EVALUATION OF THE PERFORMANCE OF MULTISECTOR SOLUTION IN A UMTS NETWORK

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Abstract— The increase in number of cellular mobile users has resulted in a corresponding growth in voice and data traffic. This has motivated network operators to implement various technologies to be able to meet this growing demand. Many technologies and concepts have been proposed in literature to improve network channel capacity, coverage and signal quality. Higher Order Sectorization (HOS) is one of these concepts that promises to improve channel capacity, coverage and signal quality. In this paper, we evaluate the performance of a HoS solution in 3G Universal Mobile Telecommunication Services (UMTS) network deployed in Ghana. We used both analytical and field measurement approaches to assess the capacity-, coverage-, quality and network KPI- performance of the deployed HoS solution. The analytical approach was used to determine the expected theoretical capacity gains when a 3-sector cell site is upgraded to HoS cell site. The field measurement method was used to determine the actual capacity, coverage, quality and network KPI values when a 3-sector cell site is upgraded to HoS cell site. It involves the collection of live data from the network over a period of time before and after the deployment of the HoS solution and a drive test. Our results showed that capacity and coverage were improved after deploying HoS solution. An average capacity gain of 1.2 and 3.0 were achieved when cell site was upgraded from 3-sector to 4-sector and 3-sector to 5-sector respectively. However, soft handover success rate was reduced and CS call drop increased after deploying HoS solution.

Index Terms—Higher Order Sectorization (HOS), Universal Mobile Telecommunication Services (UMTS), 3G Networks, Throughput, CS Call Drop Rates, Soft Handover Success Count

◆

1 INTRODUCTION

Today's mobile subscribers have high appetite for data. Mobie traffic grew 54 % between the first quarter of 2017 and the first quarter of 2018. The volume of global mobile data due to video content alone is projected to grow by 73%, reaching 107 exabytes per month by the year 2023 [1]. The growth is due to multiple factors. The number of smartphones continues to increase as does the amount of data they consume. According to recent industry reports, a high percentage of all internet users rely solely on their mobile device for internet connectivity. Smartphone penetration continues to rise, driven by the increasing affordability of devices. At the end of 2017, there were 4.3 billion smartphone subscriptions, 95 percent of which were for 3G and 4G. The number of smartphone subscriptions is forecast to reach 7.2 billion in 2023, and almost all will be for mobile broadband [1]. This therefore places much burden on cellular networks to meet this increase in appetite of users of the networks.

The deployment of 3G/4G networks has been on the rise. At the end of 2012, there were 144 4G networks worldwide. By the end of 2021, the number is estimated to swell to about 80% [2]. In some cases, wireless service providers (WSPs) are bypassing 3G altogether, opting to layer 4G directly onto their current 2G systems. The rapid adoption of 4G is placing further strain on capacity-strapped networks. In 2012, a fourth-generation connection generated 19 times more traffic on average than a non-4G connection. Although 4G connections represent only 0.9% of mobile connections today, they already account for 14% of mobile data traffic. The capacity crunch has become so critical that, as USA Today reported, Even as they build the next generation of faster wireless networks, carriers are discouraging heavy data users by eliminating unlimited data plans and enforcing monthly caps. [18]

The global increase in voice and data traffic has given rise to a corresponding increase in mobile users. Network providers are met with the challenge of finding ways to meet the growing number of users (capacity). The continuous increase in cellular mobile users in recent times has called for a corresponding increase in capacity to accommodate the users. Network operators have deployed a multi-sector solution as one method of increasing capacity. This has been implemented in and around KNUST campus and some sites in Kumasi Ghana. This paper seeks to evaluate the performance of this solution to afirm the proposed increase in capacity.

2 THEORY AND RELATED WORKS

2.1 UMTS

The Universal Mobile Telecommunications System (UMTS) is a third generation mobile cellular system for networks based on the GSM standard. It is developed and maintained by the 3GPP (3rd Generation Partnership Project). UMTS is a component of the International Telecommunications Union IMT-2000 standard set and compares with the CDMA2000 standard set for networks based on the competing cdmaOne technology. UMTS uses wideband code division multiple access (W-

CDMA) radio access technology to offer greater spectral efficiency and bandwidth to mobile network operators [3].

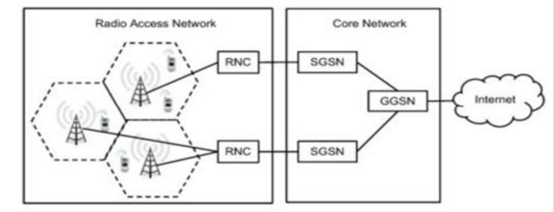


Figure 2.1: Architecture of a UMTS Network

The technology described in UMTS is sometimes also referred to as Freedom of Mobile Multimedia Access (FOMA) or 3GSM.Unlike EDGE (IMT Single-Carrier, based on GSM) and CDMA2000 (IMT Multi-Carrier), UMTS requires new base stations and new frequency allocations. UMTS supports maximum theoretical data transfer rates of 42 Mbit/s when Evolved HSPA (HSPA+) is implemented in the network. Users in deployed networks can expect a transfer rate of up to 384 kbit/s for Release '99 (R99) handsets (the original UMTS release), and 7.2 Mbit/s for High-Speed Downlink Packet Access (HSDPA) handsets in the downlink connection. These speeds are significantly faster than the 9.6 kbit/s of a single GSM error-corrected circuit switched data channel, multiple 9.6 kbit/s channels in High-Speed Circuit-Switched Data (HSCSD) and 14.4 kbit/s for CDMAOne channels. Since 2006, UMTS networks in many countries have been or are in the process of being upgraded with High-Speed Downlink Packet Access (HSDPA), sometimes known as 3.5G. Currently, HSDPA enables downlink transfer speeds of up to 21 Mbit/s. Work is also progressing on improving the uplink transfer speed with the High-Speed Uplink Packet Access (HSUPA). Longer term, the 3GPP Long Term Evolution (LTE) project plans to move UMTS to 4G speeds of 100 Mbit/s down and 50 Mbit/s up, using a next generation air interface technology based upon orthogonal frequency-division multiplexing. UMTS uses the same core network standard as GSM/EDGE. This allows a simple migration for existing GSM operators. However, the migration path to UMTS is still costly: while much of the core infrastructure is shared with GSM, the cost of obtaining new spectrum licenses and overlaying UMTS at existing towers is high [3].

