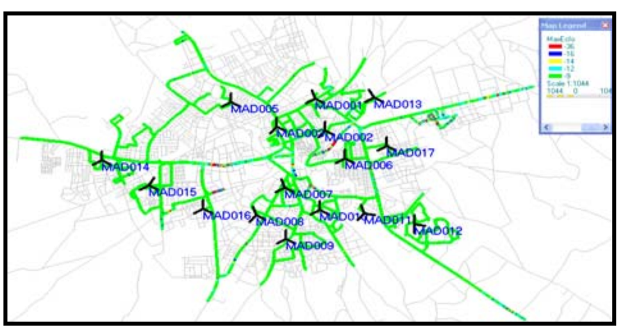

Figure 29: Max Ec/Io Distribution Map before Optimization.

<u>Rx Level Coverage</u>

Statistics in Figure 19 shows that Rx Level above -90dbm was **99.21%**, before optimization. However, after optimization, Rx Level above -90dbm came to **99.41%,** which is an improvement over the previous value.

<u>Tx Level Coverage</u>

Figure 21 shows Tx Level distribution map after optimization.

<u>Analysis</u>

As shown in Figure 17, the Tx distribution in most areas is good except for the area marked **A**, which is at the edge of the coverage. However, after optimization, the area marked **A** improved excellently, as shown in Figure 18. Statistics shows that TX level below 0 were **93.52%,** before optimization. However, as shown in Figure 15, after optimization TX level below 0 came to **96.14%**, which is a good improvement over the previous value.

FER Coverage

The value of FFER values lower than **2%** was **81.51%**. But after optimization, the value came to **83.7%**, which is a good improvement over the initial value. The quality of the network measured by FFER was poor in areas **A and B**. However, as shown in above, areas **A** and **B** have improved after optimization.

Call Drop (Long Call)

As shown in Figure 22, before optimization, call drops featured at the center of the city, marked **A**, as well as at areas toward the edges of the network, marked **B** and **C** due to GPS tracking problem on some sites. However, as shown in Figure 24, no call drops featured in the areas **A**, **B**, **C** and the rest of the network after optimization.

Short Call Statistics

Table 12 presents short call statistics before optimization was corrected. From the data above it can be seen that after optimization, the serving cells maintain their correct PN values, including the area, A.

Table 12: Short Call Statistics before Optimization.

Report Message	Count	Percent
Call Success	414	98.57%
Call Drop	6	1.43%
Call Connection	426	96.60%
Call Failure	15	3.40%

Table 13: Short Call Statistics after Optimization.

Report Message	Count	Percent
Call Success	559	99.82%
Call Drop	1	0.18%
Call Connection	576	99.13%
Call Failure	5	0.87%

SIMULATION RESULTS

Analysis of Simulation output

Downlink Received Power: Figure 30 shows the total mean received RF power over a carrier's bandwidth, found by adding the received pilot powers, common channel.

Uplink (UL) Required MS Transmit Power

Our data below shows the mean uplink required Tx Power at each pixel for the selected service. In the plot, different colors are applied to identify the different strength level of UL Mobile Transmit Power. For example, the green represents the UL Transmit Power level between -22dBm and -12dBm. The outdoor coverage threshold of the UL Mobile Transmit Power is 23dBm; meanwhile in this simulation there is 5dB-fading margin to obligate for 75% edge coverage probability that means in the area where the UL Mobile Transmit Power is less than 18dBm the uplink outdoor edge coverage can be satisfied with a probability of 75%. Moreover, here we set the penetration loss of buildings as 20dB, so the indoor coverage threshold of UL Transmit powers, traffic channel powers and background noise at any pixel. There is an improvement after the optimization in the Call Setup success ratio and call drops.

In the plot, different colors are applied to identify the different strength level of the Mean Received Power. For example, the Green represents the Received Power level between -80dBm and -70dBm.In CDMA system, downlink coverage effect lies on both DL Received Power and Pilot Ec/Io. For example, with the increase of user, the strength of Received Power will be stronger, while the strength of Pilot Ec/Io will decrease. Only if both of them satisfy the coverage threshold, the downlink coverage effect could be ensured well. The outdoor coverage threshold of Received Power is -105dBm; meanwhile in this simulation, there is 5dB-fading margin to obligate for 75% edge coverage probability, which means in the area where the Received Power is greater than -100dBm the outdoor edge coverage of downlink can be satisfied with a probability of 75%.

