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Optimization of Fourth Generation(4G) Long Term Evolution (LTE) Mobile Network Using Dynamic Intelligent Sectorization

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ABSTRACT

To realize the benefits of LTE cellular networks, thorough and exact planning is required. This telecommunications system were created to provide data, voice, and multimedia transmissions that are efficient, dependable, and effective that has ability to cope with traffic solutions of congested mobile customers' traffic, the situation was apparent that the capacity had been enhanced The challenges addressed in this paper includes; Network capacity expansion and managing expanding network capacity between different Base Transceiver Stations .The methodology employed includes Field tests which includes Sweep tests to determine the type of sectorization in use, current network capacity and the Platform Layout 4 (PL4) test to determine the basic configurations of the network. This was accomplished by employing the concept of sectorization to change the existing network capacity equation, and capacity improvement expression was also presented using the Dynamic Intelligent Cell Sectoring Scheme (DICS) Model with the theoryof twin-beam sector antennas deployed. The results of this study demonstrated that Dynamic Intelligent Cell Sectorization (DICS) increased cell capacity by twofold while reducing sector edge by 50% between base stations in the LTE wireless network.

Keywords: network, optimization, generation, evolution

I. INTRODUCTION

Mobile communication has become an important means of reaching one another from one

location to another. There are several telecommunications systems developed to provide efficient, reliable and effective form of data, voice, and multimedia transmissions. While researches continue in developing newer systems, considering the cost of research and deployment of the technological systems which run in billions of Naira, the need to improve on the existing wireless system becomes paramount.

Multiple access technology is an interface to multiple users accessing a wireless network. There are several kinds of multiple user systems. The Frequency Division Multiple Access (FDMA) that was used in First Generation (1G) (1981) network supports one (1) user per channel. The later was Time Division Multiple Access (TDMA) system used in Second Generation (2G) (1991) cellular system. **Boor-Oyibo F. (2011).**. Researchers' work on the second generation mobile network, which faced numerous problems, gave rise to the third version employed Code Division Multiple Access (CDMA); 2001 Third Generation (3G) network launched. Despite its great benefits, it still has some main drawbacks, such as insufficient bandwidth, high power consumption, and the need for closer base stations, all of which are costly.**(Idigo et al, 2006).**

4G LTEis a term used for the particular type of 4G that delivers the fastest mobile internet experience with reduced latency . You would usually see it called 4G LTE. The true 4G technology is significantly faster than 3G, which originally had data rates measured in kilobits per second, rather than megabits per second. 4G technology is an improvement over 3G, offering speed that are 10 times faster that 3G can do. In some cases, your phone may even display 4G LTE-A (Long Term Evolution Advanced) which uses cutting edge of cell phone technology.

Fourth generation (4G) Long Term Evolution (LTE) mobile networks are facing increasing demands for data due to the proliferation of smartphones and data-hungry applications. This research investigates a technique called Dynamic Intelligent Sectorization (DIS) to optimize LTE networks for better capacity and user experience. Traditional methods for increasing capacity, like adding more cell towers, are expensive and time-consuming. DIS offers a faster and more cost-effective solution by intelligently splitting cells and adjusting their size based on traffic patterns. This approach can significantly increase network capacity, improve signal strength, and reduce interference from neighboring stations, ultimately leading to a better quality of service for users.

In order to improve on the capacity of the 4G (LTE) technology, an Intelligent Dynamic Cell Sectoring (IDCS) Model was developed. The developed scheme was a better improvement with its high increase in cell capacity when compared to the existing cell sectoring scheme. This was because of its ability to dynamically repartition a sectorized network into two equal sizes without deploying extra antennas. This scheme was achieved using twin-sector antennas with an inbuilt intelligent to operate out of phase in each twin-sector section **Foo, S (2014)**

To make system capacity improvement more enticing, an intelligent system will be designed for the developed IDCS scheme. The intelligent solutions were based on rerouting a call coming to congested sectors to non-congested sectors. It was based on the fact that sometimes a cell/sector maybe handling capacity above its threshold which leads to congestion and loss of calls, and instead of losing such call connecting to the congested cell, the intelligent system decongests the cell and reroute such a call from it to a non-congested cell.

In order to improve on the capacity of the WCDMA technology, an Intelligent Dynamic Cell Sectoring (IDCS) Model was developed. The developed scheme was a better improvement with its high increase in cell capacity when compared to the existing cell sectoring scheme. This was because of its ability to dynamically repartition a sectorized network into two equal sizes without deploying extra antennas. This scheme was achieved using twin-sector antennas with an inbuilt intelligent to operate out of phase in each twin-sector section.