2.2 WCDMA

W-CDMA or WCDMA (Wideband Code Division Multiple Access), along with UMTS-FDD, UTRA-FDD, or IMT-2000 CDMA Direct Spread is an air interface standard found in 3G mobile telecommunications networks. It supports conventional cellular voice, text and MMS services, but can also carry data at high speeds, allowing mobile operators to deliver higher bandwidth applications including streaming and broadband Internet access [3]. W-CDMA uses the DS-CDMA channel access method with a pair of 5 MHz wide channels. W-CDMA systems are widely criticized for their large spectrum usage, which delayed deployment in countries that acted relatively slowly in allocating new frequencies specifically for 3G services (such as the United States) [3]. The specific frequency bands originally designed by the UMTS standard are 1885-2025 MHz for the mobile-to-base station (uplink) and 2110-2200 MHz for the base station-to-mobile (downlink). In the US, 1710-1755 MHz and 2110-2115 MHz are used instead, as the 1900 MHz band was already used. While UMTS 2100 is the most widely deployed UMTS band, some countries' UMTS operators use the 850 MHz and/or 1900 MHz bands (independently, meaning uplink and downlink are within the same band), notably in the US by AT&T Mobility, New Zealand by Telecom New Zealand on the XT Mobile Network and in Australia by Telstra on the Next G network. Some carriers such as T-Mobile use band numbers to identify the UMTS frequencies. [3]. UMTS-FDD is an acronym for Universal Mobile Telecommunications System (UMTS) - frequency-division duplexing (FDD) and a 3GPP standardized version of UMTS networks that makes use of frequency-division duplexing for duplexing over an UMTS Terrestrial Radio Access (UTRA) air interface. W-CDMA transmits on a pair of 5 MHz-wide radio channels, while CDMA2000 transmits on one or several pairs of 1.25MHz radio channels. Though W-CDMA does use a direct sequence CDMA transmission technique like CDMA2000, W-CDMA is not simply a wideband version of CDMA2000. The W-CDMA system is a new design by NTT DoCoMo, and it differs in many aspects from CDMA2000. From an engineering point of view, W-CDMA provides a different balance of trade-offs between cost, capacity, performance, and density; it also promises to achieve a benefit of reduced cost for video phone handsets [3].

2.3 CAPACITY IN A UMTS NETWORK

Capacity in cellular networks have several definitions but for this project the capacity is based on the definition below;
The maximum number of users per cell that can be supported while meeting the performance objectives (set per each service) [5].
Capacity of cellular systems is of major concern to designers due to its economic value. For any multiuser communication system, the measure of its economic usefulness is not the maximum number of users which can be serviced at one time, but rather the peak load that can be supported with a given quality and with availability of service.
In CDMA cellular systems with interference based admission control, the interference level resulting from the connected users in the cell affects the capacity and coverage of the cell and any reduction in interference converts directly into an increase in capacity. Also it is well-known for CDMA systems with nonorthogonal users and single user detection that the coverage of a cell has an inverse relationship with the user capacity of the cell. Since all users share the same spectrum, power control is exercised in the reverse and forward link [17].

2.3.1 Global Trend in Mobile Data Traffic

Figure 2.2: Global Mobile Data Traffic

Figure 2.2 clearly shows that there is a growth in the number of internet users. As mobile voice and data traffic and the number of smartphones increase it implies that there is an increasing number of users on the cellular network. This growing demand places a stress on the existing cellular network infrastructure and the available mobile resources if technologies are not put in place to make room for all these users i.e to increase capacity.

2.3.2 Mobile Data Traffic Trend in Ghana

In Ghana, a corresponding increase in data traffic has been seen. The total number of mobile subscription increased by 1.3% from 36,138,706 in the first quarter of 2016 to 36,613,987 at the end of the second quarter of 2016. Mobile penetration also increased marginally from 131.0% in the first quarter of 2016 to 131.9% at the end of the second quarter of 2016. The share of post-paid subscription increased year-on-year by 100% from 0.5% in the second quarter of 2015 to 1.0% at the end of the second quarter of 2016 [9].

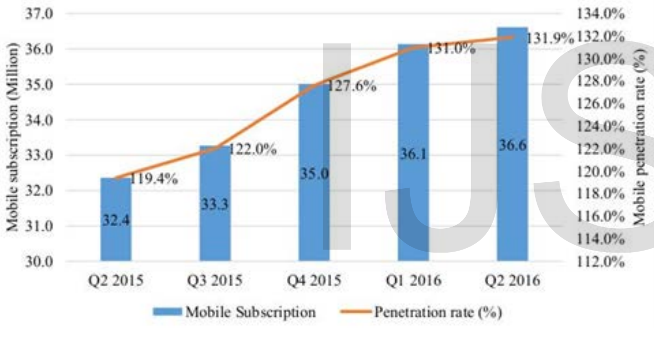


Figure 2.3: Mobile Subscription and Penetration

Domestic Mobile Voice Traffic: Total mobile voice traffic declined by 2.3% quarter-on-quarter, from 15.05 billion minutes during the first quarter of 2016 to 14.80 billion minutes at the end of the second quarter of 2016. Year-on-year total volume of mobile traffic increased by 14.6%, inching up from 12.92 billion minutes in the second quarter of 2015 to 14.80 billion minutes in the second quarter of 2016. The total minutes of use per subscriber for the second quarter of 2016 was 134 minutes, 4 minutes lower (-2.9%) than the first quarter of 2016 [9].

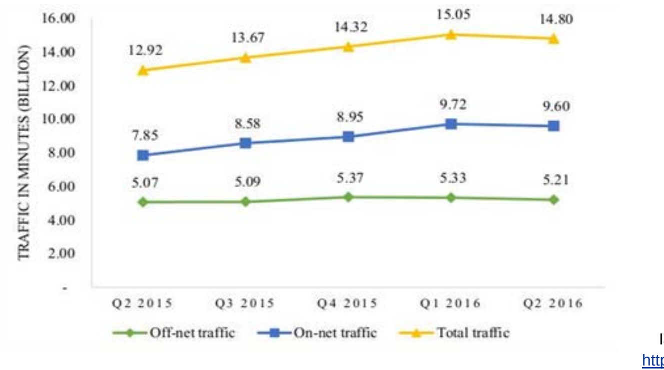


Figure 2.4: Domestic Mobile Voice Traffic

Mobile Data Subscription and Penetration: Mobile data subscription for the second quarter of 2016 was 18.8 million with a penetration rate of 67.6% [9].

Mobile Data Traffic: Total volume of mobile data usage expanded by 19.5% during the second quarter of 2016, increasing from 12.8 million Gigabytes to 15.3 million Gigabytes [9]. The Telecom Operators therefore experienced an increase in mobile traffic as well as seen in figure 2.6. They would have to develop technologies to continue providing services to the consumers in order to increase their market penetration or maintain it as the Telecom industry is highly competitive. UMTS (3G) also gives much throughput hence a lot of users who use services and applications that demand a lot of data. This explains the growing global internet traffic. Solutions to address the capacity needs which are specific to UMTS should also be looked at.

