Spectrum Bundling Architectures for Increased Traffic Capacity in Mobile Telecommunication Networks

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***Abstract*—The two most popular mobile communication standards by market penetration are the GSM and the CDMA based systems. In many developing countries, over 80% of the populace use the GSM technology while the CDMA technology is left with a dwindling share of less than 20%.Inspite of the huge investment in infrastructure by the GSM operators, the networks are still faced with poor service quality and a high rate of dropped calls due to insufficient bandwidth to cater for the increasing number of subscribers. This paper presents two network architectures that will enable the bundling of both the GSM and CDMA spectrums to maximize spectrum efficiency and also minimize the rate of dropped calls. This architecture will not require special licensing of the operators and operators can utilize their existing infrastructure with very minimal changes required for the GSM operators. The architectures have the potential of improving spectrum utilization and improving overall user experience by utilizing the CDMA infrastructure to transmit the excess GSM voice traffic. The two architectures presented in this work are both designed to be implemented by the installation of specially designed Transceiver cards in the BTS which will enable GSM operators utilize either the spectrum of the CDMA operators or both the spectrum and infrastructure of the CDMA operators to transmit the excess calls on their network. These architectures will enable the GSM operators retain their customers and their infrastructure while enabling the CDMA operators earn some revenue from their idle infrastructure and spectrum while the users will continue to use their mobile sets without having to change them.**

***Index Terms*— Spectrum; GSM; CDMA; Bundling**

I. Introduction

THE finite nature of the radio frequency spectrum places a limit on the capacity of the assigned frequency spectrum to mobile operators.

The use of efficient modulation schemes and multiple access systems increase the traffic capacity of the spectrum and the use of the cellular structure where the geographical area is broken down to cells leads to the possibility of frequency reuse within specified distances. This also increases the effective traffic capacity per cell. The rapid rate of increase in traffic capacity and need for mobile in communication services both in the rural and urban areas most cases leads to situations where the available capacity in spite of the difficult capacity increasing schemes becomes inadequate. This leads to situations of higher rate of dropped calls, customer dissatisfaction and reduced revenues to the operators. [1] Mobile communication services currently moving to its fifth generation but for the developing countries. The two most prominent of mobile communications Technologies are

1) Global system for mobile communication GSM
2) Code division Multiple Access

GSM is the most widely used wireless technology in the world, available in more than 219 countries and territories worldwide, with a market share of more than 89 percent.

GSM Technology

The GSM technology involves the licensing of operators in either the 890MHZ-960MHZ band or the 1705-1885MHZ band (for DCS 1800). Slices of frequencies in both the uplink and down link are licensed to operators who deploy service using the cellular structure with frequency reuse, the frequency band allocated to the operator is broken down into frequencies each having a bandwidth of 200KHz and the frequencies are assigned to each of the cells in either 4, 7 or 12 in repeat pattern with each set of cells in one pattern called a sector. [2] [3] [4] [5]. The specifications of the GSM frequency structure are shown in Table I.

TABLE I
DCS1800/GSM900 Standard Specifications

	DCS	GSM
		GSM
Multiple access	TDMA	TDMA
Uplink	1710-1785	890-915
Downlink	1805-1880	935-960
Modulation	GSMK	GSMK
Channel spacing	200KHz	200KHz
Number of channels	375	125

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II. CDMA Technology

Code Division Multiple Access (CDMA) is a form of multiplexing and a method of multiple access that divides up a radio channel not by time (as in time division multiple access), nor by frequency (as in frequency-division multiple access), but instead by using different pseudo-random code sequences for each user. CDMA is a form of "spread-spectrum" signaling, since the modulated coded signal has a much higher bandwidth than the data being communicated. The code division Multiple Access Scheme utilizes the same cellular structure but in its case the entire band is available to each of the cells and the individual users are differentiated by a unique code[6] [7] [8]. Table II shows the technical specification of some CDMA generations.

TABLE II
Some CDMA Technical Specifications

	IS-136	CDMA One
Uplink(MHz)	824-849	890-915
Downlink(MHz)	869-894	935-960
Modulation	π/4DQPSK	BPSK/QPSK
Channel spacing(KHz)	30	12.5
Number of channels	180	1999
Multiple access	CDMA	CDMA

In most countries, the licensing of operators is done based on the individual technologies such that operators are licensed either for the GSM service or the CDMA or fixed wireless access license. The operators then deploy services based on their license specification. The popularity of the GSM technology especially in developing countries such as Nigeria shows that over 90% of the mobile communication subscribers are on the GSM network while the CDMA and Fixed wireless access (CDMA based) share what is left of the market share. This distribution is reflected in the subscriber statistics for Nigeria as shown in Table III.

