Journal of Telecommunications System & Management
ISSN: 2167-0919

Research Article Open Access

3G Wireless Network Optimization

Bonsi WY*
Department of Electronics Engineering, Oklahoma State University, USA

Abstract

The importance of wireless communication cannot be overlooked in this modern day of sophisticated communication world. Certainly, like any other technology, wireless communication has major challenges, most of which tremendously affect our daily conversations. This research is focused on wireless network optimization specifically on the Code Division Multiplexing Access (CDMA) technology. Emphasis will be on the importance of optimization and the various strategies adopted to optimize a wireless network.

The beginning part of the research contains a comprehensive introduction of wireless optimization and specifically touched on its definition as well as the most essential aspect of its application in the wireless network. The research explicitly identified important Key performance indicators which usually monitors the performance of the wireless network.

Also, in order to solve wireless network deficiencies, several approaches are used to achieve this goal. The research touched on these approaches and described how exactly they are applied to optimize a network. Wireless optimization is mainly achieved with the use of special tools such as drive test tools. As part of the research, the most important tools were identified as well as their applications. Additionally, a broad analysis was made on some common wireless issues as well as strategies adopted to resolve them. Some of the common problems identified include: handoff issues, call failure issues PN planning issues, Neighbor list planning issues as well as pilot pollution issues.

Furthermore, in order to better understand the optimization in the practical sense, a case study was analyzed by comparing specific samples of results gathered before and after optimization. The results clearly demonstrated that wireless optimization improves wireless performance tremendously, which goes to attest to the fact that, the end results have a positive impact on subscribers and the composite society at large with tremendous benefits ranging from financial to great customer satisfaction.

Keywords: Wireless optimization; Wireless network deficiencies; Network analysis tools

Introduction

Wireless network optimization is a key process in the wireless network. The main objective of optimizing a wireless network is to ensure quality coverage of RF signal which is being transmitted by the Base Station Transceivers (BTS) or Radio Base Stations (RBS). There are various processes involved, which mainly include the collection of data, analysis of the data collected, where engineers ascertain the problems associated with the network and a final step optimization, which deals with the solutions or recommendation to the problems [1].

The first stage, data collection is mainly achieved through a drive test. Several drive test tools such as test phone, laptop, GPS antenna and other gadgets are used to collect the data. The research paper expatiates more on the procedure of drive testing. Also, data analysis is achieved with the aid of sophisticated network analysis tools. Wireless network and optimization engineers depend on both the data collected and the analysis to come out with possible solutions or recommendations to the issues encountered on the network.

However, various key performance indicators (KPI) are specifically monitored to indentify trouble spots in the network. Some of these KPIs include: call drop rate, call failure rate, handoff /Handover failure rate and paging success/failure rate. The research focused on all the various stages involved in optimization as well as the approach to reaching a viable solution for an effective wireless network. It is important to note that, when a wireless network is well optimized, the subscriber is happy, the operator maximizes revenue and also other key players that heavily rely on wireless network surely get their satisfaction. Obviously, it is essential to give great attention to wireless network optimization especially as it benefits all the stake holders involved [2].

Wireless Network Architecture

Generally, the CDMA network consists of the Radio Access Network (RAN) and the Core Network. The RAN network mainly consists of the Base Transceiver Station (BTS) which manages the radio resources while the Base Station Controller (BSC) controls and manages the base stations [3]. The core side of the network is basically responsible for all the switching activities in the network. Wireless network optimization involves most of these elements but this research mostly concentrates on major optimization practices on the RAN side (Figure 1).

Key Performance Indicators (Kpis)

These indicators show the conditions of the RF environment mainly at the end user side. They are used as a guide to monitor the performance of the wireless network to help in optimizing the wireless network shown in Appendix. Some KPIs in CDMA network include Handset Received Power (Rx power), Handset Transmitter power (Tx power), Frame Erasure Rate (FER), Ec/Io etc. Some of the most sensitive KPIs are explained into details in the subsequent sections.