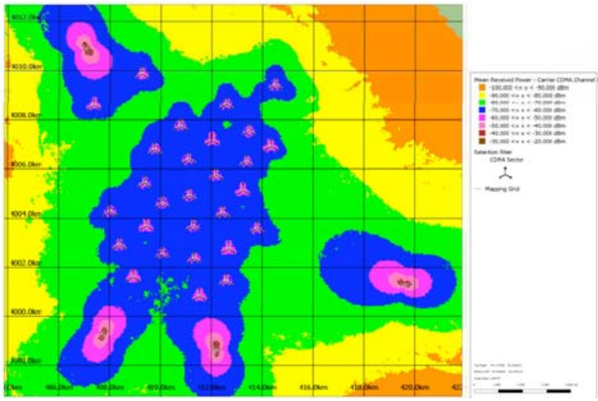

Figure 31: Downlink Simulation.

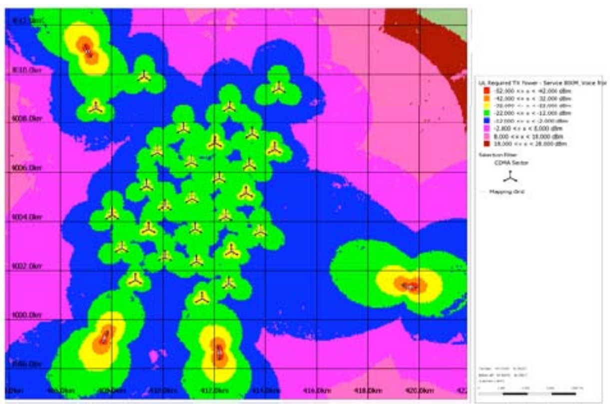

Figure 32: Uplink Simulation.

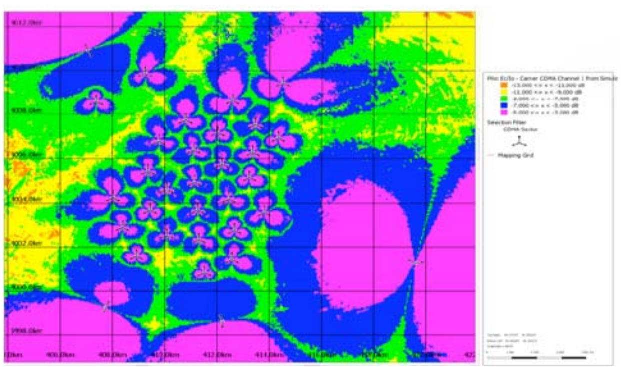

Figure 33: Downlink Pilot Ec/Io Simulation.

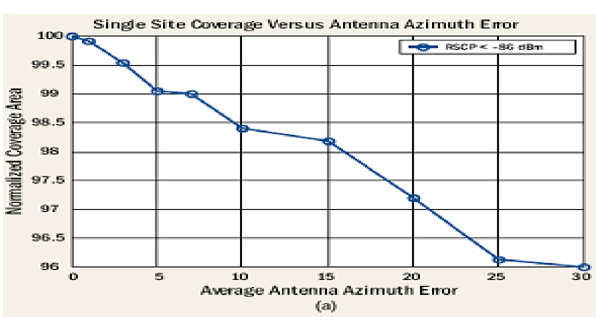

Figure 34: Average Antenna Azimuth Error.

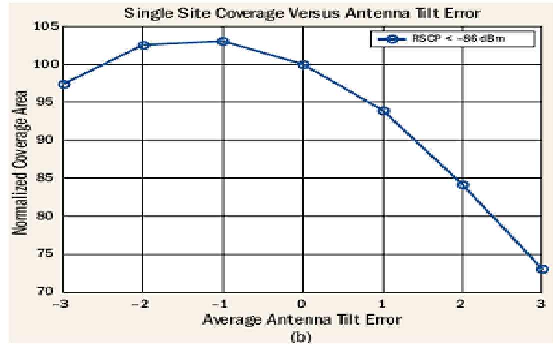

Figure 35: Downlink Simulation.

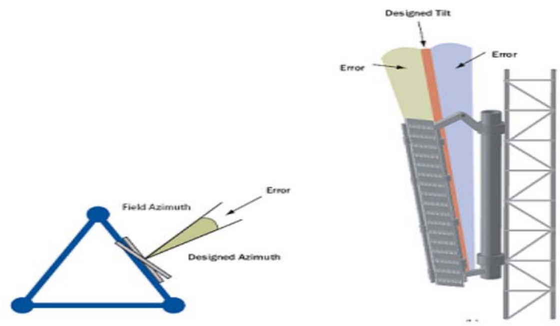

Figure 36: Antenna Errors[24].

Moreover, here we set the penetration loss of buildings as 20dB, so the indoor coverage threshold of Received power is -80dBm. As shown in the plot, the Received Power in the areas except orange, yellow is greater than -80dBm, so the downlink indoor coverage in these areas can be satisfied [21].

Power is -2dBm. As shown in the plot, the UL Transmit Power in the red, orange, yellow, green, blue area is less than -2dBm, so the uplink indoor coverage in these areas can be satisfied [21].

