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Development of an Intelligent Enhanced Dynamic Cell Sectorization Scheme for Improved CDMA Traffic Capacity

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ABSTRACT

The study on voice traffic re-distribution in Code Division Multiple Access (CDMA) technology where large number of cellular mobile users needed to access the network was the focus. Whenever mobile users suddenly gather and have more demand greater than the designed system capacity at a certain environment, any call connecting to network would be blocked ones the threshold is met. Measurement was taken at Mobile Telecommunication Network (MTN) 3G-EN0618 Base Transceiver Station (BTS) located in Enugu, South East Nigeria to verify the traffic capacity of the existing CDMA System and on how to improve on the capacity. An Intelligent Enhanced Dynamic Cell Sectorization (IEDCS) model was developed and programmed using C++ tool and embedded in a microcontroller to provide intelligent solutions to a congested sector. A Dynamic-based Microcontroller Algorithm (DMA) was developed to show steps taken for a congested sector to reroute the excess calls to non-congested sector. The simulation circuit was designed using proteus software to demonstrate how traffic capacity was improved. An idle Twin-Sector RvB1 with threshold of 323 users per second simultaneously accepted excess voice user's call from Twin-sector A and Twin-Sector B respectively and this in-turns increases the CDMA traffic capacity.

Keywords:- Code Division Multiple Access (CDMA), Mobile Telecommunication Network (MTN), Base Transceiver Station (BTS), Dynamic-based Microcontroller Algorithm (DMA), Intelligent Enhanced Dynamic Cell Sectorization (IEDCS)

I. INTRODUCTION

Wireless communication has formed basic way of sending and receiving information at ease. The data, voice, videos and multi-media forms of communication are widely used to send information from one point to another. For multi-user communication, base stations were built to provide transmissions and receptions between mobile users. The mobile user simultaneously accesses information at the base stations radio channel through multiple-user systems. Code Division Multiple Access (CDMA) technology is one of the commonly used access technology in Nigeria for third generation (3G) network. Example of CDMA for 3G wireless networks includes; Wideband-CDMA, High Speed Downlink Packet Access (HSDPA), and High Speed Uplink Access (HPUPA). The increase of cellular user traffic hotspots and unbalance call distributions are common in wireless communication networks. This affect the available traffic capacity of the wireless system.

Several techniques have been developed to improve on the traffic capacity of the 3G networks. They include; Microcell zones, Cell Splitting, Cell Sectoring, and Smart Antenna Schemes. The cell splitting scheme subdivides congested cells into several smaller cells. This requires building a new Base Transceiver Stations (BTS) which when completed provides increase in the network traffic capacity. This idea has frequent handoffs, difficulty in executing channel assignment and high cost of building these new BTSs [1-2].

In an attempt to meet the constant sudden increase of mobile users at certain areas, cell sectoring scheme was developed to provide higher traffic capacity. The scheme was achieved by sectorizing a cell into 120-degrees, 90-degrees, 60-degrees and 30-degrees respectively. A sectroized cell with more than 120-degrees requires several antennas with high cost of antenna deployment, frequent handover though less than that of cell splitting, and decrease in trunk efficiency [3-5].

Smart antenna has provided a promising way of improving the traffic capacity of a wireless networks. This concept enables beam formations and signal direction detection. It easily deployed tracking at beam switching rate and has optimum downlink Signal to Interference Noise Ratio (SINR). Low gain between beams, false locking with shadowing, interference and wide angular spread were demerit of smart antenna scheme [6].

As the splitting of cell idea evolves, the usage of smaller cells becomes efficient and it led to creation of microcells. The microcell zones technique was developed to provide increase in cellular network capacity in an area where population was high. In this concept, a given channel is active only in a particular zone in which mobile is travelling, base station radiation is localized and interference is reduced. No handoff but the scheme was better applied in highways [7].