Handset received power (Rx power)

The received power at the handset is a measure of the power

***Corresponding author:** Bonsi WY, Oklahoma State University, USA, Tel: +1 405-744-5000; E-mail: wyjnrbonsi@yahoo.com

Received August 24, 2015; **Accepted** February 17, 2016; **Published** February 26, 2016

Citation: Bonsi WY (2016) 3G Wireless Network Optimization. J Telecommun Syst Manage 5: 129. doi:10.4172/2167-0919.1000129

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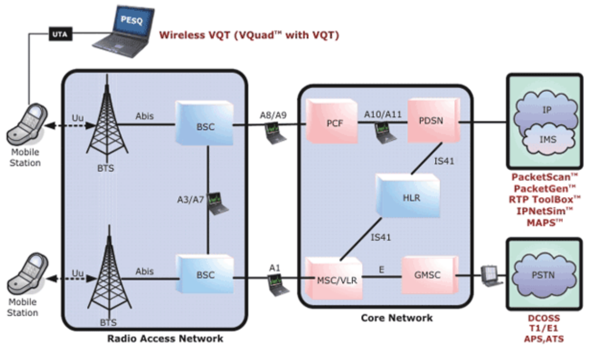

Figure 1: The wireless architecture of a CDMA network.

received by the handset from the base stations. It usually determines the strength of the signal being received by the handset. It is usually measured in dbm. Typically, Rx power of range between -40 dbm to -90 dbm is usually good enough to place a successful voice call. The stronger the Rx power, the higher the chances of remaining on a call without dropping. However, it is important to note that too much received signal of -35 dbm and above could cause serious distortions in the handset and attract noise [4]. On the other hand, too little received power of -100 dbm and below will lead to poor voice quality and allow room for noise and interference for that matter. In most cases such weak received power leads to dropped calls or call failures. This indicator is very essential for network optimization engineers as its effect is immediately noticed by the subscriber. Once the Rx power is identified as the problem, the optimization engineer gets the idea of what to optimize in the network to improve the signal strength [5].

Handset transmit power (Tx power)

The handset transmit power is usually sent by the handset to the base station when the base station requests some power. Usually in very poor coverage areas, the base station strains all its resources to satisfy the coverage conditions. In a typical CDMA system, the base station asks for the power and the handset transmits that power requested to the base station. Reasonable transmit power ranges between -45 dbm and +20 dbm. If the base station asks for too much power or too little power, something might be wrong somewhere with the network. A transmit power of -60 dbm or below is considered low while a transmit power of +23 dbm or above is exceeding the maximum capacity of the handset and that will lead to serious issues of significant noise in the network. Ideally, the base station should be able to use least resources from the handset to produce the best results because the handset also requires power to sustain itself.

Frame erasure rate (FER)

This indicator is used to measure the quality of voice in a wireless network. If FER is bad, then there must be a problem with other indicators. FER is the end result of other indicators. FER is measured in percentages and ranges from 0 to 5 percent. Basically, a FER of 0% to 2% is considered quality and acceptable voice quality in a CDMA technology. Once it gets to 3% and above, then the voice quality is depleted and must be investigated and optimized.

Ec/Io

This indicator measures the signal strength of each sector of a base station. This is what guides the handset to do handoffs or handover to another sector. A typical sector of a base station transmits a certain amount of power which comprises the sum of pilot power, paging power, synchronization power and traffic power. Ec/Io is the measure of the ratio pilot power (Ec) to the total power (Io). This indicator is greatly affected by the RF environment and the traffic on the network.

Transmit gain adjacent (TXGA)

The base station has the capability of asking the handset to do power correction from its side. This is the measure of TXGA. When the handset is having too much power, the base station asks it to reduce its power. On the other hand when the handset is having too weak power the base station asks it to increase its power to make the correction. This up and down power control is usually done by a step of 1 db at a time.

Network Optimization

Drive test

Drive testing is the process of collecting mobile wireless data to ascertain coverage conditions within a specified coverage area. This activity usually involves a moving vehicle which carries various measurements tools to collect the data. The vehicle usually follows pre-planned routes with significant attention given to bad coverage areas.

Drive test tools

It is very essential to get the following drive test tools ready before a drive test is performed.

- Drive test data collection software
- Digital map of test area
- Laptop, installed with the appropriate Windows
- Test phone
- Test terminal, including cables for connecting laptop
- Handheld GPS, including external antenna and cables for connecting laptop
- Inverter and patch board (the plug is two-phased);
- Two-port serial card or USB cable for serial port conversion
- Car, with the ignition working normal.