However to achieve success in the optimization process the Dynamic-Based Microcontroller Algorithm with ICSS Intelligent Cell Sectoring Scheme (ICSS) and the Dynamic-Based Microcontroller Algorithm with Intelligent Dynamic Cell Sectoring Scheme (IDCSS).

IDCS will simulated using **Proteus 8.9** professional software Environment to determine the capacity of the 4G capability.

In order to determine the full capacity of the network users , the graph of system capacity will be plotted against sectorization factor without a model , with ICSS model and with IDCS model. Finally , a comparism of developed model and existing model will be determined.

LTE excels in covering large areas but struggles in densely populated pockets where user demand overwhelms the network. This disrupts quality of service (QoS). Researchers in this study explore various strategies to improve capacity and coverage in 4G networks, specifically focusing on solutions that can adapt to these changing user densities.

Veritibi et al. (1994) examined how signals from neighboring cell towers (inter-cell interference) affect cellular network capacity. This interference limits how much data the network can handle. The researchers tested a power control strategy on a different channel to reduce this interference. Their findings suggest this strategy successfully reduced interference, thereby increasing network capacity.

Boor-Oyibo (2011) investigated how antennas can improve cellular network coverage and capacity within a cell. They designed, simulated and implemented a new smart antenna with multiple slanted antenna elements. This antenna can generate multiple beams to target specific areas. Their findings suggest that this smart antenna can improve network capacity by efficiently directing signals towards users, leading to better utilization of the cellular system's capacity.

Osman and Hämäläinen (2011) investigated a new approach called vertical sectorization for improving capacity in 3GPP LTE networks. They simulated a system with different antenna configurations and found that 3x2 vertical sectorization significantly increased capacity. The analysis focused on signal-to-interference ratio and did not consider other network performance metrics like bandwidth and spatial efficiency.

Idigo et al. (2012) investigated a method to estimate the capacity of multi-cellular CDMA systems using a simplified geometric model. They showed that if interference from neighboring cells follows a specific pattern, the system's capacity can be calculated by multiplying the impact of a single cell by the total number of cells. However, their method assumes all cells are identical, which isn't always true. While promising for simpler systems, this approach is not suitable for networks with cells having different characteristics.

Richard Clarke (2013) examines ways to increase mobile network capacity to meet growing demand. He explores three approaches: allocating new spectrum, geographically reusing existing spectrum, and improving the efficiency of spectrum usage in a given area. The paper offers methods for increasing capacity but focuses on traditional spectrum reuse in US networks and doesn't analyze its effectiveness in newer LTE-Advanced networks, which are struggling to meet future demands.

Sohrab et al. (2013) investigated improving capacity in CDMA networks using cell splitting, where a large macro cell is divided into smaller micro, pico, and femto cells. They simulated the system to calculate factors like processing gain and signal strength, finding it beneficial. However, they didn't demonstrate real-world deployment and acknowledged drawbacks like increased handovers due to more frequent cell transitions, which can be expensive as it requires additional base stations.

Abhinav and Vinay (2014) address the challenge of maintaining coverage area as the number of GSM users increases. This leads to spectrum allocation issues and inefficient coverage. To improve efficiency, they compared cell splitting and cell sectoring methods. Their study found that cell sectoring outperforms cell splitting in terms of increasing capacity for multiple users

Sheu et al. (2014) investigated the relationship between cell sectorization and power management in MIMO systems. They explored how cell sectorization design impacts signal strength and interference. Their analysis showed that Diamond Shaped Frequency Reuse (DSFR) outperformed Triangular Shaped Frequency Reuse (TSFR) in reducing a specific type of interference called MIMO spread interference.

Abbasi et al. (2015) investigated using peak cell sectorization to improve capacity in cellular networks. They simulated different antenna configurations and found that increasing sectors to 900 offered the best balance. While this achieved a 600% capacity increase, it also resulted in more handoffs due to the higher number of antennas. Compared to even higher sector numbers, 900 sectors provided better performance with improved signal-to-interference ratio (SINR) and reduced handoff fatigue.