Having reviewed the merit and demerits of the existing schemes, it was imperative to note that most of these techniques lacks intelligent to provide more access to mobile users at hot spot such as political gathering, football matches at a stadium, and marriage ceremony at hotels halls/event centres. Cell splitting and cell sectoring schemes does not provide intelligent solutions to enable mobile users switch from a congested cell to non-congested cell instead it drops the excess calls coming into the congested cell.

An Intelligent Enhanced Dynamic Cell Sectorization (IEDCS) model was developed to switch mobile user's traffic from a congested sector to non-congested sector which in turns increases the traffic capacity of CDMA networks. This happens when a congested sector send mobile users traffic to sector operating below its allocated threshold.

II. RESEARCH METHOD AND SYSTEM ANALYSIS

A. *Research Method*

There were five basic steps taken in developing the intelligent cell scheme for improved traffic capacity of a CDMA network. The first procedure was to derive expressions for number of users per sector in a CDMA network. This was done by modifying the traffic capacity equation of Wideband Code Division Multiple Access (WCDMA) model. Secondly, a voice traffic measurement of signal strength in a sectroization network was taken. Thereafter, the developed model was programmed in an Integrated Development Environment-C++ toolkit and embedded in CMOS microcontrollers. Finally, the simulation circuit design was done using Proteus software to demonstrate how mobile user's traffic from congested sector could be rerouted to non-congested sector. The system was designed such that logic 1 stands for a sector requesting help due to congestion while logic 0 stands for sector operating within its threshold hold.

PL4 Test Result

This test was carried out to determine the basic base transceiver stations configurations. Part of the CDMA systems configurations for 3G-EN0618 MTN base transceiver station (BTS) in Enugu were noted and shown in Table 1 below.

TABLE 1
PL4 MEASUREMENT

Frequency	23000MHz
Sectorizations factor	3
Energy per Bit (Eb/No)	2dB
Voice activity factor	0.375
Over All Processing Gain	226dB
Bit-to-Energy Ratio (BER)	7dB
Signal Power (Ps)	40dB
Thermal noise	-
Antenna height	30m

Sweep Test Measurement

The Fig. 1 below shows that the 3G wireless network located in Enugu with the code EN0618 operates with three sectors 120-degrees cell sectorization scheme. Each 120-degree sector has different signal strength; sector A has 110 user per sector, B with 323 user per sector and C with 475 user per sector. These shows that the wireless system has a varying processing gain and sector C with the highest number of user per sector was due to the peculiarity of that area.

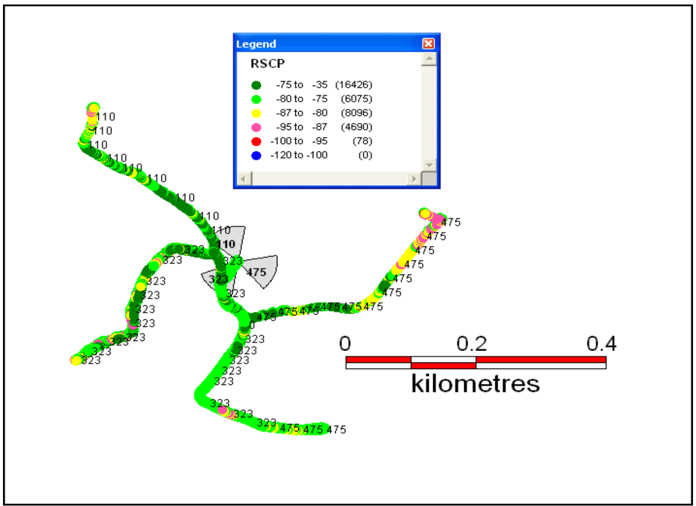

Fig. 1: Received signal level for 3G-EN0618

B. *System Model*

Wideband Code Division Access (WCDMA) Model

[8] The WCDMA model for cell sectorization scheme deploying directional antenna was given as;

$$K_d = 1 + \frac{1}{\alpha}\left(\frac{P_G}{E_b/N_o}\right) - \frac{n}{P_S \, x \, \alpha}; 0 < \alpha < 1$$

Where; K_d is number of user per sector deploying directional antenna, PG is processing gain, E_b/N_o is Energy per bit per noise spectral density, n is background noise, and P_S is signal power and α is voice activity factor