Testing routes

The test route is usually designed to cover the coverage radius of the base stations and usually focuses of the major and minor roads within a city of town.

Pre- drive test preparations

Also, before the optimization engineer sets out for the drive test, it is very important to check the following:

- Check to make sure the bases stations within the test route are up and running
- Check to make sure if all configurations are properly in place.
- Check to see if the neighbor lists of the various base stations are properly configured.
- Note the troubled areas especially from pervious tests or from complaints by customers.
- It is also very important to keep other supporting engineers in the loop so that they can help check some configurations and make editions when the need arises.

Drive test time

The test is usually performed during network busy hours unless otherwise requested by the network operator.

Drive test data collection

After all the necessary configurations are set, the engineer starts a call either voice or data then drives to test the planned routes. While drive testing, some key information must be observed, these include: layer 3 messages which display the logs of the call in progress, the pilot sets and the call status to determine if the call is up or dropped at some point. Also while testing, all issues encountered with the connections and occurrences that interrupt testing must be fixed immediately before test is resumed. Also, the engineer saves all the drive test data for analysis purposes. Once the drive test route is competed, the call is ended and the drive test is ended as well.

Drive test data analysis

The data collected during the drive test is analyzed to determine the true state of the network performance. Special software is used for the analysis and varies from operator to operator. The main idea is to analyze key performance indicators which display the actual RF environment of the wireless network. Some major problems that calls for optimization actions include: low call completion rate, poor voice quality, high call drop rate, handoff failures, call failures, missing neighbors, pilot pollution etc.

Common Wireless Problems

Low call completion rate

This is a scenario where calls being made by subscribers drop or end abruptly in the process of the calls. The essence is that the voice traffic is not established at all. Once this rate is observed, there might be an issue.

Possible cause: The possible cause for this problem is that the communication or call processing card may be faulty or it may have been loosely connected.

Optimization: The optimization engineer's first point of attention will be the call processing card. The usual action taken will be to either reset the card or replace it. Calls are made afterwards to ascertain whether the issue has been fixed or not.

Call drops

This is a very common scenario in a day to day experience of the wireless user. This is a situation where a subscriber while in call, experiences severe drops in the call and thereby making it extremely difficult to hear the other party. This problem usually records a very high FER of between 4 and 5%.

Possible cause: The neighbors of the base station transmitting signal to that handset may not have been configured right or they may not have been configured at all. In this case, once the handset moves away from that particular base station, its signal gets weaker but if the next nearest base station is not configured then once the signal becomes too weak, the call drops. It could pick up some weaker signals from other base stations and since they are too weak, the call keeps dropping intermittently.

Optimization: In this case, the best solution is to reconfigure all the neighbor cells of each base station into their respective neighbor lists. This will enable the handset to smoothly transition from one base station to another without any call interruption.

Poor coverage

This is a scenario where the base station coverage area is far below expected and as a result causing the issue of weak signals which could lead to several other complications.

Possible cause: Poor bearing or antenna or poor down tilt. If the antenna down tilt is not adjusted such that it can transmit signal far enough to satisfy the subscribers in a particular area then this issue will be inevitable. This same issue could be caused by objects blocking the signals from travelling far and also, a weak transmitting power from the base station can cause the issue of poor coverage.

Optimization: The engineer determines the appropriate antenna down tilt and bearing and adjusts accordingly. In most cases, urban and densely populated areas have higher values of down tilt while less dense areas have a much smaller tilts. On the major highways, most engineers keep a zero degrees down tilt. The optimization engineer adjusts the antenna depending on the location and other factors technical factors. Also, the engineer makes sure that the antenna is redirected towards the trouble area. The optimization engineer also checks the power settings of the base station and adjusts it accordingly. Additionally, the issue of obstructing objects must be considered greatly. The optimization engineer ensures that the antennas are positioned such that they are not obstructed by any object.

Pilot pollution

When the handset receives signal from different sectors with approximately the same strength it leads to interference. The mobile gets confused and cannot decide on which of the base stations to listen to.

Possible cause: This usually occurs when sectors with the same identity (PNs) are very close to each other and configured in the same neighbor list, a phenomenon called PN reuse. In this case, when the handset sees the same PN anywhere around, it tries to listen to it and this causes interference.