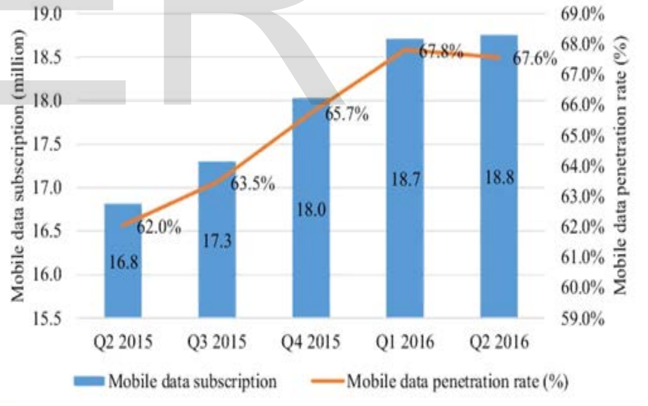
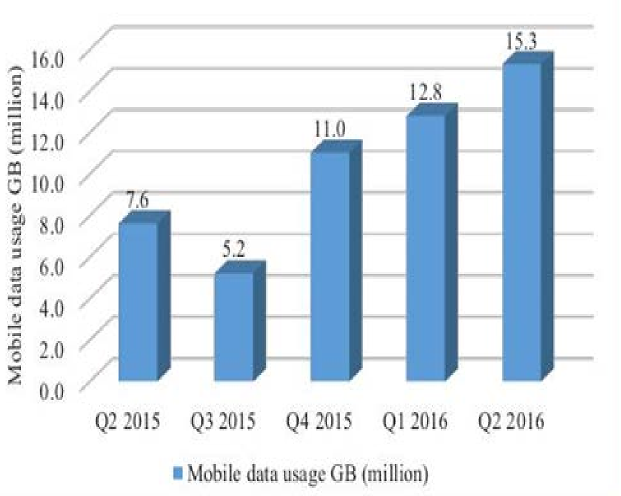


Figure 2.5: Mobile Data Subscription and Penetration

Figure 2.6: Mobile Data Traffic



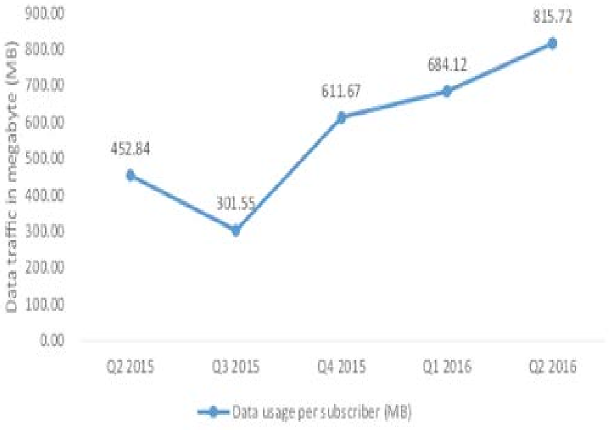


Figure 2.7: Mobile Data Traffic per User

Table 2.1: Mobile Data Traffic (GB) Per Operator

Mobile Operator	Data Usage (GB)	Q2 2015	Q3 2015	Q4 2015	Q1 2016	Q2 2016
MTN	Data Usage (GB)	2,758,496.03	2,224,110.16	3,828,998.22	4,606,691.59	6,187,603.59
	Market Share (%)	*37.1*	*43.6*	*35.6*	*36.9*	*41.4*
Vodafone	Data Usage (GB)	1,969,067.33	954,792.88	3,606,482.64	3,856,198.78	3,905,873.86
	Market Share (%)	*26.5*	*18.7*	*33.5*	*30.8*	*26.1*
Tigo	Data Usage (GB)	865,961.89	1,120,902.40	959,476.94	1,126,398.71	1,310,040.32
	Market Share (%)	*11.6*	*22.0*	*8.9*	*9.0*	*8.8*
Airtel	Data Usage (GB)	1,799,557.57	732,420.36	2,361,873.44	2,879,226.50	3,448,326.87
	Market Share (%)	*24.2*	*14.4*	*21.9*	*23*	*23.1*
Glo	Data Usage (GB)	25,172.31	21,633.17	13,853.12	32,624.35	89,151.17
	Market Share (%)	*0.3*	*0.4*	*0.1*	*0.3*	*0.6*
Expresso	Data Usage (GB)	18,229.00	41,761.82	-	-	-
	Market Share (%)	*0.2*	*0.8*	-	-	-
Total Industry Traffic (GB)		**7,436,484.14**	**5,095,620.78**	**10,770,684.36**	**12,501,139.93**	**14,940,995.81**

2.3.3 Capacity Limitations in UMTS

In UMTS, the system capacity is a stochastic value that depends on a lot of factors like:

Multipath Propagation
Orthogonality in Uplink/Downlink
Thermal Noise
Received Interference at the mobiles and Node B
etc.

However, this is not the case for systems like GSM. The system capacity is fixed and can be easily determined as it is based on factors like the number of carriers per cell and the number of timeslots per carrier and it is independent of the level of interference as in the case of UMTS. A single value can then be found for the Capacity of a GSM system [7]. Capacity of a UMTS network is then said to be mainly INTEFERENCE LIMITED, as interference places a limit as to the number of users that can be accommodated by a cell/sector without compromising on quality and Key Performance Indicators of network. In a narrowband system, new users cannot be admitted into a network once the time-frequency slots run out. This imposes a hard capacity limit on the system. In contrast, increasing the number of users in a CDMA system increases the total level of interference. This allows a more graceful degradation on the performance of a system and provides a soft capacity limit on the system. Since all cells share a common spectrum, a user on the edge of a cell can receive or transmit signals to two or more base-stations to improve reception. This is called soft handoff, and is yet another diversity technique, but at the network level (sometimes called macrodiversity). It is an important mechanism to increase the capacity of CDMA systems. In 3G systems there are both Soft Capacity and Hard Capacity resources that contribute to the determination of the capacity [23].

Soft Capacity Resources
This refers to factors that depend on the user behaviours in the network and some environmental factors within the network. These factors can be quantified by the following:

Uplink and Downlink Load
Power Consumption
Postion/Mobility profile of the users
Interference Level at Node B
Downlink Transmission Power at Node B
The number of available codes (PSC)

Hard Capacity Resources
The hard capacity Resources are the hardware resources that are associated with each radio link. These are called channel elements and they indicate how many Hardware Boards are required for each Node B. Hard capacity also includes the capacity of the link(s) between every Node B and the RNC (Radio Network Controller) that controls it. This link is referred to as Iub Interface in UMTS [7].
The various Telecom operators define their threshold for these requirements for better service quality to the consumers. Capacity of CDMA systems is also considered separately for forward and reverse links due to the difference in the interference characteristics [18].

2.3.4 Interference in UMTS Network

Interference in a UMTS network is the distortion that occurs on a UE's transmission due to the signal transmission by another U.E in the same cell/sector or in a different cell/sector. Interference is a common phenomenon in UMTS networks which uses WCDMA technology where the frequency reuse factor is one as shown in figure 2.8. All the UE's therefore transmit and receive signals on the same frequency. Scrambling Codes which are orthogonal are used in the transmissions so as not to increase interference. As the load on the particular Node B increases, the Signal-to-interference ratio also increases. Interference in a cellular systems is divided into inter-cell and intra-cell interference.

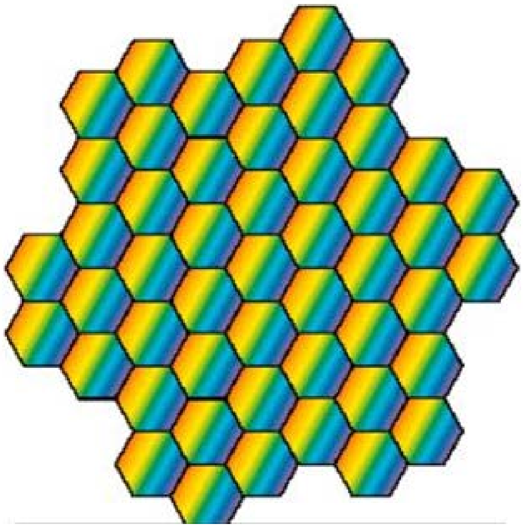


Figure 2.8: Cell Reuse factor of 1 in CDMA Networks

Inter-cell Interference

Inter-cell interference also known as Adjacent Cell Interference is one that results from transmissions that come from a nearby cell and distort the transmissions in another cell.