Introducing sectorization factor (λ), the traffic capacity of the network would be;

$$K_d = \lambda\left\{1 + \frac{1}{\alpha}\left(\frac{P_G}{E_b/N_o}\right) - \frac{n}{P_S \, x \, \alpha}\right\}, \quad 0<\alpha<1 \quad (2)$$

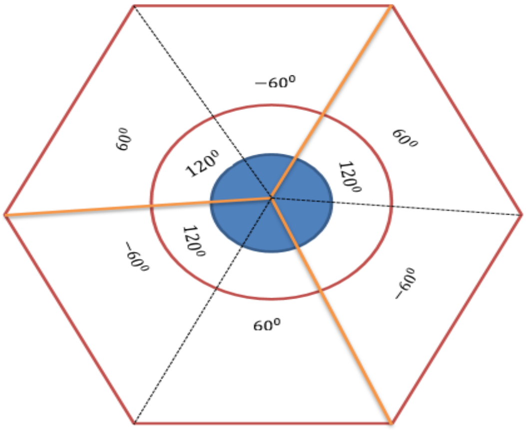

Fig. 2 Architecture of three-twin sector antenna.

In increasing the traffic capacity, the system model was modified. To achieve this, the 3G wireless network deployed a twin-sector antenna system. Fig. 2 above shows an architecture of a three-twin sector antenna system. For the case of 120-degrees sectors, the twin-sector antenna dynamically split the 120-degrees into -60-degrees and +60-degrees sectors respectively each operating out of phase. The Twin-sector antenna provides a theoretical doubling of sector capacity. Each antenna produces two separate narrow azimuth beams whose positions are directed at +60-degrees and –60-degrees of the antennas bore site. And so, the new cell capacity (K_t) of the cellular network with the application of the Twin beam sector antenna was twice the capacity of CDMA network deploying directional (sector) antenna system; Therefore;

$$K_t = 2K_d \quad (3)$$

The number of users per sector deploying twin-sector antenna could be determined using equation (3) above. This modified model was called Enhanced Dynamic Cell Sectorization model (EDCS) model. There have been need to add intelligent solutions to various cell sectoring schemes to enable it switch traffic from congested sector to non-congested sector.

To obtain an intelligent EDCS model, consider Fig. 3 below which is an architecture of Intelligent EDCS (IEDCS) scheme using twin-three sector antenna system. It indicates that a sector can support another sector that operates above its threshold by accepting the traffic coming from such congested sector.

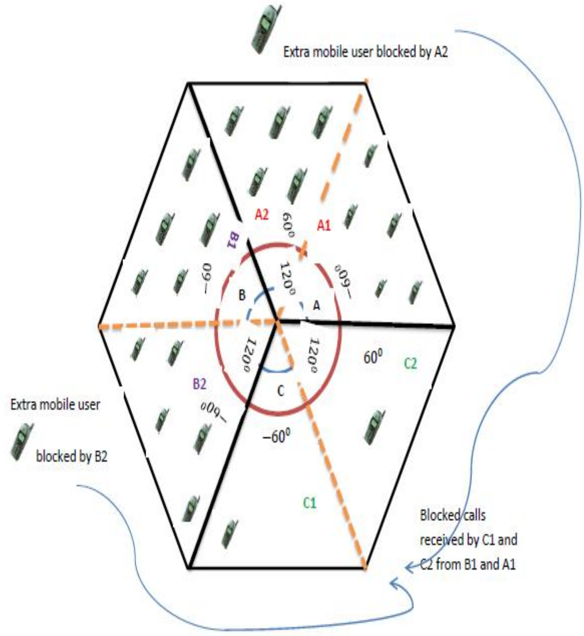

Fig.3 Architecture of Intelligent EDCS Scheme Using Twin-Three Sector Antenna System.

The number of users for the varying three sector antenna as shown in Fig. 1 above for the intelligent EDCS scheme was denoted as $K_{t_1}^1, K_{t_2}^1$ and $K_{t_3}^1$ respectively.

