Adaptive Channel Borrowing Scheme for Capacity Enhancement in Cellular Wireless Networks

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Abstract. The very limited nature of the GSM spectrum, coupled with the increasing demand by an extending number of subscribers place a strain on the network capacity. This leads to an equally raised number of calls that dropped and hence, subscriber dissatisfaction. Several strategies have been implemented in order to minimize these occurrences, with the most prominent being channel borrowing. Channel borrowing process is a scheme whereby frequencies allocated to other cells are temporarily assigned to cells with higher traffic loading so as to reduce the rate of dropped calls in the busy location, hence improving the grade of service of the entire network. This concept is implemented in such a manner as to ensure that the call quality in the original cell is not jeopardized by the borrowing process and the borrowed frequency is returned as soon as possible. The goal of channel borrowing is to ensure maximal utilization of the available spectrum to an operator in such a manner that the owner cell is not disadvantaged. This article presents a detailed review of various Channel Borrowing Schemes and proposes an Adaptive Channel Borrowing Scheme that efficiently borrows free Channels from nearby Cells deploying features in MATLAB R2012a. The ACB algorithm has suitable characteristics for a novel hybrid channel borrowing algorithm and it is based on real time call statistics using random number generators. It is measured with parameters such as Lending Potentials (LP), Borrowing Potentials (BP) and Borrowing Need (BN). These are traffic driven frequency borrowing parameters adopted in the investigation. From the result, an efficient and reliable means of borrowing additional Channels for temporary use without giving the entire system huge workload, was arrived at. The ACB algorithm has the capacity to maximally utilize the system resources hence, reducing the cost or need for the purchase of additional resources.

Keywords: Channel Efficiency, Spectrum, Cell Capacity, Cellular Traffic, Wireless Networks.

1 Introduction

The ever-growing number of mobile network subscribers and the limited available radio frequency spectrum is of major concern and therefore, requires very urgent attention and action. This problem can easily be linked to the fact that there are rapid technological advancements, coupled with tremendous shift of different applications to multimedia and mobile platforms with the aim of making information more accessible.

It is becoming difficult to see any web-based application that does not have a mobile friendly version hence, further reduction in the limited radio spectrum. Considering these factors, lots of techniques have been deployed in [1], in a bid to enhance the capacity of a cellular network.

According to Kahwa and Georganas [2], some of these techniques include but not limited to Frequency reuse, Cell splitting, Sectoring, Microcell zoning and frequency borrowing. While frequency reuse has to do with deploying same radio frequencies on the transmitter sites within a given geographic area that are separated by enough distance to prevent or minimize interference, Cell splitting is the process of subdividing large cells into smaller ones with their corresponding BTSs (Base Transceiver Stations), with reduced antenna height and transmission power. Sectoring increases cell capacity by reducing the number of cells in a given cluster and thereby increasing frequency reuse. The existing sectoring angles include angles 60, 120 and 360 degrees. Microcell zoning, on the other hand, deals with dividing cells into micro (smaller) cells or zones with each connecting with the same base station. Each zone uses a directional antenna while the Base Station Controller (BSC) keeps switching calls to the nearest zone when on transit. Frequency borrowing on the other hand is a scheme whereby frequencies allocated to other cells are temporarily assigned to cells with higher traffic loading so as to minimize the rate of dropped calls, hence improving the efficiency of the entire network.

Channel borrowing schemes are the various methods adopted in order to reduce the call dropping or blocking rates of a cell in a mobile cellular network. The major aim of frequency borrowing is to improve cell capacity utilization and also reduce blocking probability of a cellular network. In this process, cells (the acceptors) whose nominal channel sets are exhausted; borrow free channels from the neighboring cells (the donors) for temporary use in order to accommodate new or handoff calls. This process is successful once conditions for co-channel interference and other related challenges are handled properly. Channel borrowing can be Simple borrowing or Hybrid channel borrowing strategies. In Simple Channel Borrowing, nominal channel sets in a cell can be borrowed by neighboring cells for use but in Hybrid Borrowing, channel sets are divided into A (standard, local non-borrowable channels) and B (nonstandard and borrowable channels). While Set A channels are only usable in the assigned cell, set B channels can be lent to neighboring cells for temporary usage [1].