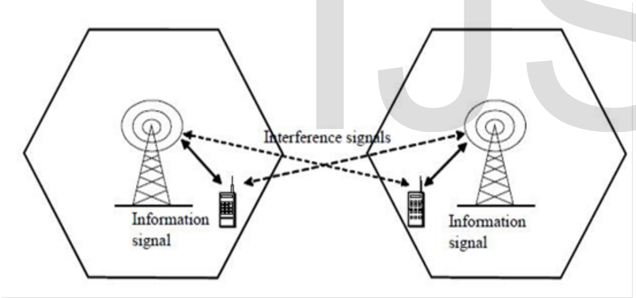


Figure 2.9: Inter-Cell Interference

Intra-cell Inteference

Intra-cell interference results from transmissions of a UE within the same cell.

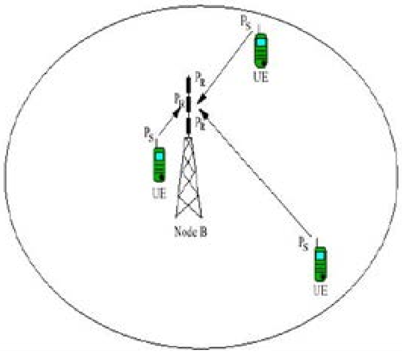


Figure 2.10: Intra-Cell Interference

2.3.5 Technologies for Capacity Improvement

There are several ways for mobile operators to increase the capacity of mobile networks, including increasing spectral efficiency, adding spectrum, wifi offloading and multisector solution [20] The main challenge for operators is not regarding solution selection, but how to promptly address such capacity crunch and be well-poised for future growing demands, and how to find the balance to maximize their cumulative benefits.

Spectral Efficiency

Spectral efficiency also known as spectrum efficiency or bandwidth efficiency refers to the information rate that can be transmitted over a given bandwidth in a specific communication system. It is a measure of how efficiently a limited frequency spectrum is utilized by the physical layer protocol and sometimes by the media access control (the channel access protocol). It involves the use of various modulation schemes that see to the minimizing of the bit error rate of the system so as to be able to accommodate a significant number of users without increasing the bit error rate.

Spectrum Addition

Adding spectrum means a corresponding increase in the number of channels available for a network. More channels means we can accommodate more users thus an increase in capacity.

WiFi Offloading

It is the use of complementary technologies for delivering data originally targeted for cellular networks. Offloading reduces the amount of data being carried on the cellular bands, freeing bandwidth for other users. It is also used in situations where local cell reception may be poor, allowing the user to connect via wired services with better connectivity. Operators can free up capacity on their cellular networks thus creating more room to provide higher bandwidth, control the experience and increase revenue.

2.4.6 Multisector Solution

This is a technology which makes use of antennas of reduced beamwidth to shoot direction beams. The use of three directional sector antennas versus one omni-directional antenna substantially reduces co-channel cell interference and triples the opportunity for frequency reuse. This therefore translates into ability to accommodate more users.

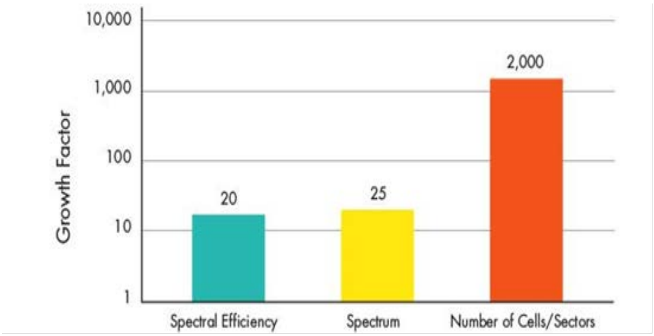


Figure 2.11: Smart Cells and Wireless Capacity Growth

Higher-order sectorization refers to the partitioning of cell sites into more than 3 sectors. Over the past few years, sectorization (sector splitting) at a site is regarded as one of the most effective means of adding extra capacity onto existing networks. Sectorization boosts network capacity and performance by increasing the number of cells and air interface resources. It eliminates the need to add sites, simplifies networking and reduces the workload, allowing easy and efficient network expansion. Splitting sectors on existing sites generates greater capacity gains and lower bit costs for operators in comparison to adding spectrum or additional 3-sector sites.

HOS is widely deployed by around 100 global cell network operators on over 85,000 sites. Other multi-sector industry solutions comprise 9-sector, 12-sector, and 18-sector. Huawei provides 9-sector and 18-sector for high-band deployment options in scenarios of capacity demand in extremely high-traffic areas where extra 6-sector sites cannot be deployed. The 9-sector or 18-sector solution can also be applied to accommodate massive traffic during major sports events, important traditional festivals, significant religious activities, and other special events [14]. One of Multi-Sector key strengths lies in its advanced technology. Multi-beam split antennas are used to effectively eliminate the interference between beams (sectors) and therefore generate more capacity gains. This is achieved by deploying narrower beams onto the cells. Each antenna has a specified capacity it can handle therefore split antennas harness the extra capacity provision attribute and employs it onto the site. The more the sectors desired, the narrower the beam deployed.
By utilizing narrower antenna beamwidth other cell interference is decreased due to less radiation power leakage to other cells and due to the fact that the base station antenna main beam is directed more precisely towards the mobiles [22]. This is how the multisector solution reduces the interference so that more users can be accommodated in a particular site. There are various configurations for Higher Order Sectorization implementation but in practice the splitting of a particular sector into Higher Order is done based on the load on the particular sector. The traditional 3 sector of a 3G network is split one at a time or can all be split at a go transforming it into a higher order sector.

Implementation of Multisector Solution
The beamwidth or each sector is reduced in higher order sectorization as the antennas are being replaced by higher directional antennas. Most operators who use this solution do not replace the single directional antenna of a higher beamwidth with 2 directional antennas in the case of a 6 sector but the existing antenna is replaced by an antenna that is able to split the beam into the desired number with its corresponding beamwith to achieve higher order sector solutionas shown in figures 2.12 to 2.14.