III. Mobile Communication In Developing Countries (Nigeria As A Case Study)

From the data in Table III, the percentage of the GSM subscribers accounts for about 98% of the total numbers of mobile communication subscribers while the CDMA based system has just about 2% of the total number of subscribers. [9] The data in Table III shows the popularity of the GSM technology. In most urban areas where GSM is deployed, the rapid and aggressive marketing campaigns of the operators often lead to their network having more subsectors than the infrastructure can handle and as such subsectors are faced with poor service quality and high dropped call rates. This situation often times leads to churn but subscribers only migrate from one GSM service provider to another GSM provider who also has the same capacity challenge. The capacity problem is a major limitation of the GSM technology and the operators have deployed different strategies to reduce its effect but these strategies also have limits.

TABLE III
Mobile Subscriber's Statistics in Nigeria. Dec 2015-April 2016[9]

	Apr '16	Mar '16	Feb '16	Jan '16	Dec '15
connected Lines	Mobile (GSM)	211,732,836	210,202,453	210,465,003	-
	Mobile (CDMA)	3,678,796	3,677,676	3,678,068	-
	Fixed Wired/Wireless	353,830	353,923	351,625	-
	Total	215,765,462	214,234,052	214,494,696	-
Active Lines	Mobile (GSM)	147,398,854	146,288,370	149,022,919	148,681,362
	Mobile (CDMA)	1,170,031	2,147,323	2,147,982	2,148,727
	Fixed Wired/Wireless	176,579	184,666	186,868	187,155
	Total	148,745,464	148,620,359	151,357,769	151,017,244
	Teledensity	106.25	106.16	108.11	107.87

The CDMA technology has a higher capacity but had the disadvantage of being originated as a proprietary standard and this prevented its worldwide acceptability. The technology is currently being deployed with low cost/low quality mobile phones and the fact that its SIM cards and phones cannot be used on the more popular GSM network limits its mass appeal and market penetration. The current situation in developing countries is such that the spectrum of the GSM technology is overcrowded while that of the CDMA which inherently has more capacity per cell/channels remains underutilized. This paper focuses on the bundling of the GSM and CDMA spectrum such that the telecom infrastructure is designed to handle both schemes and the excess traffic on the GSM network is transmitted on the CDMA network.

IV. Spectrum Bundling

The concept of spectrum bundling as presented in this paper entails the pairing of the GSM (DCS1800) and the CDMA spectrum for use by a GSM operator. In markets with auctions already done, the CDMA operators can partner with the GSM operators in an agreement that enable the GSM operator utilize the idle capacity of the CDMA operators to carry their excess capacity without having to bid for that spectrum. For new licenses, the CDMA spectrum can be bundled with the GSM license such that GSM operators pay for both CDMA and GSM spectrum and deploy the appropriate infrastructure to maximize the spectrum. The DCS 1800 used in high density urban areas can be combined with the cdmaOne spectrum which is sub 1GHz and both spectrum can exist without adversely affecting each other's transmission. From Tables 1 and 2, the GSM technology and the CDMA can be made to share the same antenna due to differences in the multiple access

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schemes and frequency/ channel bandwidth structure. The systems will however different transceivers. This work proposes two different architectures for utilizing CDMA spectrum and Infrastructure.

Figure 1 shows the topology that utilizes the CDMA spectrum. One key objective of this architecture is to ensure that there is no change in the operating specifications of the Mobile Unit. The BSC manages both the BTS for the GSM frequency and the transceiver for the CDMA frequency. The BTS communicates with all the mobile units in the cell and when it has reached its capacity and is no longer able to support other calls the BTS activates the CDMA Transceiver and directs the excess mobiles to switch the voice traffic to the CDMA frequency. The control and signaling traffic are communicated directly from the BTS to the excess traffic while the voice traffic is transmitted using the CDMA frequency. The signals are modulated using the GSM modulation scheme but on a different frequency selected such that there is no co channel interference between the cells. The traffic maintains its GSM specifications but it utilizes the CDMA spectrum to transmit its traffic.

