Mollification of WCDMA Interference on Uplink Channels in Cellular Network Using the Power Control Approach

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Authors' contributions

This work was carried out in collaboration between all authors. Author EUK designed the study, wrote the protocol, managed the literature searches and wrote the first draft of the manuscript. Author SMM performed the statistical and data analysis and author EAE managed the analyses of the study. All authors read and approved the final manuscript.

Article Information

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ABSTRACT

One of the major problems in Wideband Code Division Multiple Access (WCDMA) Radio Access Network (RAN) is interference; which reduces the signal quality of a cellular network system. Most cellular network service providers use either frequency planning or code planning techniques to analyze the interference and assign frequencies and codes based on measurement reports from network statistics.

This research presents a bright analysis of one of the main method for reducing interference in WCDMA technology using some Key Performance Indicators (KPIs) of a functional cellular network service provider in Nigeria.

From the analysis and results it was visible that using the Power Control Approach (PCA) the interference on uplink transmission in cellular networks will certainly be reduced. Hence, the signal quality would be improved and optimization of the network services could be actualized. Consequently, a better Quality of Service (QoS) would be guaranteed for the generality of the subscribers.

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ACRONYMS

AMR	: Adoptive MultiRate
CODEC	: Coding/Decoding
QoS	: Quality of Service
RTWP	: Receive Total Wideband Power
HSDPA	: High Speed Downlink Packet Access
HSUPA	: High Speed Uplink Packet Access
MSC	: Mobile Switching Center
VLR	: Visitor Location Register
HLR	: Home Location Register
AuC	: Authentication Centre
SMSC	: Short Message service center
EIR	: Equipment Identity Register
MGW	: Media Gateway
1xRTT	: Single Carrier Radio Transmission Technology
UTRAN	: UMTS Terrestrial Radio Access Network
RNC	: Radio Network Controller
WBSS	: Wireless Base Station Subsystem
R99 UE	: Release 99 User Equipment
HSDPA UE	: High Speed Downlink Packet Access User Equipment
HSUPA UE	: High Speed Uplink Packet Access User Equipment
DPDCH	: Dedicated Physical Data Channel
DPCCH	: Dedicated Physical Control Channel
HSDPCCH	: High Speed Downlink Packet Access Dedicated Physical Control Channel
HSPDSCH	: High-Speed Physical DL Shared Channels
HSDPCCH	: High Speed Dedicated Physical Control Channel
E-DCH	: Enhanced Dedicated Channel
E-HICH	: E-DCH Hybrid ARQ Indicator Channel
E_RGCH	: E-DCH Relative Grant Channel
E_AGCH	: E-DCH Absolute Grant Channel
E_DPCCH	: E-DCH Dedicated Physical Control Channel
E_DPDCH	: E-DCH Dedicated Physical Data Channel
KPI	: Key Performance indicators

1. INTRODUCTION

For about two decades or thereabout, there has been a noticeable and significant increase in the use of technology for communication; increasing demand on high-rate multimedia services and high spectral efficiency. Cellular network operations in Nigeria have witnessed moderate improvement in terms of better coverage and availability since its launch in August 2001 due to the availability of network in almost everywhere. However, the Quality of Service (QoS) generally is still far from being satisfactory, especially during major events when there is mobility of people. With the recent growing in cellular network communication the spectrum availability is becoming limited [1-4].

Network quality is a major parameter by subscribers of any network service in judging the QoS and this can be achieved when the network is sufficiently, adequately and appropriately optimized to meet the grade of services expected from its subscribers. Cellular network services in Nigeria is under-optimized and this is a motivation to trigger new research topics in optimization and performance evaluation in Universal Mobile Telecommunication Service (UMTS) uplink interference due to the rapid increase in the number of subscribers of cellular network services in the country [5].

Interference is a fundamental limiting factor in the performance of cellular network systems. In cellular networks, interference is one of the most common problems in the Radio Access Network (RAN). It is a serious challenge for wireless systems. During the initial development of cellular phones, the second generation (2G) cellular phones cause much interference.