Nicholas Nkamwesiga (2017) investigates mobility prediction for mobile devices (mobile hosts) in smart antenna systems (SASs). SASs use beamforming to optimize signal strength for each device. While SASs offer better network performance, static positioning of base stations limits their ability to predict user movement and optimize for it. This can lead to reduced network capacity and coverage. Nkamwesiga highlights the need for improved mobility prediction to fully optimize SASs.

Ishengoma (2018) explores how to improve capacity in cellular networks, focusing on limitations caused by bandwidth and signal-to-noise ratio (SNR). The paper examines two techniques for 4G networks: MIMO (Multiple-Input Multiple-Output) antennas and Carrier Aggregation (CA). MIMO tackles SNR by purifying the signal, while CA increases bandwidth. The study uses Shannon's channel capacity theory and simulations to show potential capacity improvements. Simulations suggested an 85% increase, but real-world measurements yielded a lower 45% improvement.

Narasimhaiah (2019) presents a dynamic 4G LTE network simulator to study scheduling algorithms and their impact on network congestion. The simulator examines various LTE features to improve network throughput under different traffic models. It also explores how small cells can increase overall network capacity when deployed alongside macro cells. While the simulator offers an open platform for realistic network simulations, its limitations include high implementation costs and its focus on homogeneous networks. Real-world networks are often heterogeneous, requiring solutions that consider diverse cell types and limited frequency spectrums.

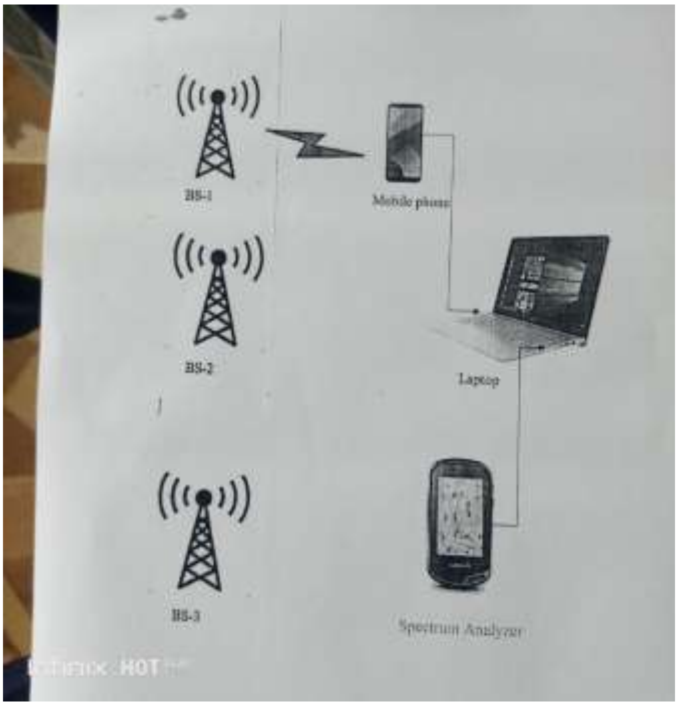
II. MATERIALS AND METHOD

This work was generally segmented into two sections; Section A deals with the development of Intelligent Dynamic Cell Sectorization (IDCS) model for improved capacity of 4G LTE network while Section B deals with the development of Intelligent Cell Schemes to provide intelligent solutions to the developed IDCS model thereby further improving on the capacity of the network. In order to achieve these schemes, series of measurements were carried out using existing 4G LTE networks belonging to one leading commercial network operator in Nigeria in urban city of Warri South South Nigeria. The two field tests were carried out which include Sweep test to determine the type of sectorization in use, current capacity of the network, the type of antenna in use through drive test to determine the impact of the environment on the network and finally the Platform Layout 4 (PL4) test was equally carried out to determine the basic configurations of the base transceiver stations. The essence of using an existing 4G network as an experimental testbed is to be able to verify the performance of the existing mobile network in Nigeria with a bid to improve their performance. Using the level of performance obtained from the field tests, this work will utilize the parameters to improve the capacity of the network.

Some of the basic instruments for data capture includes Spectrum analyzer for determination of sectorization factor, processing gain, types of antenna in used . others includes laser rangerfinder for antenna height determination and finally G-Mon pro software installed Android handset that captured signal strength as we drives along designated routes .

