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Site-Specific Assessment of Node B using Key Service Quality Indicators over 3G/UMTS Networks from Outdoor Drive-Test Measurements

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Abstract

Periodic service quality monitoring of a deployed cellular communication network by means of an innovative expert-driven field test analysis provides an in-depth understanding of the status and performances of the network as well as of the statistical behaviour of the user population. Such knowledge allows for a better engineering and operation of the whole network, and specifically the early detection of hidden risks and emerging troubles. In this paper, an experimental performance assessment of Node B based on key quality parameters considered for design, planning and network optimization was carried out via drive test at Ugbor avenue, BIU Campus and Gapiona avenue, all located in G. R. A, Benin City. It was established that the Ec/lo range measured for BEN 035 (BIU) indicates that the BS will be able to support services demanded by more subscribers accessing the network. Proper tuning is required on this BTS to eliminate the possibility of noise interference by this BS on nearby BSs when the loading is low. It was discovered that the QoS is very poor in the environs of BEN026, with the result that UEs will not be able to access data due to rapid data rate decreases, network login difficulty, difficulty in call initiation, no network, and high call drop rate. Hence the CPICH power level should be adjusted so that base station can provide service to users; however this does not guarantee that the interference caused by other nearby base stations is within the acceptable range to establish the session. At BEN 098 (Gapiona avenue) the Ec/lo is below the standard which is -9 dB for data which low means the QoS at Gapiona avenue is very poor and can only serve for voice calls with no data capacity whatsoever. The bond between RSSI/RSCP and Ec/Io performance at the different measurement locations of Node B were also assessed. It was observed from the results that Ec/Io degrades when RSSI/RSCP decreases. Degrading Ec/Io can be an indication of increased other cell interference which will also increase the need for downlink traffic power.

1. Introduction

The market for cellular and personal communication system (PCS) services has experienced tremendous growth in the recent years. Today millions of people around the world use cellular phones. It is estimated in [1] that by 2013, about 350 million people will be connected to the cellular communications network, which means approximately 200,000 new subscribers every day or 140 new subscribers every minute. This rapid worldwide growth in cellular telephone subscribers especially over these past two decades has evidently showed that the wireless communication is an effective means for transferring information in today’s society.

The cellular communication network has gone through three generations and is now evolving toward the fourth generation. The evolution has been driven by ever the increasing demand and technological development. First generation (1G) systems developed in the early 1980s employs a frequency division multiple access (FDMA) system, in which the bandwidth is divided into a number of channels and distributed among users with a finite portion of bandwidth for permanent use. Second generation (2G) systems deployed in the early 1990s uses a Time Division Multiple access (TDMA) in which in the entire bandwidth is available to the user but only for a finite period of time. Although 2G wireless system, such as the GSM is successful in many countries, they cannot still meet the requirement of high speed data and user capacity in densely areas, since they were designed with voice-oriented services in mind. Consequently, only a limited number of messaging and data services are supported. This limitation in 2G systems piloted the development of third generation (3G) communication systems. The 3G have been created to support the effective delivery of high-speed packet data services. 3G employs Code Division Multiple Access (CDMA), in which all the users occupy the same bandwidth; however they are all assigned separate codes, which differentiate them from each other.

Recently, in [2], it has also been estimated that 3G hand set shipments will exceed GSM shipment and the shipment will approach approximately one billion (1 billion) by 2013. A specific report on 3G-CDMA subscribers’ growth forecast is showed in figure 1

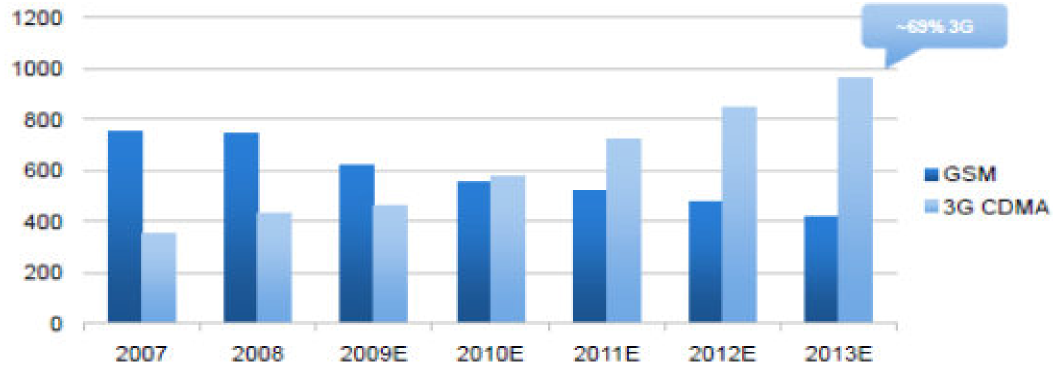

Fig 1: GSM and 3G CDMA growth forecast [2]

And the curve is still headed upward as subscribers take advantage of new data services offered by the 3G-CDMA based networks at an exhilarating rate.