Let the excess calls generated by each of the twin-three sectors antenna be given as; Y_1, Y_2 and Y_3 respectively.

Where $Y_1 = Y_{11} + Y_{12}$, $Y_2 = Y_{21} + Y_{22}$ and $Y_3 = Y_{31} + Y_{32}$

Also, take a note of when the calls entering each of the twin-three sectors were below their threshold shown in Fig.1 as $S_{1T}-, S_{1T}-,$ and $S_{1T}-$ respectively.

Now, the new number of users for Sector A was given as;

$$K_{t_1}^1 = S_{1T}- + Y_2 + Y_3 \quad (4)$$

The new number of users for Sector B was given as;

$$K_{t_2}^1 = S_{2T}- + Y_1 + Y_3 \quad (5)$$

And also, the new number of users for Sector C was given as;

$$K_{t_3}^1 = S_{3T}- + Y_1 + Y_2 \quad (6)$$

To determine the total number of users (K_t^1) for the intelligent EDCS model, the varying new number of users for the twin-three sector system were added together as;

$$K_t^1 = K_{t_1}^1 + K_{t_2}^1 + K_{t_3}^1$$

Substituting the values of equations (4), (5) and (6) into equation (7) gives;

$K_t^1 = S_{1T^-} + Y_2 + Y_3 + S_{2T^-} + Y_1 + Y_3 + S_{3T^-} + Y_1 + Y_2$

Collecting like terms;

$$K_t^1 = S_{1T^-} + S_{2T^-} + S_{3T^{-+}} + 2(Y_1 + Y_2 + Y_3) \quad (8)$$

Hence, equation (8) could be used to determine the total number of users in a single cell CDMA network deploying intelligent twin-sector antenna system. The total number of users for intelligent EDCS model was dependent on varying the number of users below the thresholds of the various sectors, and the excess voice calls generated and managed by the entire sectors.

For the model to experience a call drop, there must be a situation whereby the new traffic capacity generated by the system(K_t^1) was greater than the input (K_t) being the original traffic capacity of the network.

That was, $K_t^1 > K_t$

Note: The intelligent system added capacity only when a sector was idle or operating below its threshold and accepted a congested (excess) calls coming from another sector.

A. *System Design*

System Design Considerations

The key objective of any Code Division Multiple Access (CDMA) Technology is to provide an interface for multiple mobile users accessing the wireless network simultaneously. Cell schemes are deployed to CDMA system to improve on its traffic capacity. The designed intelligent enhanced dynamic cell sectorization has the ability to provide intelligent solutions to the existing cell sectoring schemes and the EDCS model. The intelligent system consists of three units; Central Call Processing Unit (CCPU), Slave Call Processing Unit (SCPU) and Microcontroller Master Call Processing Unit (MCPU). The CCPU was used for receiving mobile user traffic calls from the CDMA board to the intelligent unit and also route calls to all the Slave Call Processing Units (SCPUs). The mobile user traffic calls entering each SCPU were displayed using liquid crystal display (LCD) connected to the CCPU. The SCPUs receives calls from the CCPU and route all the congested calls to the MCPU. The main functions of the MCPU were to route an excess call from congested SCPU to SCPU attending to either less calls or idle. The microcontroller master call processing unit also functions as to drop excess calls when all the individual sector are simultaneously attending to calls up to their designed threshold. Fig. 4 shows a block diagram of the intelligent cell scheme

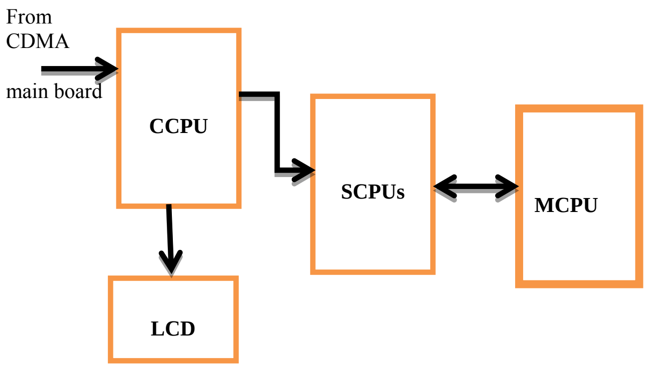

Fig. 4 Block diagram of Intelligent Cell Scheme

System Requirement and Assumptions

TABLE 2.