Though, the interference from the third generation (3G) cellular phones is considerably lower than the ones from the 2G phones. In Communications and Electronics interference is anything which modifies, or disrupts a signal as it travels along a channel between a source and a receiver. The term typically refers to the addition of unwanted signals to a useful signal. It is the sum of all signal contributions that are neither noise nor the wanted signal. Common examples include:

(i)   Electromagnetic Interference (EMI)
(ii)   Co-Channel Interference (CCI), also known as crosstalk
(iii) Adjacent-Channel Interference (ACI)
(iv)   Inter-Symbol Interference (ISI)
(v)   Inter-Carrier Interference (ICI), caused by doppler shift in OFDM (Orthogonal Frequency Division Modulation associated with LTE; Long Term Evolution) modulation (multi tone modulation)
(vi)   Common-mode interference (CMI)
(vii) Conducted interference (CI)

Interference is typically but not always distinguished from noise. Radio resource management aims at reducing and controlling the Co-Channel and Adjacent-Channel Interference because they are common with 2G (GSM technology) while Inter- Symbol and Inter-Carrier Interference are common with 3G [4,6].

Different systems and services such as mobile communications, mobile radios, Wireless Local Area Networks (WLAN) and digital video broadcasting each use an assigned spectrum to avoid transmitting different services at the same frequency; causing signal collisions or interference.

Interference can cause degradation of signal quality thereby reducing the QoS of the particular network service provider.

Some causes and sources of interference are:

(i)   Another mobile in the same cell
(ii)   A call in progress in the neighboring cell
(iii) Other base stations operating on the same frequency
(iv)   Any non-cellular system which leaks energy into the cellular frequency band

(i) and (ii) are the ones prominent with WCDMA. Moreover, even if different wireless services do not generate harmonics, frequency drifts, or

Radio Frequency (RF) leakage, cell sites are subject to internal interference caused by the improper conductivity of passive devices such as connectors, cables, or antennas. This internal interference can generate inter-modulation signals at the same frequency band as mobile transmitters (uplink). Another common case of interference internal to the RAN is caused by frequency re-farming. Network service providers evolving their mobile technology to LTE use re-farming to deliver higher throughput for mobile devices while maintaining their existing technologies such as GSM and WCDMA. This technique supports a gradual adoption of LTE. The co-existence of multiple technologies in a limited spectrum is forcing mobile operators to increase the number of carriers and to re-use frequencies, creating a RAN subject to internal interference.

Inter-modulation in passive components is created when two signals are transmitted in a cabling system with improper conductivity characteristics such as loose jumpers, bent cables, different metals in jumpers, or corrosion. This inter-modulation generates signals as products or multiples of the two transmitted signals [4,6].

2. 3G STANDARD

3G wireless service has been designed to provide high data speeds, always-on data access, and greater voice capacity. Listed below are a few notable points:

(i)   The high data speeds, measured in Mbps, enable full motion video, high-speed internet access and video-conferencing.
(ii)   3G technology standards include UMTS, based on WCDMA technology (quite often the two terms are used interchangeably) and CDMA2000, which is the outgrowth of the earlier CDMA 2G technology.
(iii) UMTS standard is generally preferred by countries that use GSM network. CDMA2000 has various types, including 1xRTT, 1xEV-DO and 1xEV-DV. The data rates they offer range from 144 kbps to more than 2 mbps.

2.1 WCDMA

The first Multiple Access Third Generation Partnership Project (3GPP) Wideband Code Division Networks (WCDMA) was launched in 2002. At the end of 2005, there were hundreds of

WCDMA networks open and more than hundred and fifty operators with licenses for frequencies for WCDMA operation. Currently, WCDMA networks are deployed in UMTS (universal mobile terrestrial system) band of around 2 GHz in Europe and Asia, including Japan, America and Korea. WCDMA is deployed in the 850 and 1900 of the existing frequency allocations and the 3G band 1700/2100 is also in use by many countries, including Nigeria. 3GPP (3rd generation partnership project) has defined WCDMA operation for several additional bands, most of which have being already commissioned and in operation. WCDMA is intended for wideband multimedia services and support for bit rates of at least 384kbit/s with good coverage and full mobility, up to 2 Mb/s can be supported with one 5 MHz carrier with local coverage [7,8].

As WCDMA mobile penetration increases, it allows WCDMA networks to carry a greater share of voice and data traffic. WCDMA technology provides some advantages for the operator in that it allows the data and also improves the voice traffic. Voice capacity offered is very high due to interference control mechanisms; including frequency reuse of one factor, fast power control and soft handover. WCDMA can offer a lot more voice minutes to customers. Meanwhile WCDMA can also improve broadband voice service with Adaptive Multi Rate (AMR) coding and decoding (codec), which clearly provides better voice quality than fixed telephone landline. In short, WCDMA can offer more voice minutes with better quality.