Measurement Set-Up and Data Collection

In order to develop suitable model for LTE cellular network situated in Warri, Warri was divided into ten sub locations which reflect the major areas of the city. This is because of the large number of base stations in Warri City. An experimental set up was designed and implemented to measure and record received signal strength data from one of the mobile network providers. The base station transmits signals using sectorial antennas spaced at 120° apart with antenna heights ranging from 32 to 38 meters. The measurement set-up consists of base stations, an smart phone, a Spectrum analyzer and a personal computer as shown in Figure 1



SWEEP TEST

On the drive test, sweep test was carried out. The Sweep test was done in order to determine the type of sectorization in use, current capacity of the network, the type of antenna in use in the experimental testbed .Cite BTS configuration EFF510667

Table 1: Number of Users of Single Cell LTE system for a varying processing gain

S/N	Twin Sector X		Twin Sector Y		Twin Sector Z	
1	Sector X1	Sector X2	Sector Y1	Sector Y2	Sector Z1	Sector Z2
2	102	102	317	317	471	471

PLATFORM LAYOUT 4 (PL4) TEST

This test was carried out to determine the base stations configurations. The LTE systems configurations for EFF510667 were noted and shown in Table 6.2 below.

Table 2:PL4 Measurement

Frequency	2600MHz
Sectorizations factor	3
Energy per Bit (Eb/No)	2dB
Voice activity factor (α)	0.375
Over All Processing Gain (PG)	222dB
Bit-to-Energy Ratio (BER)	7dB
Signal Power (Ps)	40dB
Antenna height	42

MATHEMATICAL DEVELOPMENT OF IDCS MODEL

This was done to obtain the varying processing gain of the cell sectoring EFF510667 base station and number of users of the developed IDCS model. The evaluations were done to also get some necessary parameters for the IDCS Model simulations and the designed intelligent cell schemes.

If the processing gains, PG = 222 and a minimum acceptable Eb / N_o is 2 dB, in a single cell LTE network determined the following:

1) A varying processing gain for the three (3) sectors at base station using directional antennas.

2) The number of users of a twin-sector system

3) A varying three (3) sectors at base station using cross-polar twin beam antennas.

4) Overall capacity of the measured cell sectoring system using directional antenna

5) Overall capacity of the IDCS using twin-sector antenna

6) Average number of users for fixed twin-sector and three sector antenna system

7) Percentage increase of the IDCS scheme using twin-sector antenna.

Hint: Assume the system interference is limited n=0, Take the number of users as shown in figure 3.1 for the three-sector network.

1. For a single cells LTE system using directional/sectorial antenna, the varying processing gain of the individual sectors can be determined using equation (1.1)

$$K_d = \lambda\left\{1 + \frac{1}{\alpha}\left(\frac{P_G}{{E_b}/{N_o}}\right) - \frac{n}{P_S\, x\, \alpha}\right\},\ 0<\alpha<1 \qquad (1.1)$$

From figure 2.1 ,K_d for Sector X= 102 users, Sector Y= 317 users and Sector Z = 471 users

Therefore,

Processing Gain, P_{G_1} for Sector X can be determined by substituting the values;

$$102 = \left\{1 + \frac{1}{0.375}\left(\frac{P_{G_1}}{2}\right) - 0\right\}$$

$$P_{G_1} = \frac{202}{2.667} = 76\ dB$$

Processing Gain for Sector Y denoted by P_{G_2}

$$317 = \left\{1 + \frac{1}{0.375}\left(\frac{P_{G_2}}{2}\right) - 0\right\}$$

$$P_{G_2} = \frac{632}{2.667} = 237\ dB$$

Processing Gain for Sector Z denoted by P_{G_3}

$$471 = \left\{1 + \frac{1}{0.375}\left(\frac{P_3}{2}\right) - 0\right\}$$

$$P_{G_3} = \frac{940}{2.667} = 352\ dB$$

2. The number of users for the twin-sector antenna can simply be obtained by (1.2) as follows;

$$K_t = 2K_d \quad (1.2)$$

For Sector X number of User for a varying twin-sector antenna;

$$K_t = 2\ X\ 102 = 204\ users$$

For Sector Y number of users for a varying twin-sector antenna;

$$K_t = 2\ X\ 317 = 634\ users$$

For Sector Z number of users for a varying twin-sector antenna;

$$K_t = 2\ X\ 471 = 942\ users$$

Note that each of the sectors for twin-beam antenna uses 102 users per sector. That means it divides the 204 users into two equal sizes, of 102 users out of phase with the other 102 users for Sector X. The same thing was applicable to the capacity of the Sector Y and Sector Z of the twin-beam antenna system. The table below shows a single cell LTE system capacity evaluation using the developed model.