To maintain the above growth and retain existing customers, as well as attracting new ones, the wireless service providers need to deliver new services, consistently, reliably and economically. More importantly, wireless service providers must be ready to continue to maintain the highest quality of service (QoS) to both residential and industrial subscribers. That is where network performance assessment monitoring for optimization comes in. This work will show how well the QoS performs over the 3G/UMTS wireless network via measurement-based performance monitoring.

2. Problem Statement/ Research Motivation

Capacity increase was one of the main motivations for introducing 2G systems in the early 1990s.The advent of 2G-based radio mobile communication such as the GSM started its commercial operation in Nigeria in 2001. GSM system is very good at delivering voice services to its subscribers, and is the most common 2G system in all over the world. However, for data service, the situation is not the same. This has led to continuous network facility upgrade over existing GSM system in order to support more efficient data services.

Recently, a totally new air interface, namely third generation (3G)-based WCDMA air interface for UMTS is being deployed on existing GSM core network in Nigeria with the goal of supporting more efficient data services. The introduction of 3G wireless networks has brought some new services such as video and data services that were not available in 2G GSM networks.

Specifically, in 2007, four applicants were successful in obtaining a 10MHz lot each in the 2GHz band for third generation (3G) mobile services in Nigeria. The successful operators were: Alheri Engineering Celtel, now Airtel Nigeria, GloMobile and MTN Nigeria Communications. In early 2008, GloMobile launched the first commercial 3G service on their UMTS/HSPA network, followed closely by MTN.

Despite the good number on telecom companies operating the 3G-CDMA based technology and services mentioned above, subscribers' satisfaction and quality of service (QoS) in some part of the country is far below expectation. There has been series of complaints arising from frequent call outages, call conversation echoes, drop calls, among others, from mobile subscribers. Some users even resort to the option of subscribing to more than one service provider, just to maintain seamless connectivity, thereby losing a fortune to the network operators. A rising churn rate (i.e. number of subscribers cancelling a contract and setting up a new one with a competitor operator) is an indicator that there might also be something wrong in the technical field.

Moreover, UMTS network planning is far more complicated than GSM voice planning [3]. Because in UMTS, it is not possible to think of minimum received signal level to achieve one maximum interference threshold. Each service needs a specific threshold values and also network behavior changes with traffic.

Accordingly, once a commercial telecommunication network starts its operation, the service providers must continually monitor the network for performance assessment throughout life cycle. This is to aid the network for optimisation purposes. This arises from traffic growth and geographical coverage demands with QoS guarantee, continuous changes in the radio path, including the addition of new buildings, growth of trees, changing foliage conditions and equipment deterioration, all of which contribute in the RF properties in the system [4]. In addition, interference levels changes as new cells are added (including interference from competing networks), and as the subscriber base increases, or the geographic distribution of traffic changes

Performance measurement is an effective means of assessing or scanning the whole network at any time and systematically searching for errors, bottlenecks and suspicious behaviour.

In this paper, we present a measurement-based network performance assessment of a pioneer UMTS network service provider, operating in typical built-up environments, by tackling those QoS performance parameters such as received signal code power (RSCP) and the energy per chip to total received power (Ec/Io), among others, that most influence their planned service quality of the system. For confidential and legal purposes, the names of the service provider will be designated as Operator A throughout the research.

3. Node B in UMTS

Node B corresponds to the Base Transceiver Station (BTS) in UMTS. Node B can manage one or more cells connected to RNC over interface Iub. Node B includes CDMA receiver which convert the radio interface signal into data stream and then forward to radio network controller (RNC) over Iub interface. The CDMA transmitter prepares incoming data for transport over radio interface and routes it to power amplifier, and because of the large distance between the RNC and the Node B time critical tasks are not stored in RNC. The RNC knows the exact picture of the cell current situation and makes a sensible decision on power control, handover and call admission control. The mobile station and Node B continuously measures the quality of connection and interference level and the result is transmitted to RNC. Node B, in some cases handles the splitting and combining data streams of different sectors [5]. Specifically, the Node B has as main tasks to make the transmission and reception of radio signal, filtering of the signal, amplification, modulation and demodulation of the signal and be an interface to the Radio Network Controller (RNC) [6]. The Common Pilot Channel (CPICH) transmits a carrier used to estimate the channel parameters; is the physical reference for other channels. It is used to control power, consistent transmission and detection, cannel estimation, measurement of adjacent cells and obtaining of the Scrambling Code (SC) [3].

4. Key Drive-Test Service Quality Parameters

When a network is tested from the radio interface, normally using drive-test equipment, a set of quality parameters and indicators can be obtained. The most relevant ones for the assessment of a are network are[7][8]:

- Radio link quality parameters, mainly CPICH Received Signal Code Power (RSCP) and CPICH Ec/Io.
- Radio Resource Management data, related to Neighbors Lists, Handover parameters, Cell Reselection procedures and Active Set Management.
- Quality of Service indicators, measuring Throughput in MAC and Application Layers, Block Error Rate (BLER) and Mean Opinion Score (MOS) for video quality.