SYSTEM REQUIREMENT AND ASSUMPTIONS

S/N	Requirement	Description
1	Central Call Processing Unit	To receive calls from the CDMA main board and Transmit the calls to individual sectors (Slave Call Processing Unit) using microcontroller device
2	Slave Call Processing Unit	To receive calls from Central Call Processing Unit and Route congested calls to the Master Call Processing Unit using Microcontroller devices.
3	Master Call Processing Unit	To receive congested calls from the Slave Call Processing Unit and Transmit same calls to non-congested Slave Call Processing Unit using Microcontroller

		device
4	Input / Output Mode	Variables
5	Storage Memory	Radom Access Memory, EEPROM
5	Display Interface	LCD
6	Signal Conditioning Type	Analogue and Digital
7	Data Conversion Process	Analogue to digital conversion
8	Power Supply Type	Direct Current

			indicate call being sent to the MCPU respectively
3	Microcontrollers	PIC16F877A	Used for central call processing unit
4	Microcontrollers	PIC16F648A	Used for Slave call sectors
5	Microcontrollers	PIC16F873A	Used for master call processing unit

Components Selections

To use simulation circuit to demonstrate the performance of the IEDCS, the following componenets shown in Table 3 were carefully selected.

TABLE 3
BASIC COMPONENT USED FOR SIMULATION OF THE INTELLIGENT SYSTEM DESIGN

S/N	Components	Values	Features
1	LCD	LM016L	Used to display the number calls entering each sector.
2	LED: Yellow, Green and Red		LED showing red is for congested cell, green is for cells operating below the designed threshold and ready to accept excess calls and yellow

Development of Dynamic-based Microcontroller Algorithm (DMA) for the IEDCS Model

Algorithm for Central Call Processing Unit (CCPU)

Step1 Vary the resistors representing voice calls (information signal) entering the three separate twin-sector antenna,
Step2 Use a Microcontroller 1 to receive the entire calls coming from the three twin-sector antennas,
Step3 Route all the calls to different SCPUs, and
Step4 Display the calls entering the three twin-sector antenna unit (SCPUs) on the LCD.

Algorithm for Slave Call Processing Unit (SCPU)

Step1 Receive calls coming from CCPU,
Step2 Compare the received signal with the allocated threshold of the sectors,
Step3 Route the excess calls above the allocated threshold to MCPU, and
Step4 Receive excess user traffic calls from congested sector when operating below the allocated threshold.

Algorithm for Master Call Processing Unit (MCPU)

Sector 1 (SCPU1)

Step1 Receive excess mobile user traffic coming from SCPU1,
Step2 Compare the excess mobile user traffic with the SCPU2 threshold,
Step3 Reroute the excess mobile user's traffic that SCPU2 can handle,
Step4 If the SCPU2 has reached its threshold either because it is attending to calls above its threshold or cannot handle all

the excess calls, then compare the excess calls from SCPU1 with the SCPU3 threshold.
Step5 Reroute the excess mobile user traffic that SCPU3 can handle, and
Step6 If the excess mobile user traffic is more than the threshold of SCPU2 and SCPU3, reroute only the excess user's traffic they can handle and drop the remaining excess calls.
Step7 If all the SCPUs are simultaneously having congested calls, then drop all the excess calls.