Antenna/Beam Configurations for Higher Order Sectors

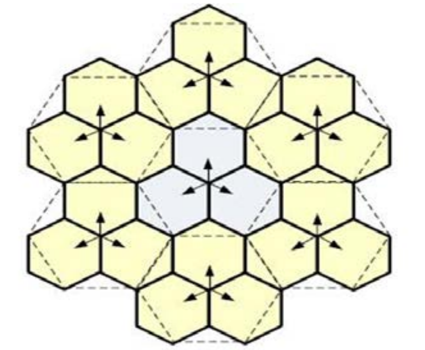


Figure 2.12: 3-Sector “Cloverleaf Layout"(4)

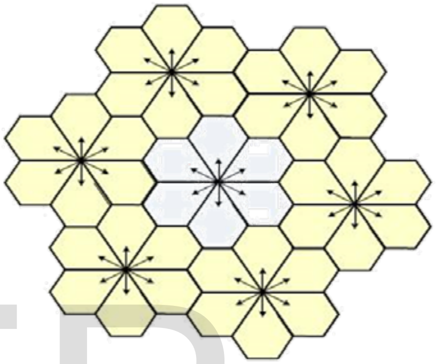


Figure 2.13: 6-Sector “Snow Flake" Layout (4)

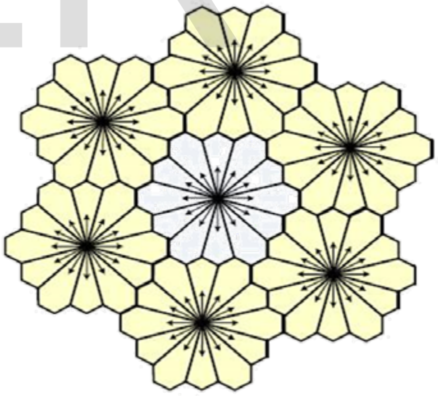


Figure 2.14: 12-Sector “Flower" Layout (4)

3 METHODOLOGY

We use both analytical and field measurement approaches to evaluate the the capacity-, coverage-, quality and network KPI- performance of the deployed HoS solution. The analytical approach was used to determine the expected theoretical capacity gains when a 3-sector cell site is upgraded to HoS cell site. The field measurement method was used to determine the actual capacity, coverage, quality and network KPI values when a 3-sector cell site is upgraded to HoS cell site. It involves the collection of live data from the network over a period of time before and after the deployment of the HoS solution and a drive test.

3.1 THEORETICAL/ANALYTICAL APPROACH

3.1.1 Capacity

Capacity of a UMTS network is characterized by the number of users that can be accommodated by a particular cell site or NodeB. The traffic that is generated is therefore dependent on the number of users that the site can support while maintaining the desired Quality of Service. For our evaluation of the performance of the multisector solution the HSDPA throughput is used as a measure of the capacity.

The throughput of HSDPA gives us an indication of the increase in traffic as observed from data gathered. It gives an indication of the number of users in a particular site taking advantage of the available network resources. This can be used to measure how much space has been created as a result of the implementation of the multisector solution.

MATHEMATICAL MODELS

In this section we figure out the signal-to-interference ratio (SIR) of users in a 3G UMTS network and the number of users per cell that can be supported for a desired SIR. The SIR in 3G UMTS network depends on several factors such as the cell layout, size, reuse distance, and propagation. In this work we assumed a simplified pathloss model for our pathloss calculation. The received power is estimates using:

$$P_r = P_t d^{-\gamma}$$

d = distance between U.E and its Node B
N_c = Number of channels per cell

There are N_c-1 asynchronous intracell interfering signals and MNc asynchronous intercell interfering signals transmitted from mobiles in the M adjacent cells. Let di where (i =1 to N_c–1) denotes the distance from the ith intracell interfering mobile.

P_i = other mobiles transmit Power

Let d_j where ($j = 1$ *to* MN_c) denotes the distance from the jth intercell interfering mobile.

All interference is reduced by the spreading code cross-correlation.

$\frac{\xi}{3G}$ where G is the Processing Gain of the system and is the parameter of the spreading cod, 1 ≤ ξ ≤ 3.

The total Intracell and Intercell Interference power is given by:

$$I_T = \frac{\xi}{3G}\left[\sum_{i=1}^{N_c-1} P_i d_i^{-\gamma} + \sum_{j=1}^{MN_c} P_j d_j^{-\gamma}\right]$$

$$I_{in} = \frac{I_T}{N_s} = \frac{\xi}{3GN_s}\left[\sum_{i=1}^{N_c-1} P_i d_i^{-\gamma} + \sum_{j=1}^{MN_c} P_j d_j^{-\gamma}\right]$$

$$SIR = \frac{S}{I_{in}}$$

$$SIR = \frac{SN_s}{I_T}$$

which yields

$$SIR = \frac{P_t d^{-\gamma}}{\frac{\xi}{3G}\left[\sum_{i=1}^{N_c-1} P_i d_i^{-\gamma} + \sum_{j=1}^{MN_c} P_j d_j^{-\gamma}\right]}$$

Assumptions: The Power transmitted by the Node B is received by the User

$$P_r = P_t d^{-\gamma} = P_i d_i^{-\gamma}$$

$$\lambda = \frac{\sum_{i=1}^{MN_c}}{(N_c - 1)P_r}$$

The ratio of average received power fom all intercell interference ti that of all intracell interference under power control.

$$SIR = \frac{1}{\frac{\xi}{3G}(N_c - 1)(1+\lambda)}$$

$$SIR = \frac{1}{\frac{\xi}{3GN_a}(N_c - 1)(1+\lambda)}$$

The user capacity can be determined using the equtions below

$$Ca = 1 + \frac{1}{\frac{\xi}{3G}(1+\lambda)SIR_o}$$

$$Ca = 1 + \frac{3GN_s}{\xi(1+\lambda)SIR_o}$$

where

$$SIR_o = \frac{E_b}{I_o} \qquad G = \frac{B_w}{R}$$

3.1.2 Path Loss Exponent Estimation

The pathlloss exponent, γ, of the cell site environment is determined by measuring the received power at different distances from the mask. Also the received power for the corresponding distances estimated using the log distance model.

$$P_i(dB) = P_i(d_o) + 10\gamma\log 10(\frac{d}{d_o})$$

The sum of square errors between the measured and estimated values is given by

$$Y(\gamma) = \sum_{i=1}^{k}(P_i - \hat{P}_i)^2$$

P_i = the actual measured received power at a distance

$\hat{P}_i$ = the estimated received power at that distance

k = number of measurement samples

The summation for the mean squared error is computed and the first differential is equated to zero to calculate the pathloss factor γ.

$$\frac{dY(\gamma)}{d(\gamma)} = 0$$

Coverage

Coverage is the Area a NodeB covers. This is the farthest distance a UE can go away from the NodeB and still receive the desired signal power within the site. In UMTS networks the RSCP (Received Signal Code Power) is used as a measure of the coverage.

Quality

The Quality in a UMTS networks denotes the clarity in the received signal. Interference is a major issue in a UMTS network as it uses Code Division Multiple Access (CDMA). The clarity is less as the level of interference increases and more when the interference reduces compared to the Chip Energy. The quality is therefore determined by Ec/Io which is the Chip Energy to Interference ratio.

3.2 FIELD MEASUREMENT

The Drive Test is a test performed in cellular networks regardless of the technology (GSM, CDMA, UMTS, LTE, etc...). It is usually performed for the analysis and optimization of the Network Quality. The drive test is the method by which the values for the evaluation of Coverage and Quality can be determined. The pathloss exponent estimation also uses values that are got from the drive test that is conducted on the site under test. The drive test was done for the site when it was using the traditional 3 sector and after it was changed to HOS to be able to make the comparison for our evaluation.