Optimization: The engineer eliminates cells that are not intended to serve a particular area from the neighbor list. Also, the optimization engineer ensures that all sectors that have reuse PNs are far apart.

Handoff failures

This is a case where a handset traveling away from the serving sector fails to transition to the next available and closest sector to receive the required signal to sustain a call. This is a very common failure in the wireless network and leads to very high rate of drop calls.

Possible causes: There could be an obstruction blocking the signal of the new sector from reaching the handset. Also, it could be due to the fact that the new sector is not configured in the neighbor list and hence the handset could not see it. It could also be that the new sector is not functioning properly due to the base station being down or other technical issues.

Optimization: The optimization engineer solves the obstruction problem by repositioning the sector antenna while avoiding any obstruction along its path. Additionally, the engineer ensures that all sectors are configured appropriately in their respective neighbor lists and also makes sure that all the base stations are up and running.

Case Study

Introduction of case

This case study was a typical example of a network coverage issue in Ghana. The Network optimization team of ZTE Corporation Ghana received complaints from subscribers that travel along the Southern Ghana roads that they were experiencing frequent call drops. As the lead of the Optimization team at that time, I carried out a drive test to ascertain the situation and implemented the necessary steps to improve the coverage. From Figure 2, the map captures the towns along Southern Ghana which was used as the test route. The base stations serving the major road were also captured in Figure 1 and they are as follows: Kakasunan, Nyigbenya, Kasseh, Adafoah, Keta and Denu. All the base stations have three sectors except Keta which has only two base station sectors.

Data collection process

Drive test was conducted along the road. All the base stations were up and running before the drive test was conducted. The drive test tools were used to collect the test results and the data analysis software was used for post analysis of the data. A continuous uninterrupted call was placed while the data was being collected. As the engineer in charge, I took note and made sure that anytime a call drops along the way, the vehicle came to a complete stop and a new call was started before test resumes. Also, the test data was collected both before and after optimization using the same test route.

Coverage analysis

As indicated in Figure 3, a handset with Rx power ranging from -85 dbm (yellow) and above will have a strong signal enough for uninterrupted call. However, as the Rx power approaches -95 dbm (red) and below, the call quality begins to fade and eventually drops. Areas circled A, B and C recorded the worse Rx power and that is a clear indication that calls were interrupted in those areas. The idea was to investigate the poor coverage in those areas and take optimization steps to improve the coverage. A similar test was performed after optimization to really ascertain if the situation improved or not.

Optimization

Area A: In area A of Figure 3, the coverage was poor before optimization. The bearing of the alpha sector of Nyigbenya facing area A was changed from 30 to 70 degrees to have a better direction towards A. It was also realized that the antenna was tilted such that it could not transmit far away from the base station hence the down tilt of the antenna was reduced from 4 to 1 degree. Also, from the other side of A was another base station with the name Kasseh. One of the sectors of Kasseh was facing area A. In order to have a better coverage on A, the bearing of that sector (alpha) was also altered from 240 to 260 degrees whilst its down tilt was altered from 3 to 1 degree. After optimization, there was a great improvement in the coverage in area A without impacting other areas negatively.

Figure 2: Capture of the major roadunder test (in red).

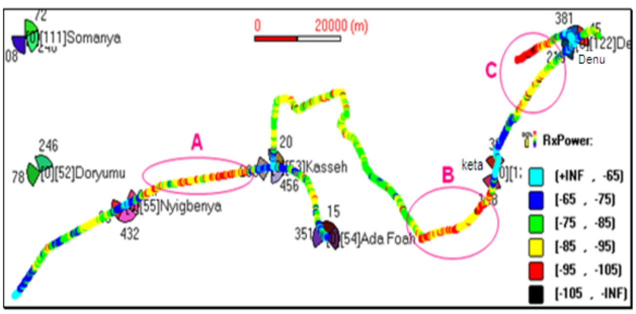

Figure 3: Cover age condition along the Southern Road of Ghana.