In Simple Borrowing Scheme (SBS) [2], a nominal channel set is assigned particularly to a cell as it is in the case of Fixed Channel Assignment and when the assigned channels are completely used, more channels are borrowed from the neighboring cell. This borrowing strategy is only possible if the channel does not interfere with or completely disrupt any calls in progress. This borrowing strategy can as well, reduce call blocking rate but also causes interference in the lending cell, hence preventing the completion of other ongoing calls. As demonstrated in [3], this SBS presents improved lower call blocking probability when compared to FCA despite the fact that the channel assignment schemes are similar to each other. Quite a reasonable number of SBS were proposed in [4] for channels to be borrowed only from non-adjacent cells. They include; Borrow from the Richest (SBR), Basic Algorithm (BA), Basic Algorithm with Reassignment (BAR) and Borrow First Available (BFA).

2 The Erlang Traffic Model

An *Erlang* is the basic unit of telecommunications traffic measurement which represents the continuous use of one voice path or a single circuit [5].

The Erlang is mathematically dimensionless and it is used to describe the total traffic volume of one hour. In practice, one voice path (single circuit) used continuously carries 60 minutes of calling in an hour therefore, one erlang is usually defined as 60 minutes of traffic. When someone receives 200 two-minute calls in an hour, it implies the person received 400 minutes, or 6.7erlangs of traffic in that hour. Similarly, if another person makes one call and occupies one channel for one hour (60 minutes), it is said that the system under consideration has just 1 Erlang of traffic on it at that time [6].

The traffic in Erlang is usually represented by the letter A and the formula is given as

$$\mathbf{A = \lambda \times T} \qquad \textbf{(1)}$$

Where:

λ = the mean arrival rate of new calls

T = the mean call length or holding time

A = the offered traffic in Erlangs.

Using this simple Erlang function or Erlang formula, the traffic can easily be calculated.

In terms of total number of calls, the offered traffic in erlang A is given as

$$\boldsymbol{A = \frac{QT}{60}\ Erlangs} \qquad \textbf{(2)}$$

Where;

A is the offered traffic in Erlang

Q is the total number of calls in busy hour

T is the mean call length or holding time

The total number of calls in the busy hour Q is given as

$$\boldsymbol{Q = ncW} \qquad \textbf{(3)}$$

Where;

Q is the total number of calls in busy hour

nc is the total number of subscribers and

W represents a given number of subscribers

Erlang calculations are further broken down into Erlang B and c depending on the respective use of each of them. While Erlang B model is applied in determining the number of lines required from the knowledge of the traffic figure during the busiest hour and with the assumption that blocked calls are immediately cleared, the Extended Erlang B model is used to determine how many calls are blocked and are tried again immediately. It is the most commonly used figure for any telecommunications capacity calculations and a sample of the Erlang B table with its associated readings can be seen at [7]. This work took certain readings from the Erlang B.

How many channels per cell are needed in a cellular system to ensure a reasonably low probability that a call will be blocked or dropped as the case may be? In order to provide the answer to this question, we determined the number of subscribers and subsequently the capacity of a given network. Some other factors under consideration include the call blocking probability (probability that a call will not go through), the offered traffic, A (in Erlang), the total number of calls at busy hour Q in that given location, the number of Channels, N and the duration of each call, T (in secs). To determine the number of subscribers the system can accommodate at busy hour, there is need to assign values to the above parameters. This will be done based on the frequency allocation dataset provided by the Nigerian Communications Commission (NCC). Table 1 shows the frequency band allocation to Network operators in Nigeria on the 1800MHz GSM Band by NCC.