Figure 3.1: Node B at KNUST Brunei Site

Figure 3.2: Node B at Sokoban Site

Tools for Drive Test

The following are the tools used for the drive test.

GPS device
A Laptop (GENEX Probe Software Installed)
A UMTS User Equipment
A vehicle.

Figure 3.3: Tools Used for Drive Test

Setting up for Drive Test

The tools that are used for the drive test would have to be configured before the drive test begins as in figure 3.3 The GPS device is tested to see if it is functioning properly and we ensured that the UE is connected to the Laptop. In the GENEX software on the laptop, the site configurations and engineering parameters are loaded unto it. The engineering parameters include details of:

Site/Cell ID,
Site name,
Primary Scrambling Code
Radio Network Controller (RNC ID)
Base station parameters
Antenna parameters
Neighboring cell parameters
Various technology parameters of the current test area.

How the Drive Test was done and the values acquired?
On the interface of the GENEX Probe, the UE is latched to a particular sector which is analyzed at a time. The vehicle is then moved in the direction of the particular sector until there is a handover. This is repeated for all the other sectors. The GENEX Probe records all the values that are needed for the evaluation. This recording is known as Logging.

Figure 3.5: Drive Test Coverage after HOS implementation at Sokoban Site

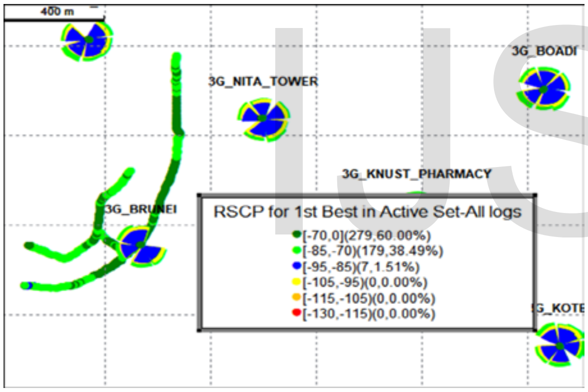


Figure 3.6: Drive Test Coverage after HOS implementation at KNUST Brunei Site

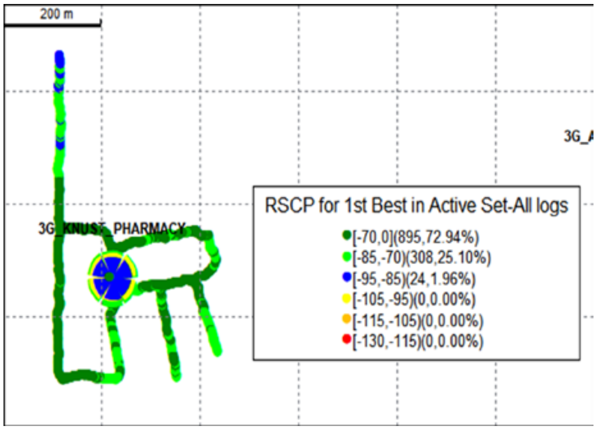


Figure 3.7: Drive Test Coverage after HOS implementation at KNUST Pharmacy Site

4 RESULTS

In this section, the estimated theoretical capacity per number of sector in UMTS network and actual results of the field measurements at KNUST Brunei, Sokoban and KNUST Pharmacy are presented. The Sokoban site was upgraded from 3-sector to 4-sector. The KNUST Brinei and KNUST Pharmacy sites were upgraded from 3-sector to 5-sector. The actual capacity, coverage, quality and network KPI values when a 3-sector cell site is upgraded to HoS cell site are presented.

4.2 CAPACITY

The estimated theoretical capacity per number of sectors is presented in Figure 4.1. The estimated capacity gain factor from 3-sector to 4-sector is 1.33, to 5-sector is 1.7 and to 6-sector is 2. These values and the field measurement values are later compared.

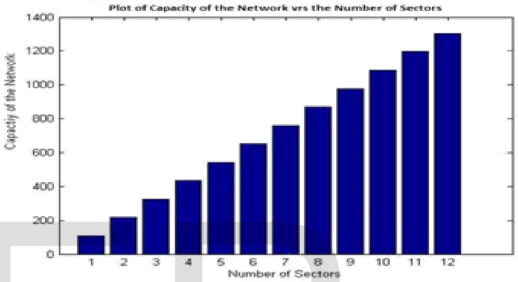


Figure 4.1: Theoretical Capacity Estimation Per Number of Sectors

Figure 4.2 shows the total mean channel throughput for 3G Brunei site. It displays a plot of total mean throughput to sampled days during which the traditional 3-sector was employed as well as when the 5-sector was deployed. The sample was done at a four-day interval for the periods before and after the HOS. A blue vertical line points to the transition period when more sectors were split to result in the 5-sector. According to the graph, the period before HOS implementation records a relatively low throughput with a peak value of 10 000kbps. HOS saw the peak value rose to about 33 000kbps. Thus there was an increment by a factor of about 3.0. This shows a rise in the total mean throughput which corresponds to an increase in the channel usage hence an increase in the number of users of 3G KNUST Brunei site.

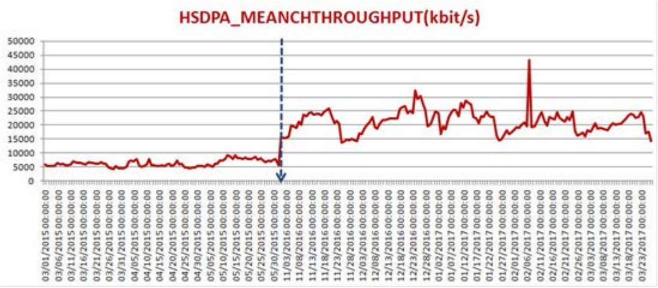


Figure 4.2: Throughput for Brunei Site

Figure 4.3 also shows the total mean channel throughput for 3G Sokoban site. It similarly displays a plot of total mean throughput to sampled days during which the traditional 3 sector was employed as well as when the HOS was deployed. For 3G Sokoban, the period after 4-sector implementation records a slight increment in throughput with a factor of 1.2. The 3G Sokoban HOS site is a new site which was about 2 months old during the time of the study. This explains the low factor by which the throughput increased.

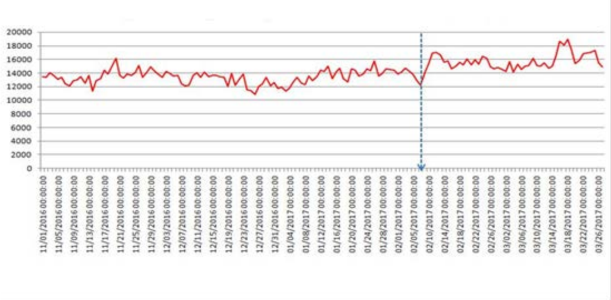


Figure 4.3: Throughput for Sokoban Site

Figure 4.4 also shows the total mean channel throughput for 3G KNUST Pharmacy site. This site shows a clear graphical interpretation to the improvement that was experienced when the site was upgraded from 3-sector to 5-sector. According to the graph, the period before HOS implementation records a throughput with a peak value of 13000kbps and after the implementation of HOS the graph saw the peak value rise to about 33 000kbps. Thus there was an increment by a factor of about 3.0. This shows a rise in the total mean throughput which corresponds to an increase in the channel usage hence an increase in the number of users of 3G KNUST Pharmacy site.