Area B: In area B of Figure 3 our investigation revealed that the coverage was very poor because the transmitting (Tx) and receiving (Rx) cables of Keta site were wrongly connected. Specifically, the beta sector and the Gamma sector cables were swapped and so it affected transmission greatly. These cables were reconnected correctly. Also the other side of Area B which was served by Adafoah, was also not facing area B correctly so the respective sector (alpha) sector was adjusted from a bearing of 40 to 90 degrees. These optimization steps brought a great improvement in coverage of area B.

Area C: The Coverage in area C of Figure 3 was also really bad before optimization. The major cause of coverage problem was the antenna direction and it's down tilt. The antenna of the Denu beta sector which was facing area C was altered from a bearing of 180 to 240 degrees, whilst its down tilt was as well adjusted from 4 to 1 degree. Also, Denu gamma sector was also changed from a bearing of 350 to 310 degrees whilst the down tilt was changed from 4 to 1 degree. These actions were taken so that the coverage in C will improve without negatively impacting the coverage of any other area. After optimization, there was a great improvement in coverage around C.

Analysis of forward receiving (RX) power of handset before and after optimization: The contrast between before and after optimization is clearly seen in Figure 4. As indicated earlier, a good received power by the handset ranges from -75 dbm and above. Obviously, the bar graph in Figure 5 shows that for ranges above -65 dbm, the handset recorded 27.18% after optimization against 17.78% before optimization. Also for a range of -65 dbm to -75 dbm, 22.8% was recorded after optimization while 18.28% was recorded before optimization. The same trend was recorded for the range of -75 dbm to -85 dbm which recorded 33.26 after optimization and 21.38 before optimization. That is a clear indication of as tremendous improvement in coverage as a result of the optimization steps taken.

Analysis of EC/Io before and after optimization: As stated earlier, the Ec/Io indicates the power strength being transmitted from each sector of the base station. Figures 6-9 clearly reveal the signal strength before and after optimization. For the purpose of comparison, Figure 7 gives the statistics of the composite Ec/Io throughout the test for both scenarios. High Ec/Io produces a better coverage. Specifically, Ec/Io of -10 dbm and above is the most ideal for a handset. The results in Figure 7 shows that for a power of -6 dbm and above, the Ec/Io recorded before optimization was 69.57% as against 88.55% after optimization. This is a tremendous improvement over the initial power.

Analysis of Handset Transmitting Power before and after optimization: This indicator as stated earlier is sent by the handset to the base station. The most ideal situation is that the base station requests very little from the handset but produces quality call results in the end. With this indicator, the least power requested from the handset the better. As indicated in Figure 10, comparing the results of Tx power being transmitted before and after optimization, the following are obvious:

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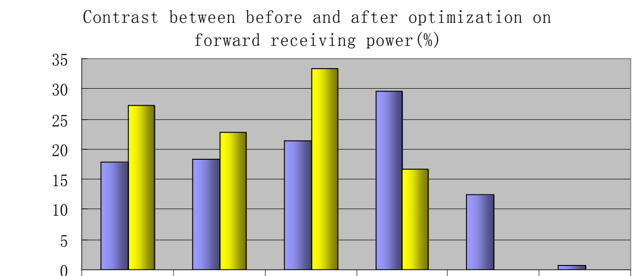


	>=-65dBm	-65 to -75dBm	-75 to -85dBm	-85 to -95dBm	-95 to -105dBm	<-105dBm
before	17.78	18.28	21.38	29.58	12.34	0.64
after	27.18	22.8	33.26	16.67	0.09	0

Figure 4: Contrast between before and after optimization Rx power.

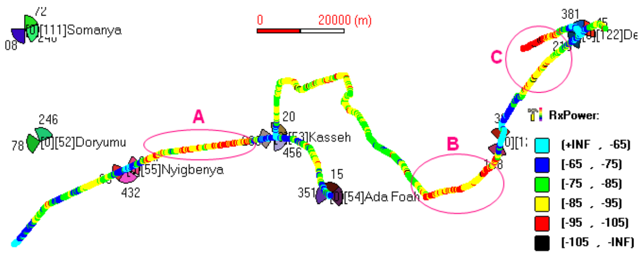


Figure 5: Forward receiving power of handset before optimization.