4.1 RSCP Parameter

RSCP stands for Received Signal Code Power – the energy per chip in CPICH averaged over 512 chips. It is the collected RF energy after the correlation / descrambling process, usually given in dBm. In our previous work in [9], an experimental study of UMTS radio signal propagation characteristics was carried for signal coverage monitoring and prediction by field measurement in the present study locations. Though, experience shows that, at the coverage borders, measuring a parameter comparable to the field strength (in UMTS expressed as RSCP) is sufficient to evaluate coverage. However, for proper function of UMTS equipment, it is not only sufficient to provide enough field strength. Moreover, for the downlink, CPICH coverage should be verified by considering not only if the received signal code power (RSCP) of the pilot channel (CPICH) is sufficient once all the margins are included, but also by estimating the level of interference generated by the other cells. Such interference is typically quantified by the energy per chip to total received power (Ec/Io) of the CPICH. Such quantity effectively estimated how much of the received signal can be used at a given location, or put it in other word, how clean is the signal received.

4.2 Ec/Io Service Parameter

Ec/Io is the ratio of the energy per chip in CPICH to the total received power density (including CPICH itself). This is the ratio of the received energy per chip (= Ec) and the interference level (Io), usually given in dB. Io = own cell interference + surrounding cell interference + noise density. In case no true interference is present, the interference level is equal to the noise level. Interference is typically measured by the energy per chip to total received power (Ec/Io) of the CPICH, that is to say, how clear is the signal that is received. Ec/Io is defined by the pilot cannel, is measured before of the dispreading, all channels contribute to the total power of Io. Therefore it is possible that even at a location close to a base station, with a high RSCP; no logon is possible, due to high interference levels from a second nearby base station. This effect is called “pilot pollution” and network planners try to avoid too close spacing of base stations to minimize regions where it can occur. The value of Ec/Io must be -9dB or higher in 95% of coverage area, so that a UE is associated with a Node B and set in a voice call [10].

4.3 RSSI Parameter

The Received Signal Strength Indicator (RSSI) is a value that takes into account both RSCP and Ec/I_0. It is calculated in dBm by [11]:

$$RSSI[dBm] = RSCP[dBm] - Ec/I_0[dB] \qquad (1)$$

RSSI is used to measure the power between the received radio signals [12]. For each Node B, there is a threshold point below which connection break with active base station. Therefore the signal strength must be greater than threshold point to maintain the connection with active base station. The signal gets weaker as mobile moves far away from active base station and gets stronger signal towards new base station as it move closer. As with RSCP and Ec/I_0, it can only be measured in the code domain and needs the special monitoring equipment as described above.

5. Drive-Test Equipment and Measurement locations

The measurements were conducted from a UMTS network of a Nigerian telecom operator with Node B, located at the BIU Campus, Ugbor and Gapiona Avenues, all evenly distributed in Government Reservation Area (GRA), Benin City. The driving routes in these different locations are shown in figure 2-4. The measured (Ec/Io) and RSCP at different transmitter-receiver (T-R) separation distance (d) are recorded in dB and dBm respectively. Every point of measurements is recorded evenly from all the predefined routes of three base stations. Each measurement point is represented in an average of a set of samples taken over a small area ($10m^2$) in order to remove the effects of fast fading [13].

The data collection tool consisted of ERICSSON TEMS (i.e. a 3G Test Mobile Systems) Cell-Planner tool with an antenna mounted on a moving vehicle 1.5 meter above ground level, Global Positioning System Receiver Set (GPS system) and a personal computer and a piece of compass. The personal computer houses the operating system and the data collection software (ERICSSON TEMS Investigation 8.0). The personal computer serves as the communication hub for all other equipment in the system. The GPS operates with global positioning satellites to provide the location tracking for the system during data collection position on a global map which has been installed on the personal computer. The compass help to determine the various azimuth angles of the base station transmitters. Average height of transmit antenna is about 30 – 32 meter above ground level, with the same transmit power. Sampling rate of the collected data, on the average, is about 2 – 3 samples per meter. Figure 2 shows a scheme of equipment we have used in the measurements.

Figure 2: Measurement equipment

The TEMS software simulates the drive test in real time, that is, it shows the path taken as well as the different Rx levels with different colour codes, as shown in Figure. 3. The green colour is the best case signal reception (-70~-10), red being the worst case (-120~-100), that is, almost no signal and intermediate colours (for example, orange) are regions of call drops or bad quality signal.