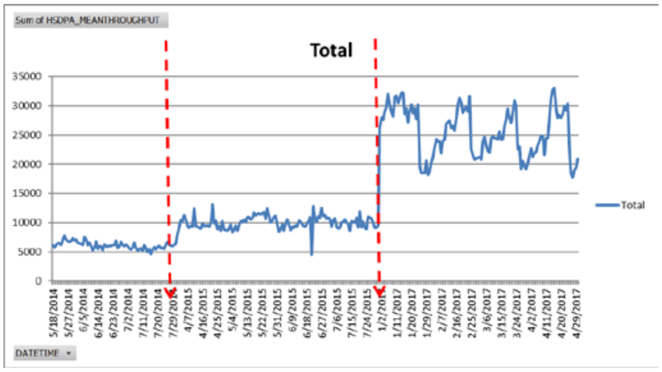


Figure 4.4: Throughput for KNUST Pharmacy Site

4.3 COVERAGE

Figure 4.5 and 4.6 below shows the power thresholds that determine the desired signal attributes. The colour scheme correspond to power ranges that determine the signal attribute in descending order of received power during the drive test. Figure 4.5 is concerned with signal coverage durng the drive test. Thus power levels between 0 to -68dBm are classified as very good, -68 to -73dBm are classified as good, -73 to -78dBm are classified as fairly good. The aforementioned thresholds are considered desirable and power levels below these thresholds, thus between -78 to -95dBm are poor and therefore undesirable. Figure 4.6 is concerned with quality. Similarly, power levels between 0 to 6dBm classified as very good, 6 to 8dBm are classified as good, -8 to -10dBm are classified as fairly good. The aforementioned thresholds are considered desirable and power levels below these thresholds, thus between -10 to -40dBm are of poor quality and therefore are undesirable

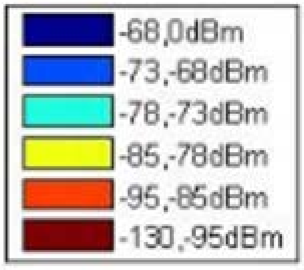


Figure 4.5: RSCP Thresholds Figure 4.6: Ec/Io Thresholds

Figure 4.7 is a pie chart showing measured RSCP, measure of coverage, for the 3-sector 3G Sokoban BTS. In comparison with the standard thresholds 12% of the signal received was considered desirable and the remaining 88% was regarded as undesirable. Figure 4.8 also shows a pie chart for RSCP for 3G Sokoban after HOS implementation. The comparison with the standard threshold values show that 29% of the power received was considered desirable and 71% was undesirable. Comparing figure 4.7 to figure 4.8, thus RSCP for traditional 3 sector and HOS for 3G Sokoban shows that there was about 18% increment in the RSCP. Since RSCP is the measure of coverage in this evaluation, we can say that there was an 18% increase in the coverage when the HOS was implemented.

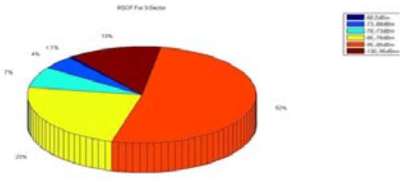


Figure 4.7: Coverage of 3 Sector for Sokoban Site for Various Thresholds

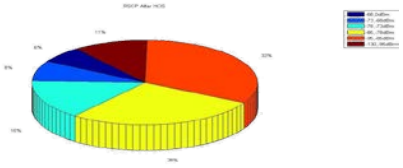


Figure 4.8: Coverage of HOS for Sokoban Site for Various Thresholds

4.4 QUALITY

Figure 4.9 is the measured Ec/Io for the 3G Sokoban site during the traditional 3-sector period. In relation to the set thresholds in figure 4.2, the BTS recorded a 53% desired signal quality and 47% undesired signal. In Figure 4.10, the measured

Ec/Io for the 3G Sokoban after HOS deployment shows 57% desired signal quality and 43% undesired signal. Comparing Figure 4.9 to Figure 4.10, thus Ec/Io for traditional 3-sector and HOS for 3G Sokoban shows that there was a 5% increment in the Ec/Io and since Ec/Io is the measure of quality in this evaluation, we can say that there was a 5% increase in the quality when the HOS was implemented.

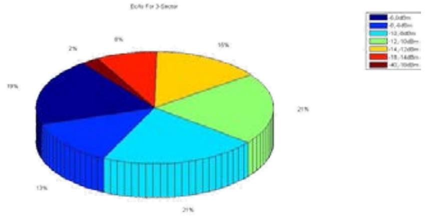


Figure 4.9: Quality of 3-Sector for Sokoban Site for Various Thresholds

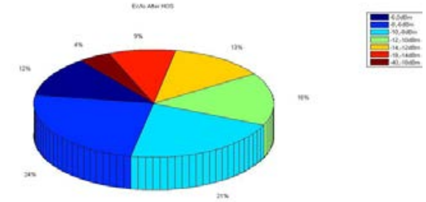


Figure 4.10: Quality of HOS for Sokoban Site for Various Thresholds

4.5 Network KPIs

To throw more light on the findings of this paper, we use data collected from the selected sites to evaluate the soft handover success and CS call drop rates. Soft handover success rate of Sokoban, KNUST Pharmacy and Brunei Sites as well as CS call drop rates of Sokoban, KNUST Pharmacy and Brunei Sites are discussed in this section. Soft Handover success count and CS call drop rates are characteristic of multi-sectoring of HOS discussed in this section. These data were recorded for the 3G Sokoban Sokoban, KNUST Pharmacy and Brunei sites. Dropped-call rates also can occur during handover. The significant increace in handover failure can explain the increased CS call drop rates. Call drop rate is seen to have increased drastically after HOS implementation. This means that HOS comes at a price of increase in calls dropped.

Figures 4.11, 4.12 and 4.13 shows the soft handover success counts. Soft handover success count refers to a feature in cellular network whereby a communication between a BTS / NodeB and an MS or UE is transferred to a different Node B as the UE or MS leaves the coverage area of the particular cell. The soft handover success count per figure 4.11 is seen to be reducing after HOS implementation. This means that communication was unsuccessfully transferred as a user was exiting a particular cell. This also drives at another demerit of HOS. Figures 4.14, 4.15 and 4.16 show CS call drop rates for the periods before and after the 4/5-sector implementation at the Sokoban, KNUST Pharmacy and Brunei sites. The CS call drop rates shown in these figures are indicative of the increased users in the same site and the presence of multi-sectoring.