Table 1. NCC frequency allocation to GSM Network operators in Nigeria

Network	Airtel	Etisalat	GLO	MTEL	MTN
Tx	1850-1865	1865-1880	1820-1835	1805-1820	1835-1850
Rx	1755-1770	1770-1785	1725-1740	1710-1725	1740-1755

From Table 1, the following parameters are seen
Total allocated bandwidth for a duplex wireless cellular system for each operator, A $= 30\ MHz$
The networks are allocated 30 MHz of spectrum with a full *duplex channel bandwidth* of 200 kHz.
This implies that Channel bandwidth for each duplex channel, B $= 200\ kHz$
Hence to determine the number of Channels, it is given to be $= \frac{A}{B}$ [Dunlop and Smith, 1994]
Therefore, number of available Channels

$$= \frac{(30*10^6)}{200*10^3} = \mathbf{150} \quad (5)$$

Number of Duplex channels in a cluster

$$= \frac{150}{2} = \mathbf{75} \quad (6)$$

Hence, the number of Channels per Cell

$$= \frac{75}{7} \approx \mathbf{11} \text{ Channels per Cell} \quad (7)$$

It is necessary to find the total offered traffic during heavy traffic (busy hour).
From [7], we extracted the formulas, Equations (4)-(7)

If we assume *W* subscribers per cell and that during busy hour a fraction $\boldsymbol{nc}$ of these makes or receives a call of duration *T* minutes.
From Equation (3), the total number of calls in the busy hour is $\boldsymbol{Q = ncW}$ and equation (2) showed the offered traffic to be

$$\boldsymbol{A = \frac{QT}{60}\ Erlangs}$$

In Nigeria, the blocking probability for calls is placed at 2% by the Nigerian Communications commission (NCC). This implies that only two (2) out of every hundred (100) calls placed will be dropped. Although there is improvement in call drop rate according to recent research reports during uniform traffic, this 2% standard blocking probability is still not achieved in cellular network services in Nigeria during heavy traffic.

Working with the 2% blocking probability, the Erlang B table has the relationship between offered traffic, blocking probability and number of channels as shown in a typical Erlang B table.

From any Erlang B table, 21 channels will support an offered traffic of 14.04 Erlangs with a blocking probability of 2%. Therefore, from equation (2),
Offered traffic A is given as $\boldsymbol{14.04 = \frac{QT}{60}}$
Substituting equation (1) into equation (2) gives

$$\boldsymbol{14.04 = \frac{QT}{60} = ncWT/60}$$

Hence the number of subscribers, **W** is given as

$$\boldsymbol{W} = \frac{\mathbf{14.04 \times 60}}{(\mathrm{nc}\boldsymbol{T})} \qquad (8)$$

Where nc refers to the total subscribers in the network and T, the average call duration of calls.
Typical value of T = 1.76 minutes. Assuming 80% of the total subscribers nc make a call during the busy hour, substituting into equation (8) gives;

$$\boldsymbol{W = \frac{14.04 \times 60}{0.8 \times 1.76} = 598.3}$$

Therefore, the number of subscribers that can be accommodated at busy hour is **598**.
Taking similar assumption from [7], a user density of $\mathbf{1.74 \times 10^{-3}/m^2}$
User density =

$$\boldsymbol{\frac{W}{\pi R^2}} = \boldsymbol{\frac{598.3}{\pi R^2} = 1.74 \times 10^{-3}} \qquad (9)$$

Therefore, $\boldsymbol{R = 330.75m}$ and the approximate cell diameter is **662**m.
Where $\boldsymbol{R}$ is the Cell Radius in meters.

With the above analysis, we discover that the major reason behind increased call drops in cellular networks is due to limited available resources. Quite a large number of subscribers are demanding access to this limited number of network resources thereby leading to increased call drops.
In order to tackle the issue of Call drops, we consider the spacing distance between Cells. The formula for the spacing distance between interfering Cells is given as;

$$\boldsymbol{D = R\sqrt{(3N)}} \qquad (10)$$

Where:
D is the spacing distance between interfering Cells
R is the radius of the Cell and N is the cluster size.