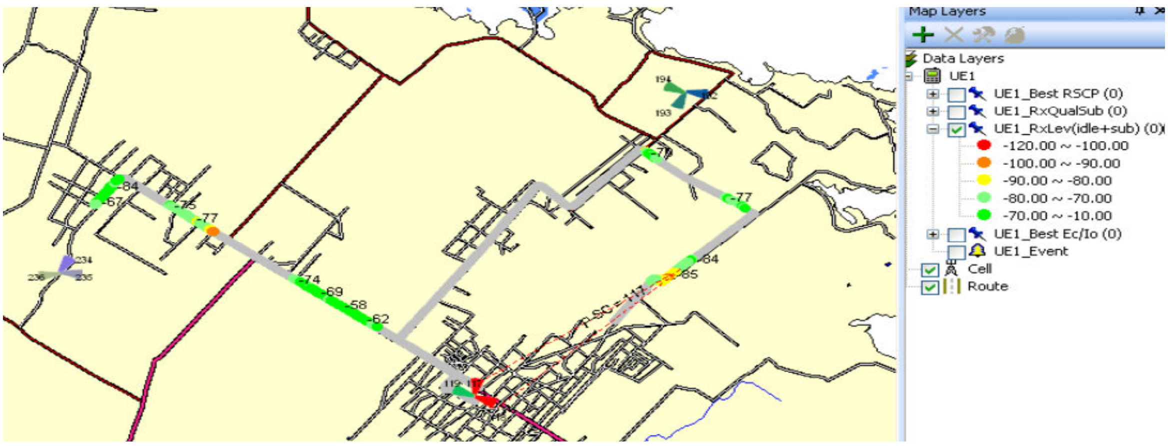

Figure 3: Drive Test Simulation using a Probe

6. Results and Discussion

Figs. 4a – 6a and figs 4b – 6b below show the plot of Ec/lo at various distance of from the Base Station and their analysis solution worksheetof drive test areas for BIU Campus, Gapiona Avenue and Ugbor Avenue. We have fitted a line of best fit to the graphs in 4a – 6a to predict an optimized QoS for each area plotted.

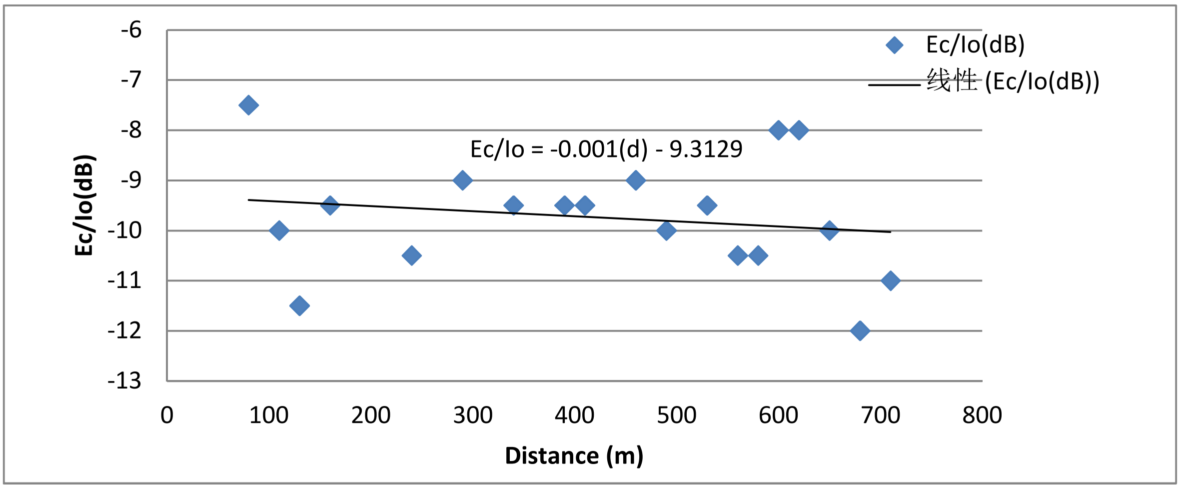

Figure 4a: Plot of Ec/lo vs distance for BEN 035 (BIU)