The Downlink (DL) Pilot Ec/Io

The Pilot Ec/Io figure displays the achieved pilot Ec/Io for each pixel and is in effect, the same as Ec/Io for the first best server. In the plot, different colours are applied to identify the different level of DL Pilot Ec/Io. For example, the Green represents the Pilot Ec/Io level between -9dB and -7dB.

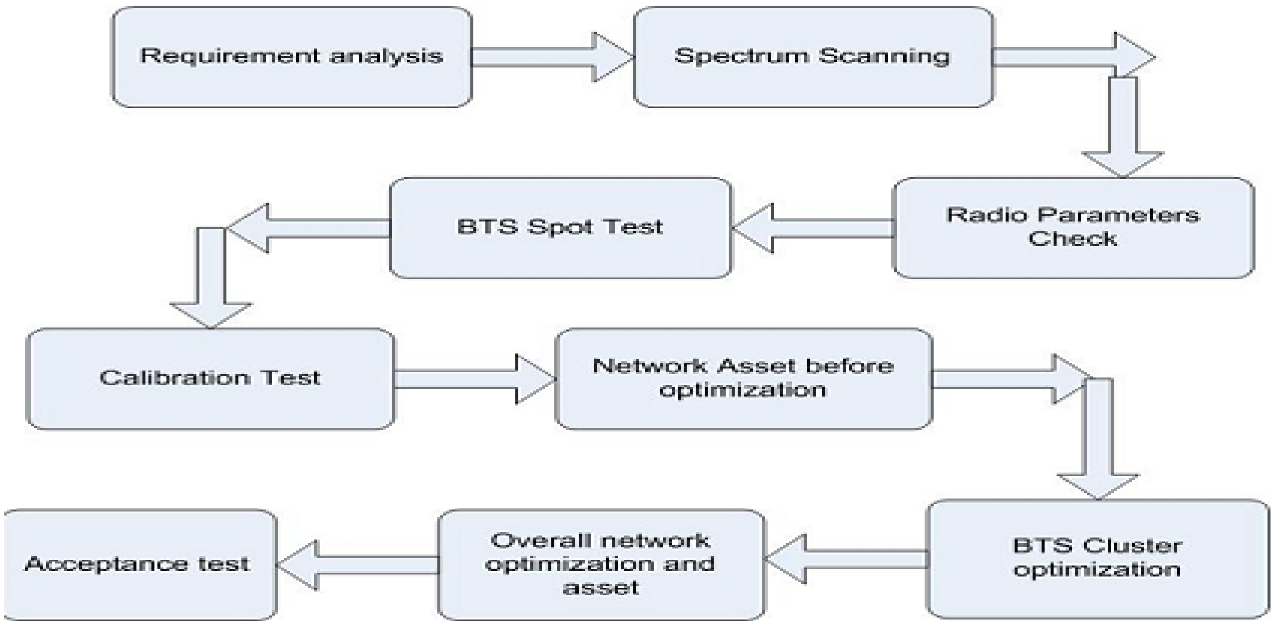

Figure 37: Recommended Optimization Procedure.

In CDMA system, the Tdrop threshold is –13dB, which is to say that when the Pilot Ec/Io level is below this threshold, the DL coverage can't be satisfied; and when the DL Pilot Ec/Io level is below –11dB, the DL coverage effect may be not good. As shown in the plot, the Pilot Ec/Io in the pink, blue, green, yellow, orange area is greater than –13dB, so the downlink outdoor coverage in these areas can be satisfied; and the pilot coverage effect in the pink, blue, green area, yellow is good.

CONCULSIONS

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, for a successful outcome. The antenna hardware changes (tilt and azimuth) are important issue in the network optimization, as it is observed that most times the advised changes are not correct.

The load on the system increases with time and thus affecting the network performance, hence the need to periodically monitor the carrier loads, and expand the network if necessary. Interference affects network capacity and the overall performance and quality of end user experience (call setup, call drop rate, etc) and these are considered key issues that need to be resolved.

Network planning must be based on standard value to predict the demand services area and QoS. It is important to know the network layout and QoS before implementing optimization procedure. There are radio elements to use as check to adjust the parameters to enhance the QoS. The threshold values of the parameters must be used as performance indicators to effect radio interface optimization. Knowing the radio interface protocols of cdma2000 1x is essential for radio interface optimization. The function of channels in setup call and the messaging can provide one with the reasons behind higher call setup failure and also high call drop rate.

CONTRIBUTION OF RESEARCH

The study of the performance optimization of cdma2000 1x networks would help network operators among other things:

i. To identify and eliminate hidden problems that can reduce their network availability.

ii. Maximize the capacity of their current configurations and improve cell coverage.

iii. Increase network capacity and improve user experience.

iv. Maintain user's satisfactions and reduce operational cost.

v. Utilizing network capacity more efficiently without overspending on spectrum and network infrastructure.

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