For the study of our interest where R is given as 330.75m and N = 7, the frequency reuse distance D is therefore obtained as shown;

Substituting into equation (10); $= 330\sqrt{21}$

$$= 330 * 4.583$$

$$= 1515m$$

This implies that the distance between interfering Cells, D (that is the closest or minimum distance between two cells using the same frequency) in this case is 1.515km. If the above condition is not met, it leads to co channel interference and increase in call dropping rates due to excessive closeness of clusters to each other [8]. But if using a channel causes no interference in a cell, then the channel is said to be available for use in such cell(s).

3 System Design

The reason behind the choice of this specific layout is that our algorithm will consider the first tier of neighboring cells only. This helps in dealing with the effects of co-channel interference which occurs when channels are reused incessantly. Considering the diagram of Figure 1, the cluster is divided into three sub regions of Hot, Warm and Cold regions. This subdivision is done to aid simulation. For this work only, Cells A, B and C are in the Hot Region, Cells D and E are in the warm Region while Cells F and G are in the Cold Region. These regions were categorized due to the level of call traffic they have per time. Cell A is an acceptor cell and is surrounded by one tier of six (6) cells. It can borrow free Channels from any of its other surrounding neighbor cells (with priority from the Cold Region) to service any new calls. It must fill up the other two members of the Hot region (Cells B and C) to maximum capacity, before proceeding to borrow more Channels from Cells in the Cold region (F and G). When these Channels are used up to maximum capacity, the ones from Cells in the Warm region are further borrowed for use by the acceptor Cell A in the Hot region. The number of call simulations in each Cell determines the region it belongs to. The same factor forms the parameters from which the Capacity Utilization (CU) table is built as shown in Table 2.

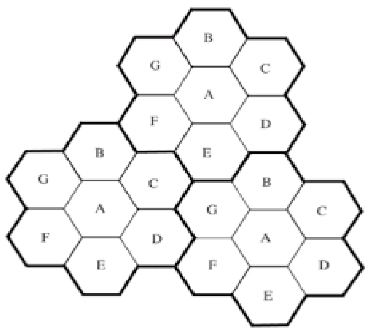

Fig 1. A 7 Cell Cluster

This table contains entries of various characteristics of each Cell and the cumulative represents that of the regions they belong to. Furthermore, the acceptor Cell A can borrow channels from one and only one neighboring Cell in a region at a time. The algorithm does not allow for multiple donations in order not to increase the system calculation time and bring about overhead. Also, until a Cell gets above 15 simulated calls (call activity rate); it cannot be in the Hot region. The system threshold is set at 60%. Having reviewed quite a number of works done in this field of study, the choice of having the threshold placed at 60% was made considering some works already done in literature such as that by Rappaport [1].

Cells with less than 60% threshold are not permitted to borrow Channels from neighboring Cells. In this arrangement, a particular channel cannot be busy in two different Cell locations at the same time except if their geographical distance apart exceeds the minimum reuse distance value also known as the spacing distance between interfering Cells (D) [9]. This condition of having a channel locked up in other Cells when in use in one Cell is known as Channel locking and is more prevalent with fixed channel allocations. Our algorithm tackles this problem by returning every borrowed Channel after each use.