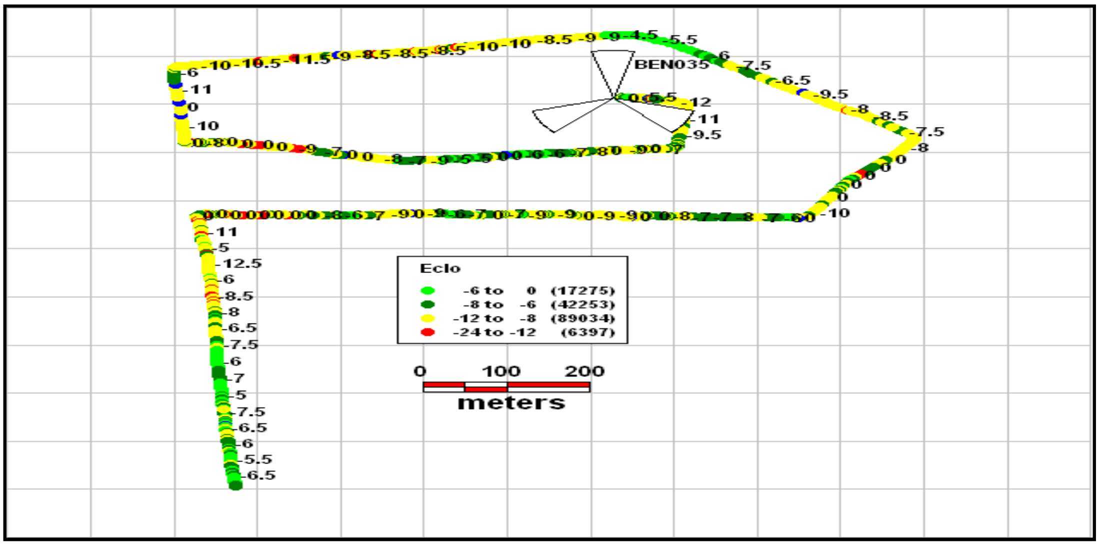

Figure4b: Ec/Io distribution worksheet for site BEN 035 in drive test area

The trend line fitted indicates that the QoS decreases with increase in the distance of the UE from the base station as expected. This is expected but the implication of this is that data rate decreases, network logging becomes impossible, calls cannot be initiated, network signal disappears, and calls are dropped. This low throughput could have been caused by the effect of missing neighbours, low 3G network coverage or no 3G network coverage at all. The Ec/lo range measured for BEN 035 (BIU) is between -12 and -7.5. Using our model where Ec/Io = -0.001(d) - 9.3129 we can improve the Ec/lo to between -10.1 and -9.4 which is comparable to the standard which is -9 dB for data services.

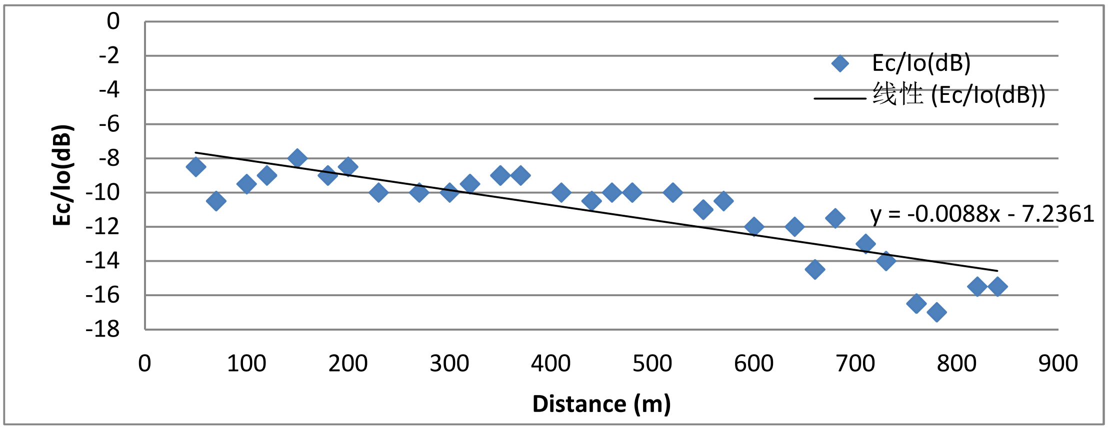

Figure 5a: Plot of Ec/lo vs distance for BEN 026 (UGBOR)

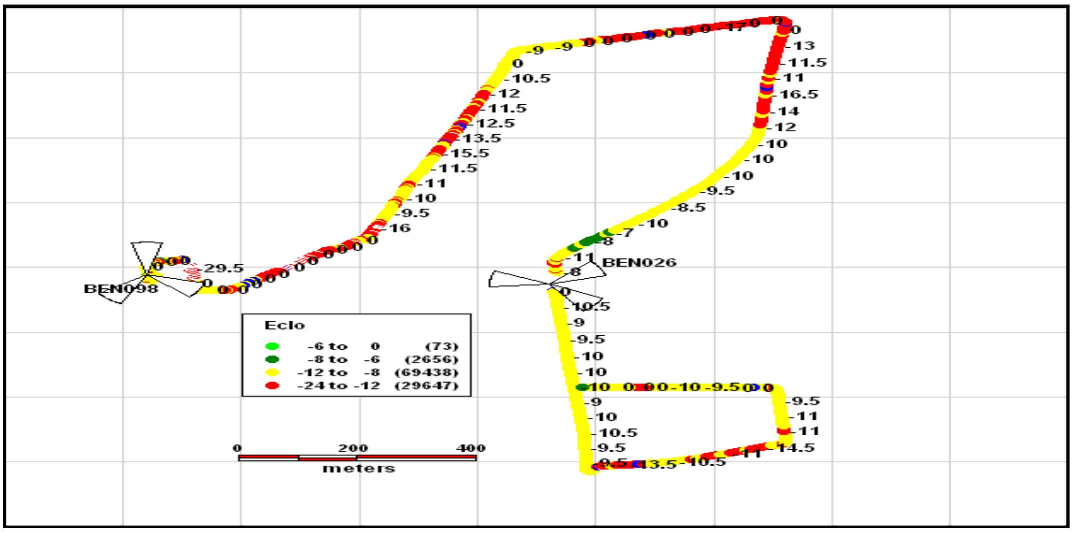

Figure 5b: Ec/Io distribution worksheet for site BEN 026 in drive test area

For BEN026, we discovered that the QoS is very poor with the result that UEs will not be access data due to rapid data rate decreases, network login difficulty, difficulty in call initiation, no network, and high call drop rate. The Ec/lo range measured for BEN 026 (UGBOR) is between -16.5 and -8. Using our model where y = -0.008x - 7.236 we can improve the Ec/lo to between -14.5 and -7.5 which is not up to the standard which is -9 dB for data services at distances of even 200m from the Node B station.