In addition to the high spectral efficiency, third-generation (3G) WCDMA provides even more dramatic change in capacity of the base station and the efficiency of the equipment. The high level of integration in the WCDMA is achieved due to the broadband carrier: a large number of users supported by the carrier, and less RF carriers are required to provide the same capacity. With less RF parts and more digital baseband processing, WCDMA can take advantage of the rapid evolution of digital signal processing capability. The level of integration of the high base station enables efficient building of high capacity sites since the complexity of RF combiners, additional antennas or power cables can be avoided. WCDMA operators are able to provide useful data services, including navigation, person to person video calls, sports and video and new mobile TV clips.

WCDMA enables simultaneous voice and data which allows, for example, browsing or email when voice conferencing or video sharing in real time during voice calls.

Table 1. Frequency band of WCDMA [7,8]

Uplink	1920 – 1980 MHZ
Down link	2110 – 2170MHz
Carrier Spacing	5MHz (Nominal)
Duplex Distance	190MHz
Chip Rate	3.84Mcps

2.2 Sub-systems of 3G Network

A WCDMA system is basically designed as a combination of three major subsystems:

(i) Network Subsystem (NSS): MSC/VLR, HLR, AuC, SMSC, EIR, MGW. Common for both 2G & 3G Network.
(ii) UTRAN: RNC & WBSS.
(iii) Operation and maintenance Support Subsystem (OSS).

There are three dominant interfaces, namely,

(i) IuCS: Between RNC and MSC for speech & Circuit data;
(ii) IuPS: Between RNC & SGSN for packet data;
(iii) Uu interface: Between the RNC and MS[5]

WCDMA is a self-interference system (Internal Interference System). The capacity and performance of the WCDMA system is mainly affected by the following factors:

(i) Multiple Access Interference (MAI) or Inter-User Interference (IUI)
(ii) Inter-Symbol interference (ISI)
(iii) Near-Far Interference (NFI)

3. MATERIALS AND METHODS

Cellular wireless mobile networks are still the workhorses of network operators. 3G mobile systems have being fully deployed in developed countries of the world. The higher the traffic load in such cellular wireless mobile networks (primarily, due to data upsurge) and the higher the number of subscribers added per sector, the greater the risk of problems caused by interferences which translates into poor QoS. However, owing to the amount of new infrastructures required, it will still be some time before 3G is ubiquitous in most developing countries like Nigeria [7].

4

On a broad level, there are two approaches to tackle and reduce interference in WCDMA system. These are:

(i)   Power Control Approach and
(ii) Interference Cancellation Approach

In this research we shall be considering the power control approach technique, because controlling the power transmission on uplink channels can help in reducing the amount of interference caused to other users [7].

The uplink control channels consume most of uplink power load. This introduces much interference in the system and reduces the uplink data rate.

Fig. 1 shows channels that were impacted as a result of this research. In Release 99, only DPCCH (Dedicated Physical Control Channel) would be impacted. For Release 5 UE's (HSDPA UE), both DPCCH (Dedicated Physical Control Channel) and HSDPCCH (High Speed dedicated physical control channel).For Release 6 UE's (HSUPA UE), both the Enhanced dedicated physical control channel and the Enhanced dedicated physical data channels would be impacted in addition to the pre-existing DPCCH.

Three data rate states (High Rate state, Medium Rate state, and Low Rate state) were defined with different power control parameters, including the target number of HARQ retransmissions (NHR), E-DPDCH HARQ offset (HARQ offset), and target SIR (SIRtarget).

They are described as follows:

(i)   In the high-rate state, NHR is 1% or 10%, HARQ offset is 0 dB, and SIRtarget is greater than or equal to about 8 dB.
(ii) In the medium-rate state, NHR is 1% or 10%, HARQ offset is 4 dB, and SIRtarget is greater than or equal to about 4 dB.
(iii) In the low-rate state, NHR is 10%, HARQ offset is 6 dB, and SIRtarget is greater than about 2 dB

After a UE accesses the network, the RNC initiates the UE's data transmission state transition based on the uplink load (including the RTWP and the uplink service load) and UE's uplink throughput. The three data rate states are defined as follows:

a) In a procedure of RAB setup, CELL_PCH/URA_PCH to CELL_DCH

(P2D) state transition, CELL_FACH to CELL_DCH (F2D) state transition, or hard handover, the UE is seen as being in low-rate state if all the following conditions apply:

(i)   The total uplink power load (RTWP) in a cell becomes insufficient.
(ii) The uncontrollable service load in the cell exceeds a specified threshold

Uncontrollable service load in the cell includes R99 load, control channel load, and part of HSUPA GBR load.

b) While the service is running, the UE is in high-rate state or medium-rate state, the UE would be configured as being in low-rate state if:

(i)   The UE throughput is below the specified threshold, for example, 20 kbit/s.
(ii) The total uplink power load (RTWP) in a cell becomes insufficient.
(iii) The uncontrollable service load in the cell exceeds the specified threshold, for example, 60%.

c) For low-rate state;

(i)   The UE is configured as the high-rate state if the UE throughput is above the specified threshold, for example, 120 kbit/s.
(ii) The UE is configured as the low-rate state if the UE throughput is less than 120 kbit/s but greater than or equal to 40 kbit/s.

Note that all the settings were not typical to what was obtainable in practice.

In networks that have a high Smartphone penetration rate, the number of online UEs is large. The uplink control channels (such as the DPCCH and HSDPCCH) consume most of the uplink power load, thereby resulting in an increased RTWP. The average HSUPA rate is very low, 90% of which is below 10 kbit/s.

In the preceding scenario, when the average HSUPA rate is very low, this feature can lower the target SIRs over the DPCCH, thereby reducing the uplink interference on the control channels and improving the uplink cell capacity with improved QoS.
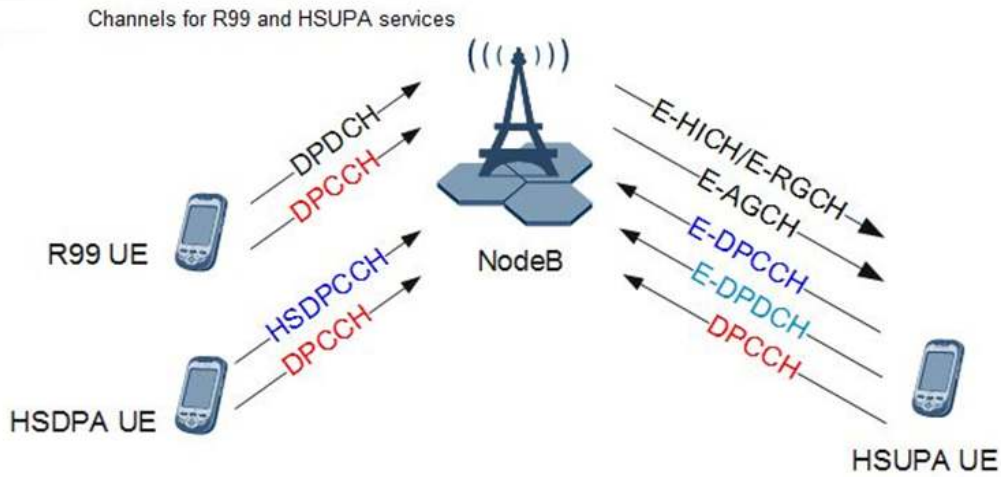
Channels for R99 and HSUPA services

Fig. 1. Channels for R99 and HSUPA services

4. RESULTS AND DISCUSSION

Fig. 2 shows the existing status of uplink power utilization. It can be deduced that most of the power is consumed by DPCCH 2ms TTI (Transmit Time Interval). 10 ms TTI channels share almost the same uplink power.