Sector 2 (SCPU2)
Step1 Receive excess mobile user traffic coming from SCPU2,
Step2 Compare the excess mobile user traffic with the SCPU1 threshold,
Step3 Reroute the excess mobile user's traffic that SCPU1can handle,
Step4 If the SCPU1 has reached its threshold either because it is attending to calls above its threshold or cannot handle all the excess calls, then compare the excess calls from SCPU2 with the SCPU3 threshold.
Step5 Reroute the excess mobile user traffic that SCPU3 can handle, and
Step6 If the excess mobile user traffic is more than the threshold of SCPU1 and SCPU3, reroute only the excess user's traffic they can handle and drop the remaining excess calls.
Step7 If all the SCPUs are simultaneously having congested calls, then drop all the excess calls.

Sector 3 (SCPU3)
Step1 Receive excess mobile user traffic coming from SCPU3,
Step2 Compare the excess mobile user traffic with the SCPU1 threshold,
Step3 Reroute the excess mobile user's traffic that SCPU1 can handle,
Step4 If the SCPU1 has reached its threshold either because it is attending to calls above its threshold or cannot handle all the excess calls, then compare the excess calls from SCPU1 with the SCPU2 threshold.
Step5 Reroute the excess mobile user traffic that SCPU2 can handle, and
Step6 If the excess mobile user traffic is more than the threshold of SCPU1 and SCPU2, reroute only the excess user's traffic that they can handle and drop the remaining excess calls.
Step7 If all the SCPUs are simultaneously having congested calls, then drop all the excess calls.

Microcontrollers' Codes

There were five microcontrollers deployed in the designed system. Three of such were of the same rating and dedicated for Twin-sector A, B and C respectively. That is PIC16F648A was for slave call processing unit. The microcontroller PIC16F873A was dedicated to master call processing unit while the PIC16F877A was for central call processing unit. The codes running on the microcontrollers were written in the MPLAB Integrated Development Environment (IDE). The IDE is a complete development environment which allows developers to write the codes both in Assembly and C languages, thanks to the integration C++ toolkit. These codes dealt with the call management of each unit and for communications between different units. Fig.5 IDE for generating codes and programming microcontrollers. The traffic capacity of the twin-sector system was designed in-line with the Fig.1 above. That is, 220 users per second for Twin-Sector A (RvA1 =110 user per second and RvA2 =110 users per second), 646 users per second for Twin-Sector B (RvB1 =323users per second and RvB2 = 323 users per second) and 950 users per second for Twin-sector C (RvC1 = 475 users per second and RvC2 = 323 users per second) respectively.

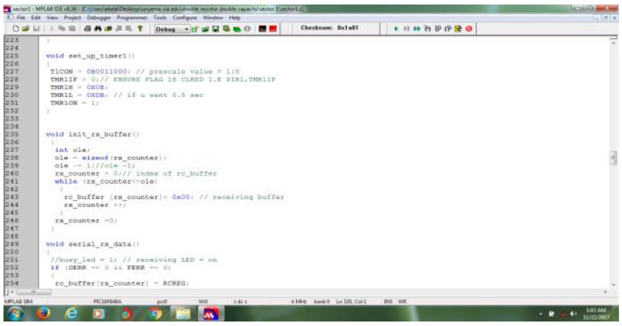

Fig.5 IDE for generating codes and programming microcontroller

III. RESULTS AND ANALYSIS

The simulation circuit shown in Fig. 6 was used to demonstrate the performance of the IEDCS scheme. The circuit has twin-sector A (RvA1 and RvA2), Twin-Sector B (RvB1 and RvB2) and Twin-Sector C (RvC1 and RvC2) respectively. The mobile user's voice traffic coming into various sectors were accepted by the central call processing unit and channelled to slave call processing units. When sector RvB1 was idle, it receives congested calls coming from Twin-Sector A and Twin-Sector B simultaneously. The RvB1 with the designed threshold of 323 users' accepted 3 excess calls from Twin-Sector A and 21 excess calls from Twin-sector C respectively.
Also, Fig. 7 below shows a time when RvB1 was operating with the capacity of 49 mobile user per second which was below the designed threshold of 323 as indicated in Fig.1 above, it accepted 25 users per second excess calls from Twin-Sector A and 15 user per second excess calls from Twin-Sector C respectively. The intelligent system added capacity as it was able to channel mobile user's voice from

congested sector to non-congested sectors. It has the ability to simultaneously reroute excess calls from congested sector to non-congested sector and this in-turns increases the traffic capacity of the 3G cellular networks as those calls that would have been dropped were managed by the scheme.