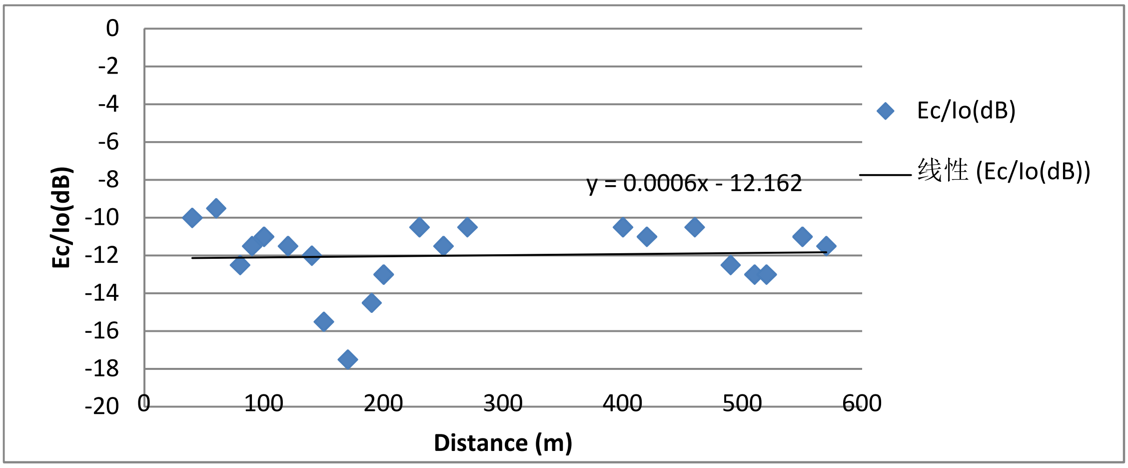

Figure 6a: Plot of Ec/lo vs distance for BEN 098 (GAPIONA AVENUE)

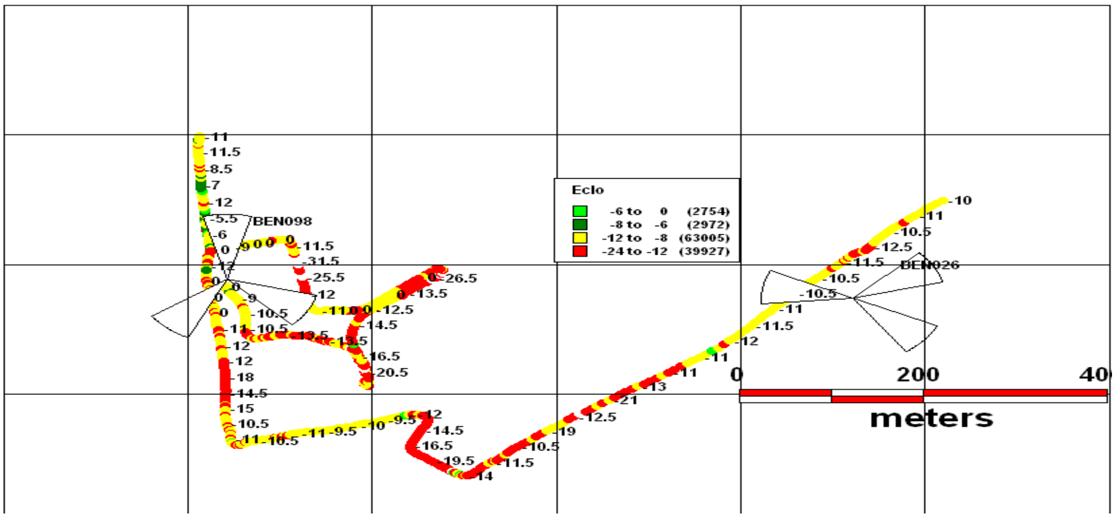

Figure 6b: Ec/Io distribution worksheet for site BEN 098 in drive test area

The Ec/lo range measured for BEN 098 (GAPIONA AVENUE) is between -17.5 and -10. Using our model y =

0.000001x - 12.16 we cannot improve the Ec/lo up to the standard which is -9 dB for data which means the QoS at Gapiona avenue is very poor and can only serve for voice calls with no data capacity whatsoever.