Fig. 3 shows the network behaviour after the changes were done. Most impacted channels were the DPCCH 2ms and the DPCCH 10ms UE's. Almost 10% Uplink power Utilization was gained indicating a 10% equivalent reduction in Noise level (Uplink interference). However, HSDPCCH power utilization increased by almost 5%. This indicates that while there was great gain on Release 6 UE's, Release 5 UE's were more interferred. This however, is minimal as compared to the capacity gain on the Release 6 UE's.
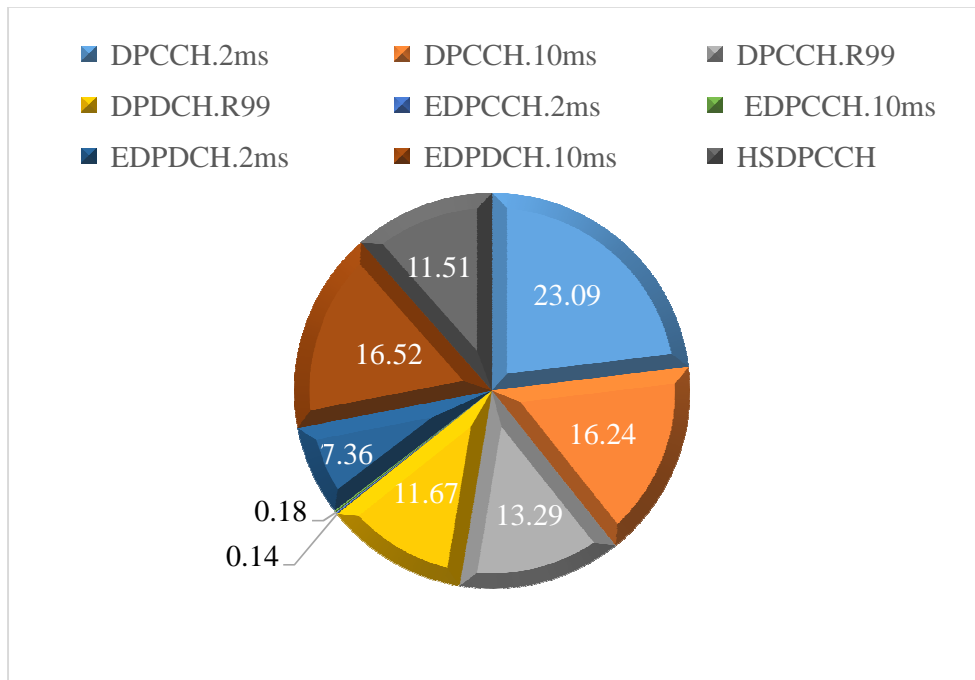
Fig. 2. Uplink load distribution-Pre
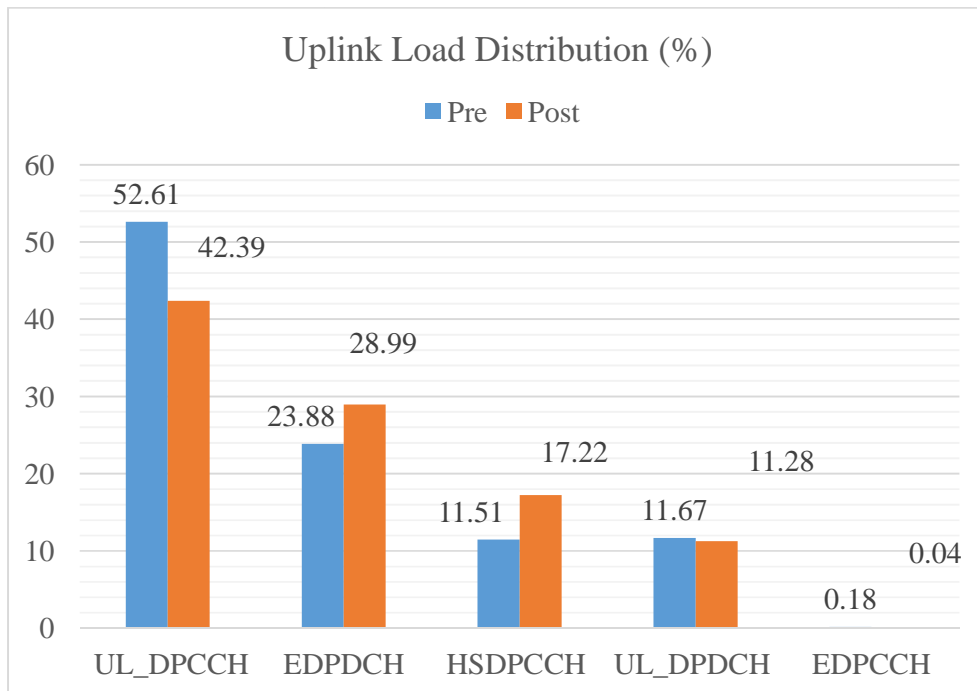
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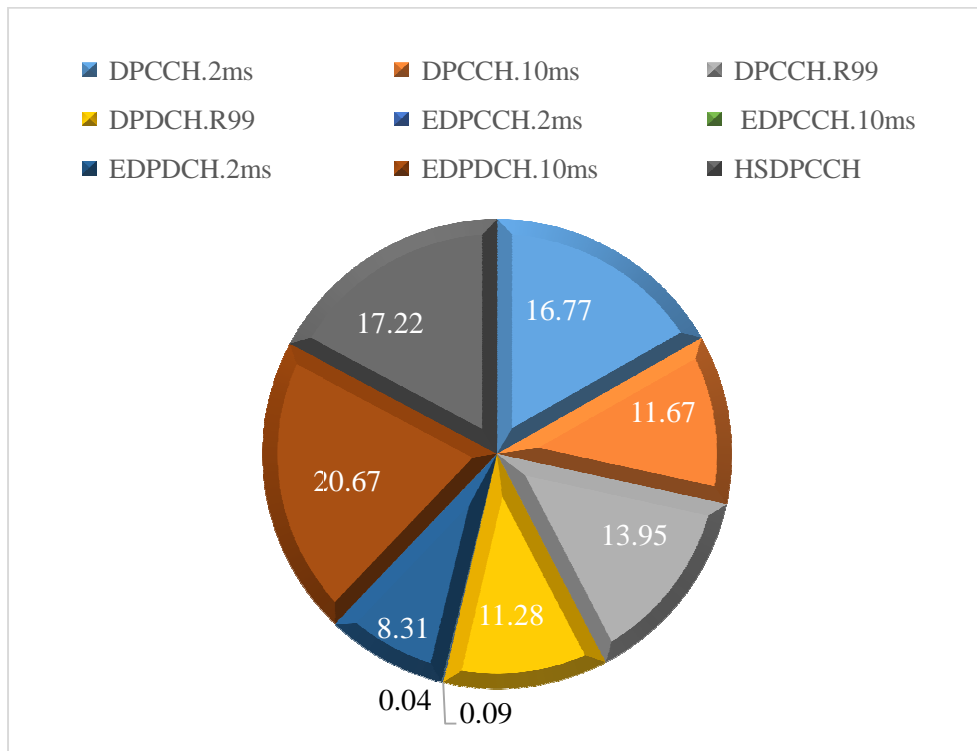
Fig. 3. Uplink load distribution-post