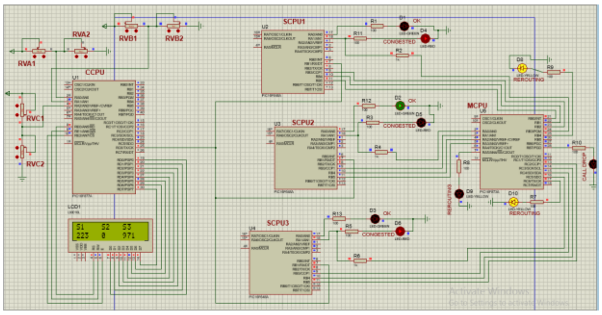

Fig. 6 IEDCS Simulated Circuit showing SCPU2 being Idle

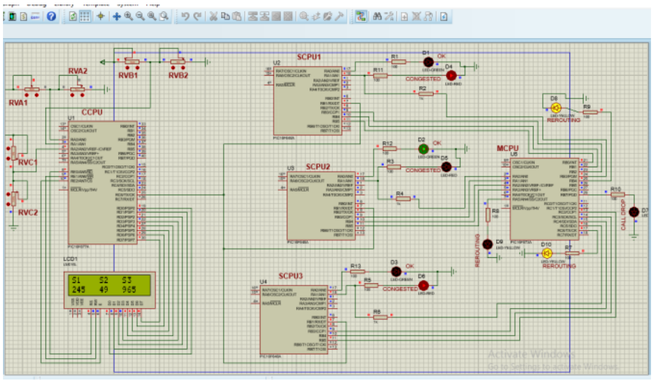

Fig. 7 IEDCS Simulated Circuit showing SCPU2 Operating below Its Threshold

The result of the implemented circuit diagram was shown in Table 4 below. The Table indicated when a cell was congested, requested help and its excess voice calls being handled by non-congested cell/sector. Whenever a sector was requesting help, all other sector operating below the designed threshold could help by accepting the excess calls.

TABLE 4

TRUTH TABLE OF THE IEDCS

S/N	INPUT K_t			OUTPUT K_t^1			LED INDICATOR
	A	B	C	S 1	S 2	S 3	Statement for each of the sector
0	0	0	0	0	0	0	None of the sector is requesting help
1	0	0	1	0	0	1	Only sector 3 is requesting help
2	0	1	0	0	1	0	Only sector 2 is requesting help
3	0	1	1	0	1	1	Sector 2 and 3 requesting help
4	1	0	0	1	0	0	Only sector 1 is requesting help
5	1	0	1	1	0	1	Sector 1 and 3 requesting help
6	1	1	0	1	1	0	Sector 1 and 2 requesting help
7	1	1	1	1	1	1	Call drop due to all sector requesting help

IV. CONCLUSION

The need to meet the increasing demand of mobile users remains the main goal of Wireless Service Providers (WSPs). Cell sectoring scheme have been deployed to improve on the traffic capacity of the cellular network but it lack intelligent to manage the excess calls of various ssctors. An Intelligent Enhanced Dynamic Cell sectoring (IEDCS) model was developed to provide traffic management solutions to various sectors. The performance of the model was demonstrated using simulation circuit. Each of the twin-sector has its designed threshold. The scheme shows that at a time when Twin-Sector B (RvB1=0 user per second) was idle, it simultaneously accepted excess calls from congested Twin-Sector A and Twin-Sector C respectively. Equally, the scheme demonstrated its ability to manage excess traffic from congested Twin-Sector A and Twin-Sector C respectively when Twin-Sector B (RvB1=49) operating below its threshold simultaneously accepted the excess mobile users traffic up to 274 users per second. This IEDCS having the ability to manage traffic solutions from various sectors increases users' traffic capacity of the wireless systems at a point when excess calls generated from congested sectors were managed by non-congested sector.

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