4. Overall capacity of the three-sector antenna is given by

Sector X number of users + Sector Y number of users + Sector Z Number of users

= (102 + 317 + 471) users

= 890 users per three sector systems

5. Overall number of users for twin-three sector antenna system is given by

Overall number of users for three sector antenna system multiplied by 2

= 890 X 2 = 1780 users per three-twin sector antenna system.

6. The average number of users for fixed three sector antenna system is given by

$$\frac{890}{3} = 297\ users\ per\ sector$$

The average number of users for fixed twin-sector antenna system is given by

$$\frac{1780}{6} = 297\ \ users\ per\ sector.$$

7.If a single cell LTE network operates with a twin-sector antenna system, the percentage increase without any form of interferences can be 100% because the systems doubles the capacity of the network when compared with normal cell sectoring antenna that uses directional/sectorial antenna.

III. RESULTS AND DISCUSSION

Table 3 : single cell LTE system for a fixed processing gain using sectorization formula

S/N	Sectorization factor, **λ**	Number of users provided by directional antennas,K_d (users/cell)	Number of users provided by cross-polar sector antennas,K_t (user/cell)
1	3	890	1780
2	4	1184	2368

3	6	1776	3552
4	9	2664	5328

Table 4Processing gain of a single cell LTE system using sectorization formula

S/N	Sectorization factor, **λ**	Processing Gain of the system using directional antennas,K_d (users/cell)
1	Sector X	76 dB
2	Sector Y	237 dB
3	Sector X	352 dB

From the Table 1, it is seen that deploying a cross-polar twin beam antenna would increase the capacity of a LTE system better than the common directional antennas already in use at EFF510667 MTN base station as it doubles the number users per cell if deployed. It is important to note that the increase in sectorization factor increases the number of users/cell but more cost of antennas deployment, more handover, interference, environmental factor and other effect could be seen as disadvantages. Hence using sectorization factor of three (3) is of a better option.

3.1 DISCUSSION

The results of Intelligent Cell Sectoring Scheme (ICSS) and the Intelligent Dynamic Cell Sectoring Scheme (IDCS) using**Proteus 8.9** professional software simulation Environment shown below in figure 3.1 and 3.2 respectively.