Presented in figures 7-9are charts showing the bond between RSSI/RSCP and Ec/Io values at the different measurement location of Node B. It can be observed from the charts that Ec/Io degrades when RSSI/RSCP decreases. Degrading Ec/Io is an indication of increased other cell interference which will also increase the need for downlink traffic power. Power being a limited resource, the higher required transmit power may not be available, thus the coverage not being met in loaded condition: this represent the coverage and capacity trade-off for the downlink in a WCDMA systems. Also, looking at the charts, the RSSI seems to be the most sensitive parameter to observe. However, UMTS network planners mostly design their network to provide certain RSCP and Ec/Io values. Moreover, it should be noted that the total received signal power (Received Signal Strength Indicator – RSSI) is never considered in a WCDMA system as an indication of coverage. It is mainly due to the inability to estimate the quality by this value: 10 weak cells would result in a strong RSSI, but the lack of any dominant server would yield poor system performance. This concept is sometime called pilot pollution, where multiple servers contribute to a high RSSI, but where the signal cannot be used due to lack of strong dominant server.

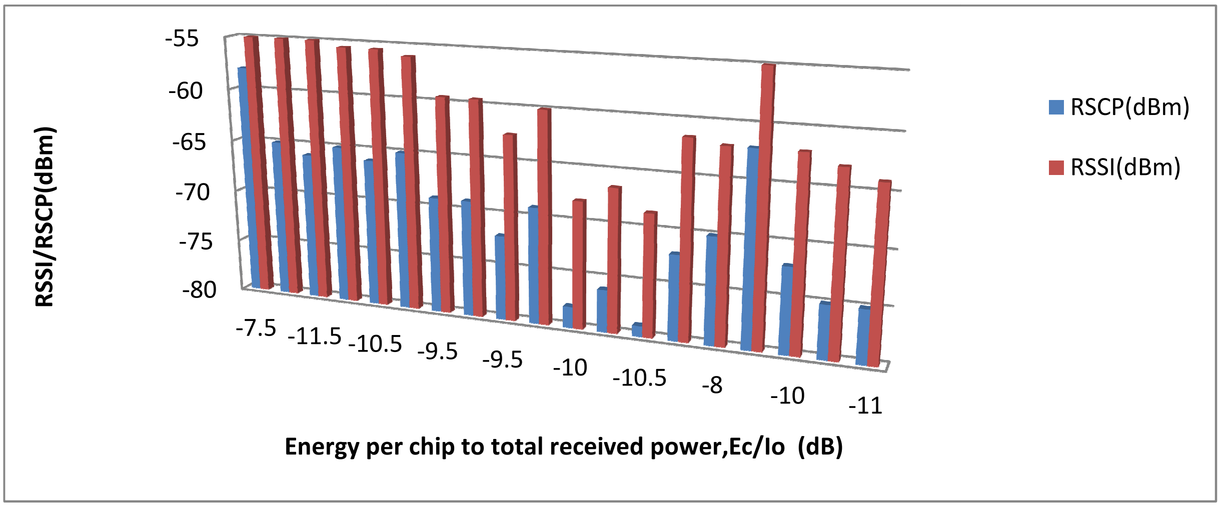

Figure 7: Ec /Io assessment at different RSSI/RSCP in site BEN-035

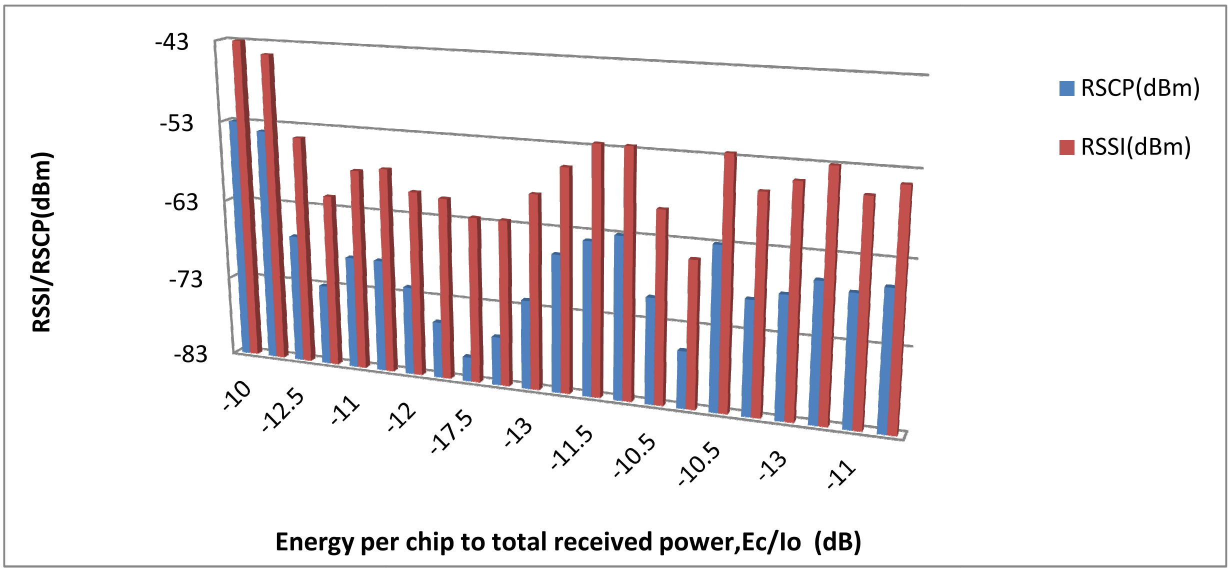

Figure 8: Ec /Io assessment at different RSSI/RSCP in site BEN-098

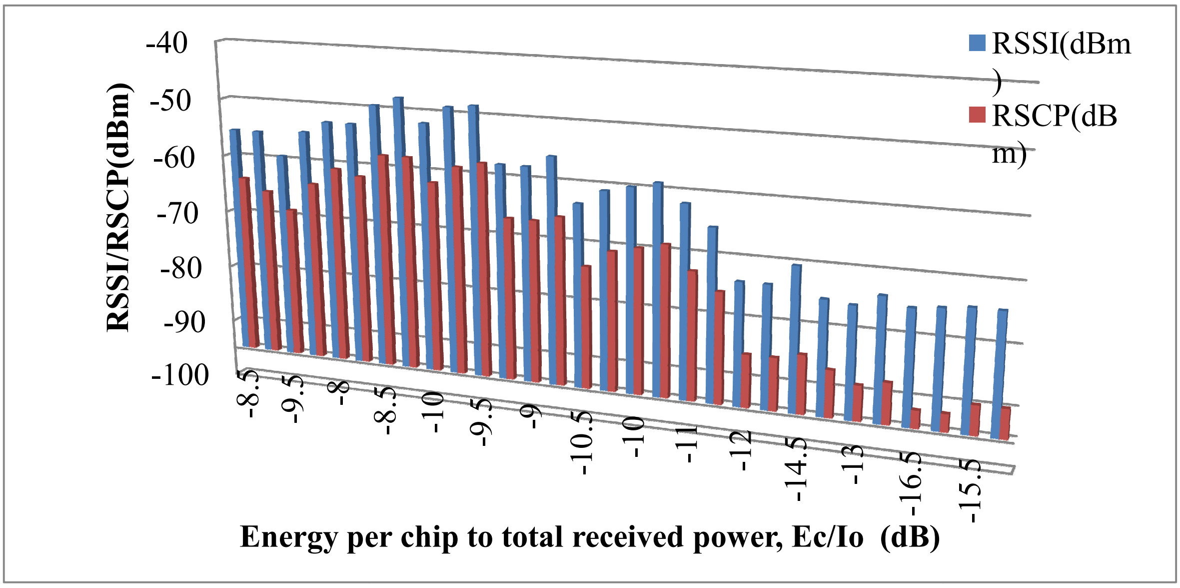

Figure 9: Ec /Io assessment at different RSSI/RSCP in site BEN-026

7. Conclusion

The current evolution of 3G networks worldwide is driven by new and faster data services and the introduction of HSDPA technology to support it. This growth adds more constraints to the Radio Access Network (RAN) configuration in order to offer the required transmission capacity while maintaining the Quality of Service (QoS) indicators above acceptable levels.