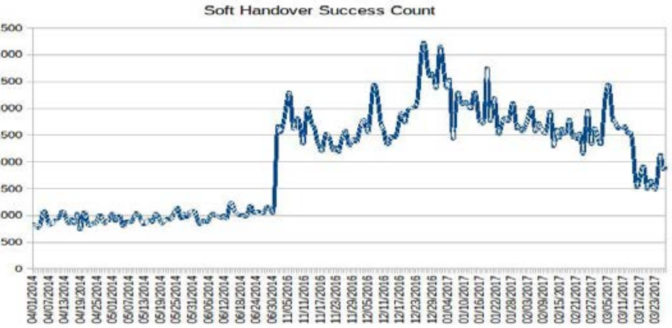


Figure 4.11: Sokoban Site Soft Handover Success Count

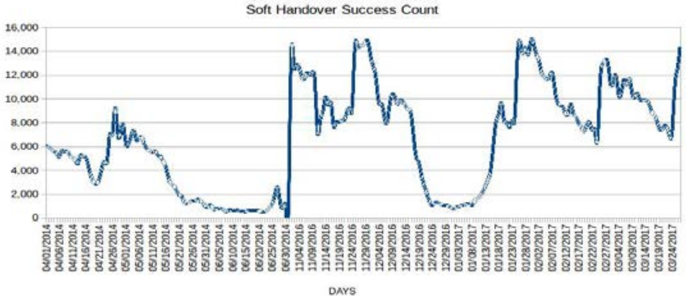


Figure 4.12: KNUST Pharmacy Site Soft Handover Success Count

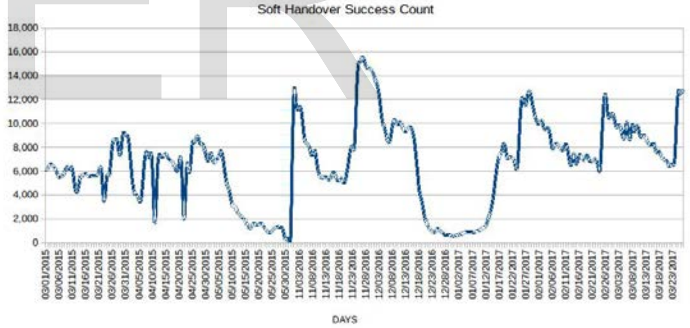


Figure 4.13: Brunei Site Soft Handover Success Count

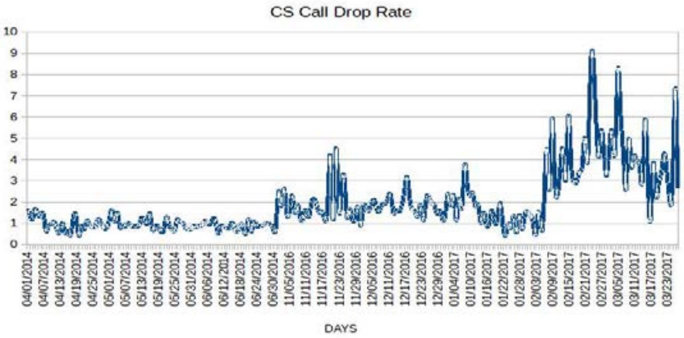


Figure 4.14: Sokoban Site CS Call Drop Rate

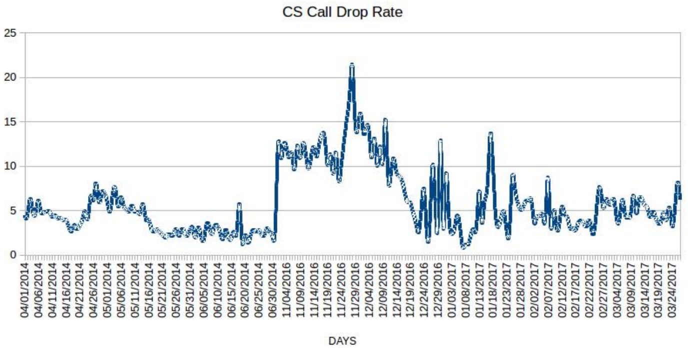


Figure 4.15: KNUST Pharmacy Site CS Call Drop Rate

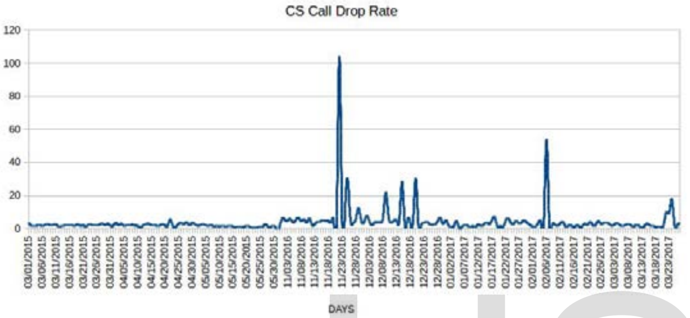


Figure 4.16: Brunei Site CS Call Drop Rate

5 CONCLUSION

5.1.1 Capacity

HOS implementation is one of the most used techniques for increasing capacity due to the relatively low cost involved and easy deployment. It promises that an increase in the number of sectors of a Node B will give a corresponding increase in the capacity. The significant increace in handover failure can explain the increased CS call drop rates. Call drop rate is seen to have increased drastically after HOS implementation. This means that HOS comes at a price of increase in calls dropped.

The performance monitoring data of 3G KNUST Brunei, 3G KNUST Pharmacy and 3G Sokoban sites proved to have higher throughput after the HOS was implemented than for the traditional 3 sector. The total mean throughput relates to number of users in this evaluation and so therefore the HOS implementation resulted in higher capacity at the 3G KNUST Brunei, 3G KNUST Pharmacy and Sokoban sites. The table 5.1 below is a comparison of the capacity improvement for the both theoretical and measurement evaluation approaches.

5.1.2 Coverage and Quality

The drive test conducted to determine the coverage and quality improvement of the multi-sector implementation showed a 4% improvement in quality and an 18% improvement in coverage at the 3G_Sokoban site. Hence the HOS implementation gave a slight increase in quality and an appreciable increase in coverage. The sites studied had basic functionalities working very well and were stable as seen in the drive test results. The performance of the sites are satisfactory with very good coverage. The coverage (RSCP) plots of the sites shows the measured RSCPs for the multi-sector approach. Per the defined thresholds for RSCP, all the signal received are considered to be very good. However, with Quality (Ec/Io), about 95.48% of 3G_BRUNEI's coverage was considered to be desirable. The remaining 4.52% were considered undesirable. Network Quality (Ec/Io) for 3G_KNUST_PHARMACY recorded about 70.08% to be desired signal while 29.92% were considered undesired.

Table 5.1: Comparison of Capacity Evaluation Using Analytical and Measurement Approaches

Evaluation Approach	Capacity Ratio of HOS to Traditional 3-Sector		
No. of Sector	4 (3G_Sokoban)	5 (3G_Brunei)	6
Theoretical/Analytical	1.33	1.67	1.98
Measurement	1.2	3	n/a

5.1.3 Pathloss Exponent

The drive test produced values for Received Power at various intervals from the Node B. These values were used in the model assumed to nd the pathloss factor. Pathloss factor at 3G Brunei site was found to be 2:4 and 1:75 was found for 3G Sokoban site.

5.2 RECOMMENDATION

From the evaluation of the implemented HOS, it can be concluded that capacity was increased at the sites. However, the handover success rate and the call drop rate after implementation was recorded as lower and higher respectively relative to the traditional 3-sector system. In future work, technologies to mitigate these demerits can be looked at in the implementation of Multisector Solution.

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