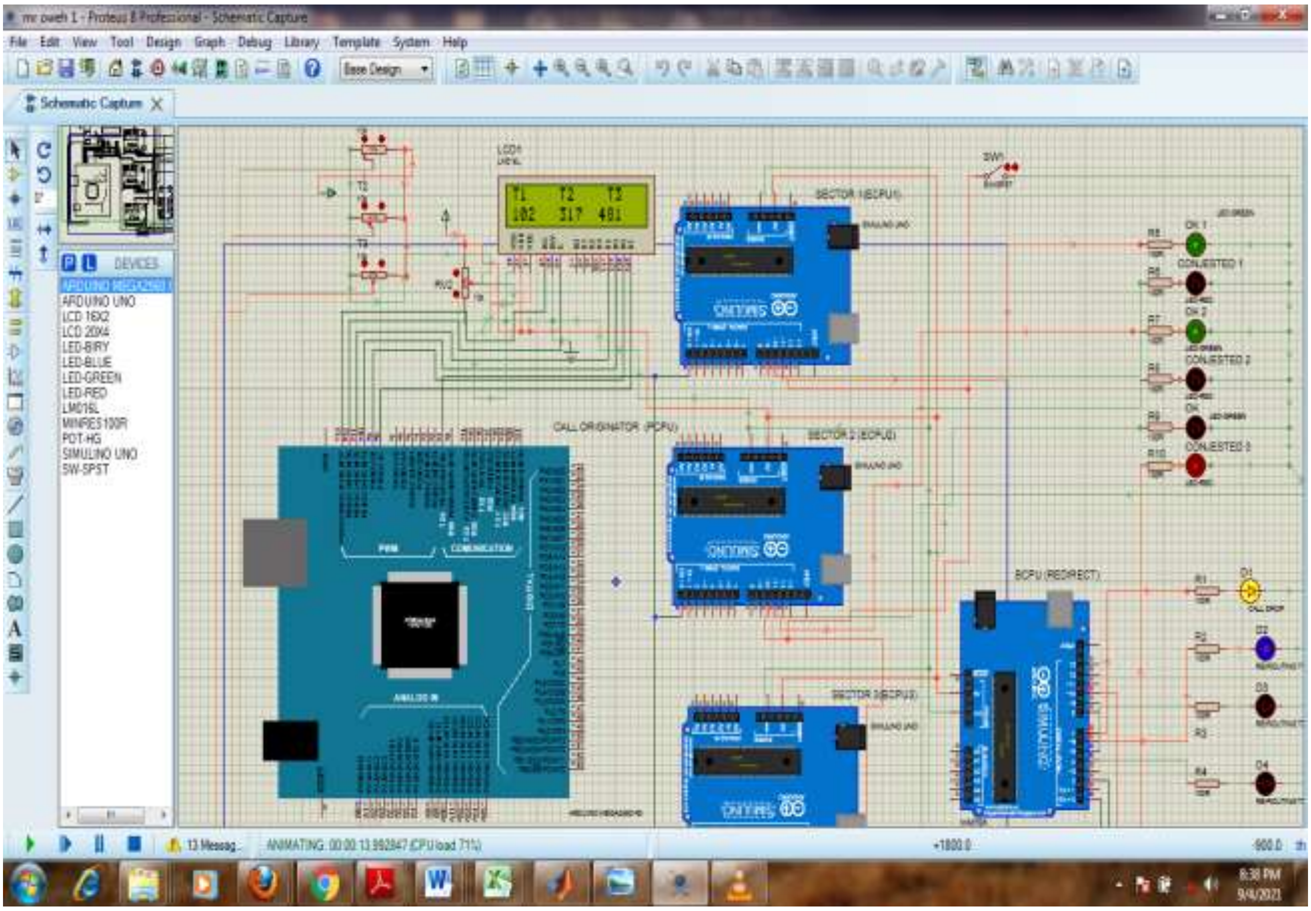


Figure 2: Simulated Circuit Diagram of congested Sector X for ICSS

Figure 2 shows the simulation circuit diagram of when the sector X reached it threshold of 102 calls per second. The sector Y its threshold of 317 while Sector Z out stretched it threshold as Red LED indicated congested and Re-routing with Blue LED. Extra 10 calls since the threshold is 471 therefore call drop as indicated with yellow LED .

Figure 2 showed the LED of call drop glowing signifying the system was dropping an incoming call coming to sector3

And so, $K_d^1 > K_d$

Where $K_d = 890$

$K_d^1 = 102 + 317 + 481 = 900$

Therefore $900 > 890$ which satisfies the condition that the intelligent cell sectoring scheme automatically drop mobile user voice call accessing the system whenever it reaches its overall capacity. This means that the extra ten(10) calls coming into the network would not be allowed to infer with the network, and consequently it would automatically be dropped.