One of the major drawbacks of Wideband Code Division Multiple Access (WCDMA)-based technologies, like the Universal Mobile Telecommunications System (UMTS), is that its performance is highly dependent on the interference level, which at the same time is related to the load of the cells. This makes crucial to find an optimization process that ensures the minimum interference levels by adjusting the configuration of some parameters of the network, so as to reach the maximum feasible QoS.All possible optimization techniques start with the measure of Key Performance Indicators (KPI) obtained at different elements of the Network. The most used are the Operations and Maintenance Centre (OMC) and the Testing Equipment (Call-Tracing terminals and Drive-Test (DT) tools).

In this paper, we have studied the QoS of three UMTS type 3G network BTSs in G.R.A, Benin City. We have concluded that the Ec/lo range measured for BEN 035 (BIU) is between -12 and -7.5, indicating that the BTS will be able to support services demanded by more subscribers accessing the network. With proper tuning using our model we can improve the Ec/lo to between -10.1 and -9.4 which is comparable to the standard which is -9 dB for data services. This tuning is required to eliminate the possibility of noise interference by this BTS on nearby BTSs when the loading is low. We discovered that the QoS is very poor in the environs of BEN026, with the result that UEs will not be able to access data due to rapid data rate decreases, network login difficulty, difficulty in call initiation, no network, and high call drop rate. The CPICH power level should be adjusted so that base station can provide service to the users; however this does not guarantee that the interference caused by other nearby base stations is within the acceptable range to establish the session. At BEN 098 (GAPIONA AVENUE) the Ec/lo is between -17.5 and -10. Using our model we cannot improve the Ec/lo up to the standard which is -9 dB for data which means the QoS at Gapiona Avenue is very poor and can only serve for voice calls with no data capacity whatsoever. We suggest re-planning and re-dimensioning the BTS to meet the service quality requirement for the area.

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