Fig. 4. Uplink load distribution (%)

Table 2. Percentage share on uplink channels

Index	DPCCH .2ms	DPCCH .10ms	DPCCH .R99	DPDCH.R99	EDPCCH .2ms	EDPCCH.10ms	EDPDCH .2ms	EDPDCH .10ms	HSDPCCH
Pre Share %	23.09	16.24	13.29	11.67	0.14	0.18	7.36	16.52	11.51
Post Share %	16.77	11.67	13.95	11.28	0.09	0.04	8.31	20.67	17.22
Delta(Post-Pre)	-6.32	-4.56	0.66	-0.39	-0.05	-0.14	0.95	4.15	5.71
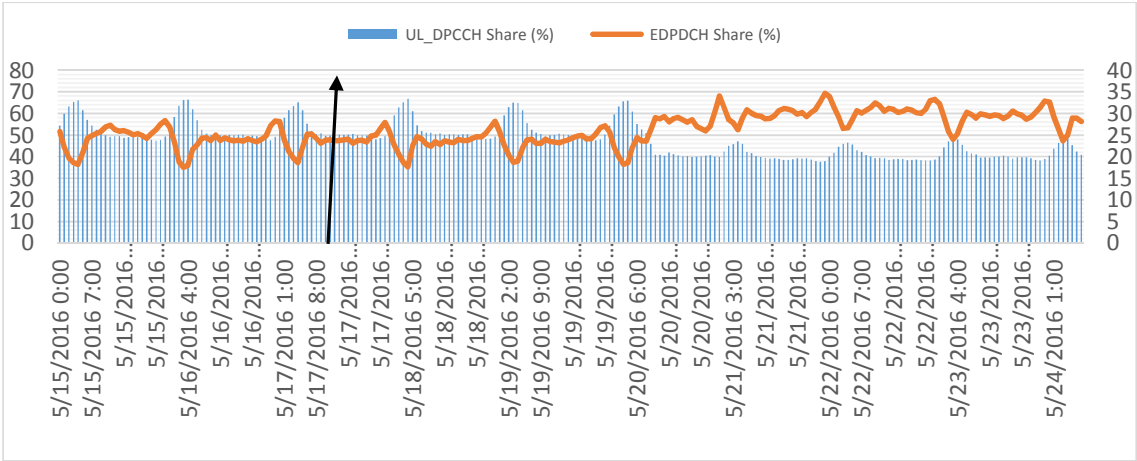
Fig. 5. UL_DPCCH and EDPDCH share in uplink load (%)