In the configuration shown in figure 2, the excess traffic is routed through a GSM-CDMA converter which receives the GSM traffic, decodes, demodulates the signals and modulates/ repackages the signals as CDMA traffic. It is then routed through the CDMA operator network. The CDMA operators' network treats the calls as originating from a CDMA mobile device and transmits the calls through its infrastructure to the Public Switched Telephone Network (PSTN) for onward transmission to its destination.

V. Conclusion

The huge investments in the GSM technology in most developing countries is such that operators will not be too eager to abandon their infrastructure and migrate to the 5G communication standard .There must be a novel approach at catering for the increased demand from the users without the operators having to commit huge funds to the rollout of new communication technologies. The decline in CDMA subscribers has led to a huge idle capacity which cannot be utilized by the GSM operators whose networks has reached it maximum carrying capacity. The architectures presented in this work has the potential of utilizing these idle CDMA spectrum and infrastructure without altering the current network deployment. The architecture is transparent to the users thus enabling them retain their mobile devices, their phone numbers and their operators. The GSM operators will be able to retain their customers and make some added revenue by investing in extra transceiver cards or GSM-CDMA converters and CDMA transceiver depending on the architecture selected. Both architectures presented will enable the GSM operators keep their subscribers satisfied while enabling the CDMA operators generate revenue from their otherwise idle spectrum and infrastructure.

Architecture 1: Utilizing CDMA spectrum

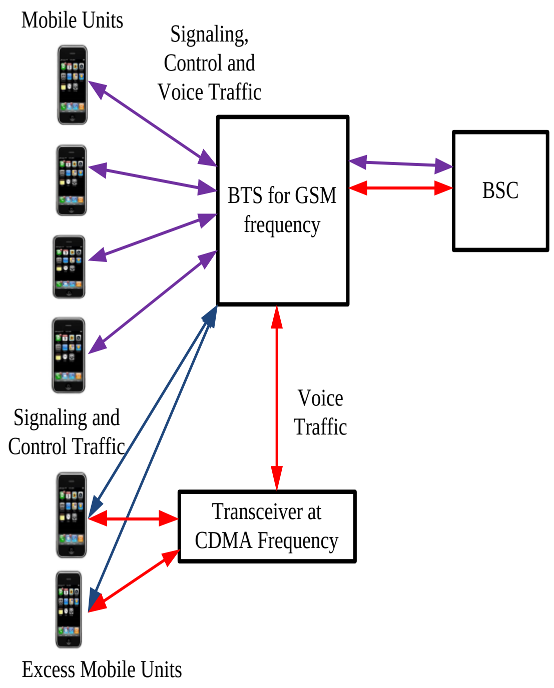

Figure 1. Spectrum bundling utilizing the CDMA Operators Spectrum

Architecture 2: Utilizing CDMA Operator Infrastructure

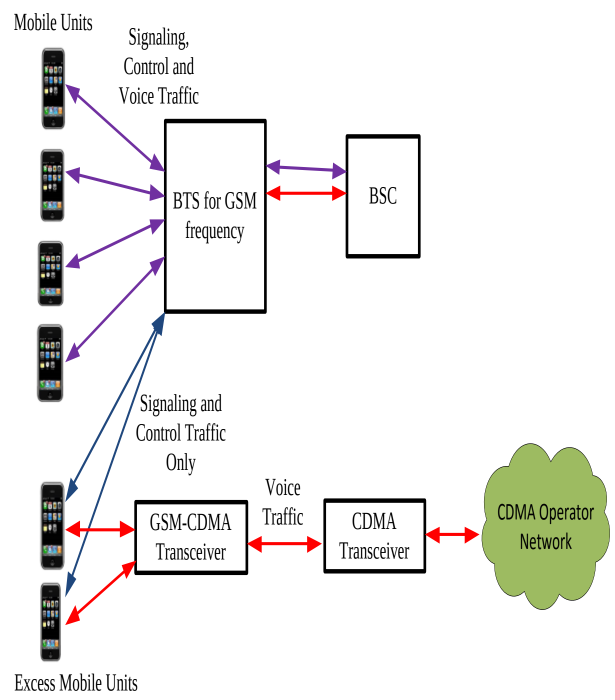

Figure 2. Spectrum bundling utilizing the CDMA operator Infrastructure

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