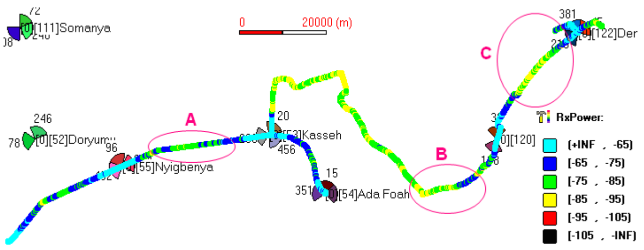
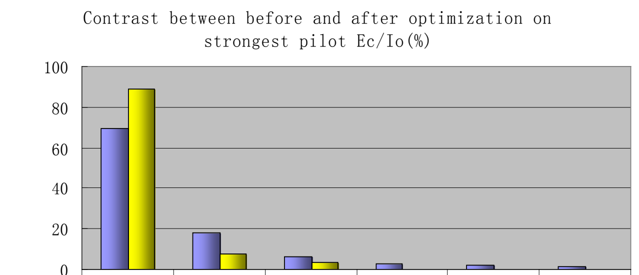


Figure 6: Forward receiving power of handset after optimization.



	>=-6dB	-6 to -8dB	-8 to -10dB	-10 to -12dB	-12 to -15dB	<-15dB
before	69.57	17.91	6.28	2.57	1.96	1.71
after	88.55	7.93	3.32	0.17	0.03	0

Figure 7: Contrast of Ec/Iobefore and after optimization.

For a low power of -20 dbm and below the Tx power before optimization recorded 24.19% against 31.48 after optimization. It is realized that there was an improvement after optimization. The trend of improvement after optimization continued for low power ranges of -20 dbm to -10 dbm as well as the range of -10 to 3 dbm which is the objective of the Tx power (Figure 11).

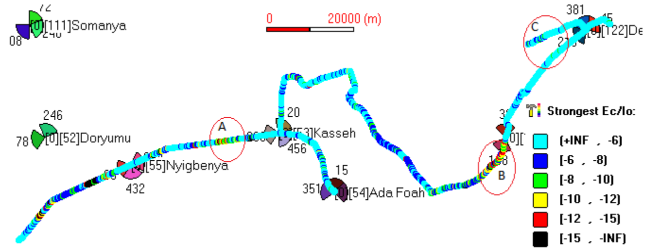


Figure 8: Ec/Io results before optimization.

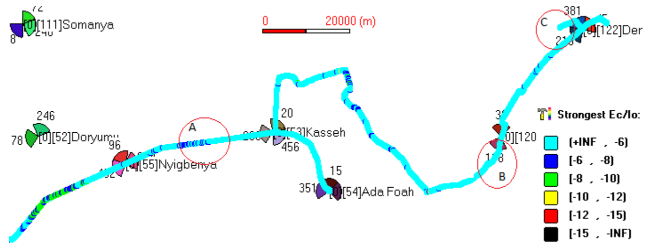
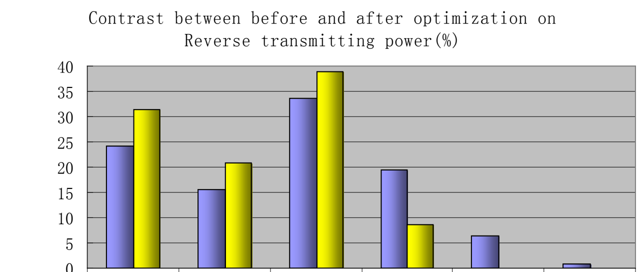


Figure 9: Ec/Io results after optimization.



	<=-20dBm	-20 to -10dBm	-10 to 3dBm	3 to 13dBm	13 to 23dBm	>23dBm
before	24.19	15.57	33.71	19.43	6.32	0.78
after	31.48	20.91	38.89	8.67	0.05	0

Figure 10: Contrast of Handset Tx power before and after optimization.

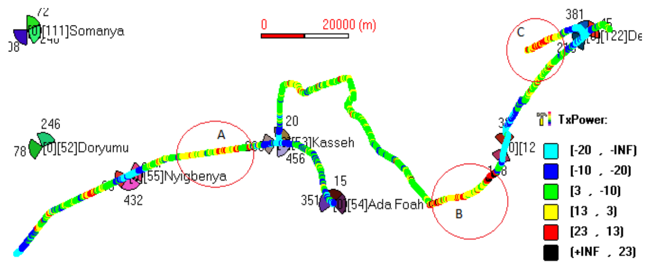


Figure 11: Handset Transmitting (TX) power before optimization.