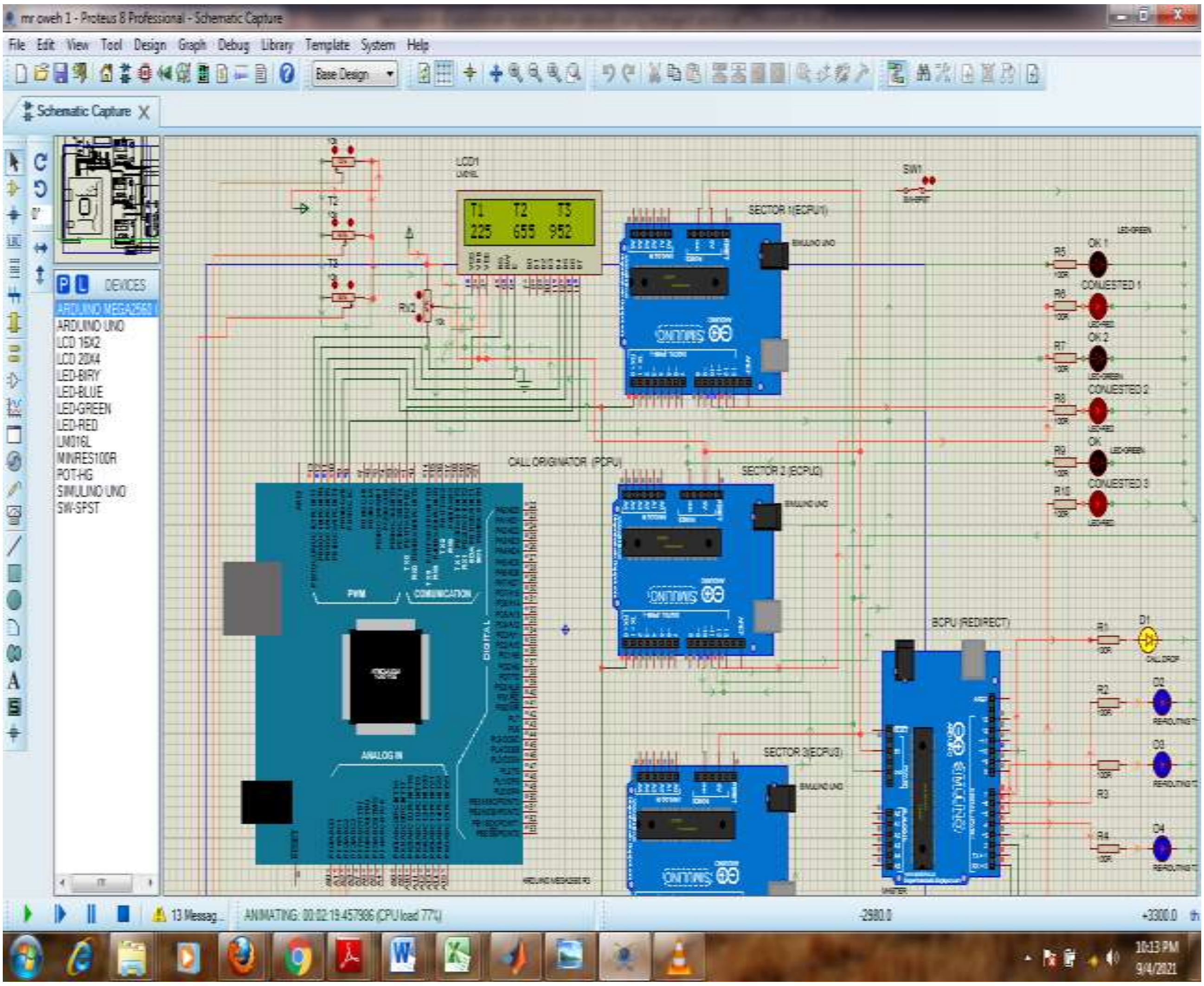


Figure 3: Simulated Circuit Diagram of IDCS showing call drop

The result in figure 3 displayed a scenario when the Sector Z had congested 10 calls per second which was greater than needed calls at sector X and sector Y congested 10 calls each respectively .since there were above their threshold.

Recall that for the intelligent system to drop calls , the 30 drop call will occurred ;