Fig. 4 shows the behaviour of different uplink channels to the parameter changes done during the study. It can be deduced that while there was great gain on the Uplink DPCCH, about 5% more interference was observed on the HSDPCCH with the data channel (Uplink DPDCH) being almost stable.
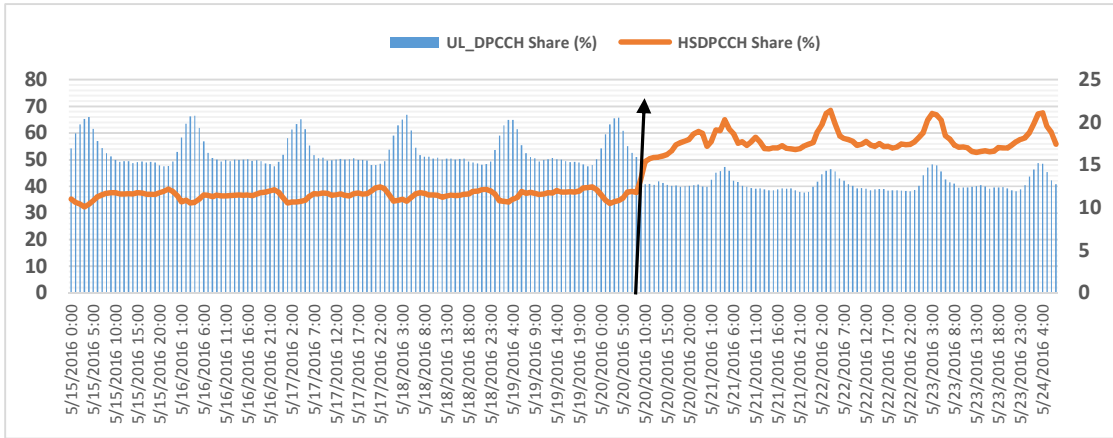

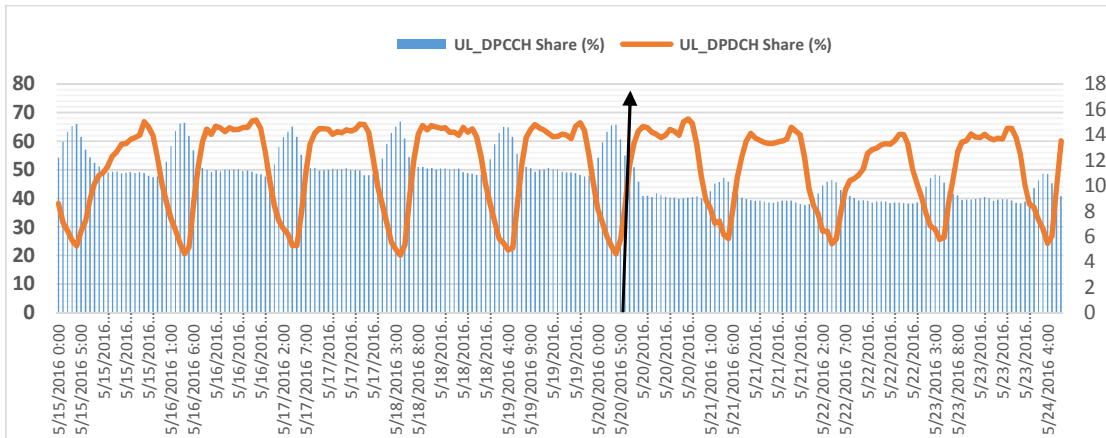
Fig. 6. UL_DPCCH and HSDPDCH share in uplink load (%)