Analysis of Frame Erasure Rate (FER) before and after optimization: This indicator shows the voice quality of the calls and once this is bad, it is obvious there is a problem somewhere. This was very important as it helped quickly notice trouble spots along the test route (Figure 12). The FER which is measured in percentages produces the best voice quality at the range of 0 - 1. From Figure 13 the FER before optimization for a range of 1 or less, recorded 83.27% while that after optimization shot up to 99.46%. For the range of 3 to 5, the FER after optimization was 0% which implies that there were no drop calls.

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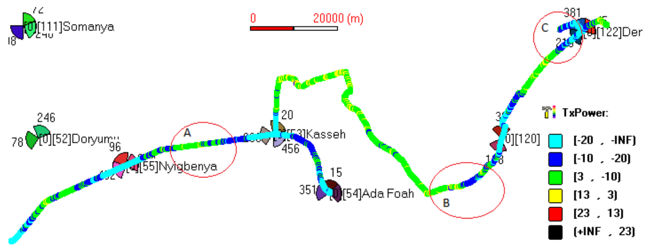
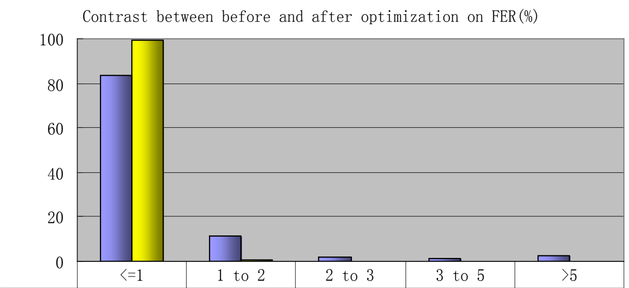


Figure 12: Handset Transmitting (Tx) power after optimization.



	<=1	1 to 2	2 to 3	3 to 5	>5
before	83.27	11.11	2.13	1.1	2.39
after	99.46	0.5	0.04	0	0

Figure 13: Contrast of FER (Voicequality) before and after optimization.

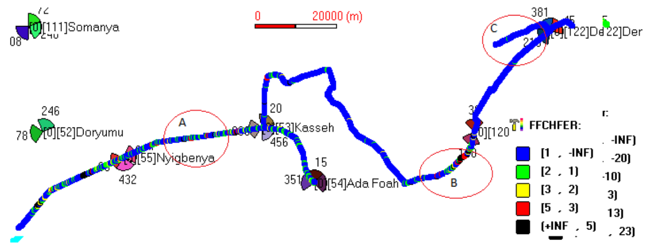


Figure 14: Analysis of FER (voicequality) before optimization.

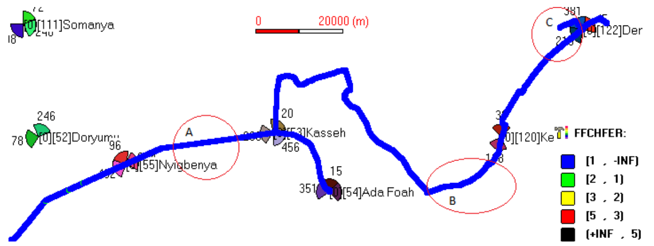


Figure 15: Analysis of FER (voicequality) after optimization.

It is obvious that the optimization steps taken tremendously improved the voice quality (Figures 14 and 15).

Conclusion

Wireless network optimization is one of the most essential aspects of engineering in the wireless network. Certainly, the essence of optimizing a wireless network as highlighted earlier in the report leads to improved customer experience. Also, a well optimized network reduces cost of the operator as well as saving resources for other uses such as expansion of the network. Furthermore, a quality operating network brings in huge revenue for the operator as well as other customers especially those who rely heavily on telecommunication. Some government instituted security features such as 911 and Location Base Services largely depend on a reliable wireless network. As such, meticulous optimization benefits not only the individual subscriber but the entire citizenry at large. Surely, with all the advantages both in the area of satisfaction of the customer on one side and revenue generation for the operator on the other side, one can be quick to conclude that a wireless network cannot exist without a thorough optimization.

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