$K_t^1 > K_t$

Where $K_t = 1802$ i.e overall threshold

$K_t^1 = 225 + 655 + 952 = 1832$

Therefore,

Since 1832>1802, the 30 calls will drop from the system

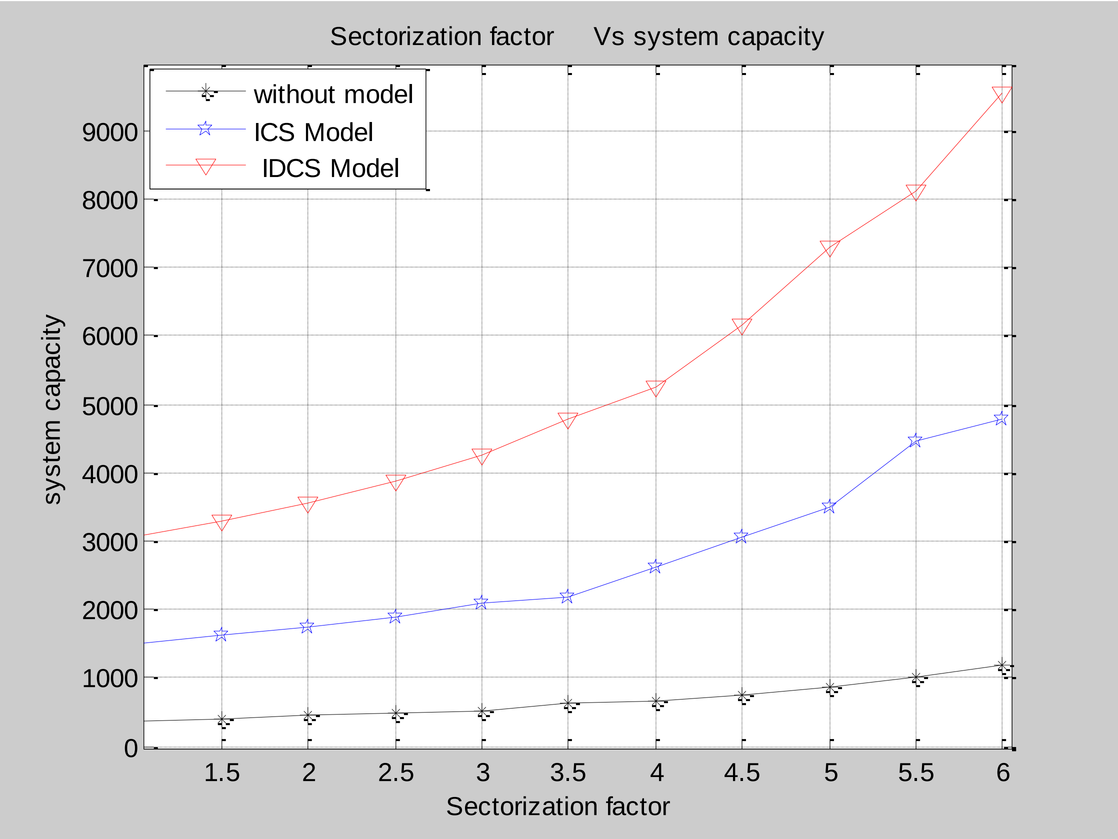


Figure 4 : The graph of system capacity vs sectorization factor

The graph depict the following when sectorization factor is 2 , Without model capacity is 400 users , the ICS model is 1800 users while IDCS model 3600 users . When sectorization factor is 4, Without model capacity is 800 users , the ICS model is 2800 users while IDCS model 5400 users

It will be deduced that increase sectorization factor will cause the system capacity increases twofold it capacity.

Proportional Analysis of the Developed Scheme and the Existing Scheme

The aims as specified overhead earlier can further analysis with comparative analysis using the table showing the existing cell sectoring and intelligence dynamic cell sectoring scheme.

Table 5: Comparison of the IDCS and the existing cell sectoring scheme

Parameters	**Existing Cell Sectorization/ICCS**	**IDCS Scheme**
No. of sectorization factor for 120-degrees	3	6
Network capacity	High	Doubled when compared with cell sectoring scheme
Interference	High	Low
Power consumption	Lower	Higher
Algorithms	Dynamic-Based Microcontroller Algorithm (DMA) for ICCS	Dynamic-Based Microcontroller Algorithm (DMA) required for IDCS
Antenna Deployment	Directional Antenna	Twin-Sector antenna
Area of Applications	Both in rural and urban areas	More efficiently in urban (densely populated area) environment
Handover	Higher	Lower
Antenna Gain	Lower	Higher

To deliver higher capacity rate effectively in model system and proffer solutions to the problems associated with 4 G (LTE) network and the techniques deploy to improve its capacity necessitated the need for this work. In this work, an analytical model called Intelligent Dynamic Cell Sectorization (IDCS) model will be develop with twin-beam sector antennas deploy in the sectors so as to reduce the cost of antenna deployment in cell sectoring and reduce more handoff.

Also, an Intelligent Cell Scheme (ICS) will be design to provide intelligent solutions to the Intelligent Dynamic Cell Sectoring (IDCS) model. The IDCS scheme provides great reduction in the number of base station (BS) that will be build.

More so, the develop Intelligent IDCS Scheme will be very useful in densely populated areas as demand will be met not regarding your location in that particular geographical area called cell. This will have the ability to reroute calls from congested cells to non-congested cells.

IV. CONCLUSION

This research proposes a solution to increase network capacity and improve user experience in mobile data networks. Traditional methods like adding more cell towers are expensive and time-consuming. The Twin Beam sector-splitting approach offers a faster and more cost-effective way to boost capacity in congested areas. It allows operators to significantly increase data speeds without substantial additional investment. The study demonstrates that combining Twin Beam with Intelligent Dynamic Cell Sectorization (IDCS) can double cell capacity while reducing interference from neighboring stations. This leads to a significant improvement in signal strength and allows the network to handle more users. Additionally, the research introduces Intelligent Dynamic Cell Sectorization (IDCS) that can dynamically adjust cell sizes based on user traffic. This ensures efficient use of network resources and helps manage congestion by offloading users from overloaded sectors. Overall, the proposed methods offer a promising approach to improve network capacity and user experience for mobile data services. Finally, the IDCS model have twofold cell capacity of the network with 3.69% reduction in sector edge.

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