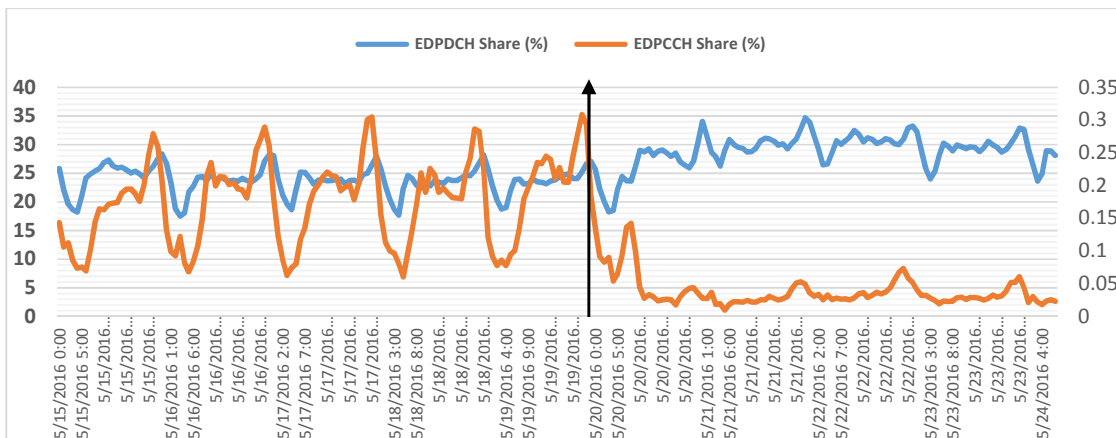**Fig. 7. UL_DPCCH and UL_DPDCH share in uplink load (%)**

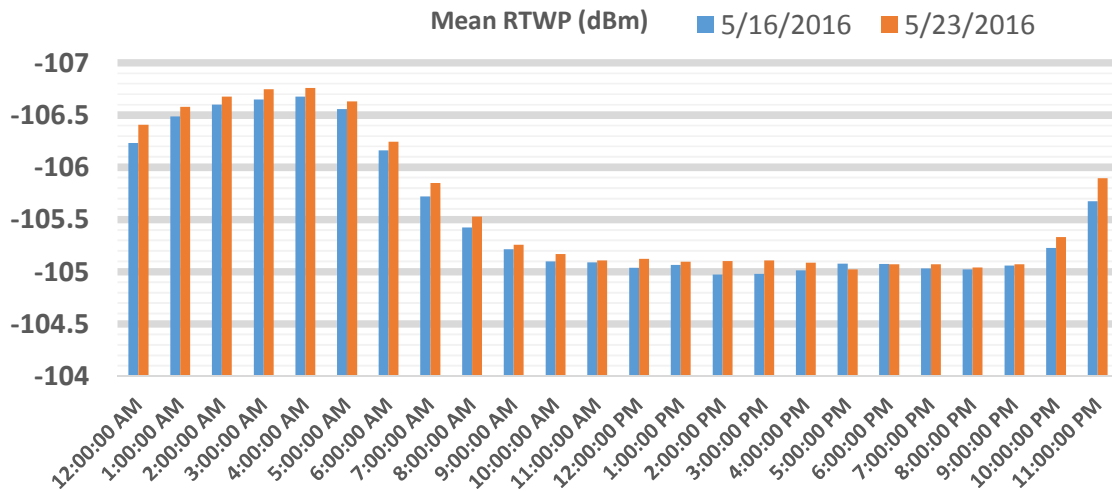**Fig. 8. EDPDCH and EDPCCH share in uplink load (%)**

Fig. 9. Mean RTWP (dBm)

Based on the above analysis, the following deductions were made:

(i) Control channel overhead specifically UL_DPCCH in total uplink load is reduced by almost 10%
(ii) EDPDCH load share increased by almost 5%
(iii) Mean RTWP level decreased by 0.2 dB
(iv) All accessibility KPIS are stable
(v) Both HSDPA and HSUPA throughputs are stable after feature implementation whereas slight increase in traffic observed
(vi) Slight Increase in PS drop rate observed by almost 0.05%
(vii) Soft handover is decreased by almost 0.01%

5. CONCLUSION AND RECOMMENDA-TIONS

Unavoidable signal interference is becoming more prevalent in cellular wireless networks with the increasing number of active transmitters on the RF spectrum. It affects the transmission of the cell to the mobile (downlink). However, it is the uplink (Mobile to Cell site) that is mostly affected by interference, since cell sites have higher or no restrictions for power level transmission [7].

From the analysis and results in this research using the PCA the control channel overhead specifically UL_DPCCH in total uplink load was reduced, EDPDCH load share increased, mean RTWP level and soft handover were decreased,

all accessibility KPIs were stable; both HSDPA and HSUPA throughputs were also stable after feature implementation while there was slight increase in PS traffic and PS drop rate. Since the interference has been reduced in the uplink transmission using the PCA thereby improving the signal quality of the network service, we therefore, recommend that network service providers in Nigeria per se should use this approach to mollify interference so as to improve and optimize the QoS for the generality of their subscribers. Other methods for reducing interference would be considered and 4G/5G would also be understudy as future scope.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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