4 The Proposed Algorithm

The Adaptive Channel Borrowing Scheme (ACBS) is the proposed algorithm in this work. Each Cell has six other neighboring cells. Each of the seven (7) Cells in the cluster has a total of 21 Channels allocated to each of them as against eleven (11) calculated Channels. This is the minimum number of Channels that can be allocated to a GSM network. This is because; a Telecommunication Service Provider in practice can decide to assign more Channels to a particular area depending on the traffic demand of the area under consideration. These seven Cells are further subdivided into three regions of Hot, Warm and Cold. Normally, every Cell in each region is able to manage its call allocations without having issues. At busy hour with increased traffic density, the rate of Call arrival increases tremendously. This triggers the BSC to check for the level of traffic for each region by computing the Capacity Utilization (CU), using the Call activity rate of each Cell. These Call activity rates were obtained using MATLAB random number generation. A threshold of 60% is set as a standard to determine the various levels of Hotness, Warmness or Coldness of a particular region. The state of a Cell or any region depends on the Call activity rate of the region. The first three (3) Cells with activity rates above 15 calls are classified as Hot region Cells. Their cumulative Capacity Utilization value is more than the set 60% threshold. As this value is being calculated, the BSC also executes the channel borrowing process simultaneously and subsequently reallocates a channel, if need be. This it does by looking through the computed values in the Capacity Utilization table for the Cell with the greatest number of free Cells which is inadvertently the Cells and region with the least cumulative Capacity Utilization threshold values, to borrow Channels from.

Normally all the Cells in the Cluster are not busy; they have varying levels of simulated call activity rates going on in each of them in the Cluster. The region with the highest call activity rate is termed the Hot region (C1). The total call activity rate (total number of simulated channels in use) in the Hot region is 49 out of 63 Channels allocated to the entire region (21 Channels per Cell for the three Cells in the Hot region). This results in 77% of the region's total capacity. This automatically qualifies this region for borrowing since its calculated CU value is above the threshold of 60%. The Warm region (Cells F4 and F5) is next with a cumulative value of 15 Call activity rate and a cumulative capacity utilization value of 40%. This value is still less than the threshold value and therefore does not meet the conditions for borrowing Channels. Once this region exceeds the 40% capacity and meets the 60% threshold value, it will qualify to borrow. The Cold region has very low Call activity rate of 8 with a CU value of less than 20% of the entire region's capacity. Each Cell can in any point in time migrate from one region to the other depending on the level of traffic or the amount of call activity taking place in such Cells. For the purpose of the simulation, it was necessary to assign the Cells to regions for more clarity and perform the CU calculations as shown in expression below.

Capacity Utilization is given as $\left(\frac{Ci}{CT} * \frac{100}{1}\right)$

Where Ci is the individual or Cumulative (in case of a region) call activity rate, CT is the total number of Channels in the individual Cell or the entire region

Using the above formula to derive the results of Table 3.2, it will have the region as;

$$C3 = \left(\frac{8}{42} * \frac{100}{1}\right) = 19.04\%$$

$$C2 = \left(\frac{17}{42} * \frac{100}{1}\right) = 40.47\%$$

$$C1 = \left(\frac{49}{63} * \frac{100}{1}\right) = 77.77\%$$

As the cellular traffic at the location of Cells F1, F2 and F3 increases, the Base Station Controller (BSC) gets to work by looking through the Capacity Utilization Table (CUT), to determine the freest Cell to switch new calls to, in order to prevent possible call block or drop due to lack of sufficient resources. A threshold of 60% is set and once a Cell in any region gets to this threshold, it attains a high Borrowing Affinity (BA) to borrow Channels from neighboring Cells. The neighboring Cells are often characterized with equally high Lending Potentials (LP) and a low Borrowing Need (BN). In order to generate the values for Borrowing Potential (BP), Borrowing Need (BN) and Borrowing Ability (BA) for each of the Cells (A, B… G), we need to determine the individual CU values for each of the seven Cells in the cluster.

The table below is a summary of the regions and their levels of activities

Table 2. Cumulative CUT Values for each region

Regions in the Cluster	Cells in each Zone	Capacity utilization ($\frac{Ci}{CT} * 100$) (%)	*Cumulative Call activity rate* (x)
Hot Region (C1)	Cells A, B, C	>60% to 100%	49

Warm Region (C2)	Cells D and E	30% to 59%	15
Cold Region (C3)	Cells F and G	0% to 29%	8

5 Results and Discussion

Lending Potential/Ability (LP) is the factor that determines the possibility of a Cell to lend Channels to neighboring Cells in need. It is obtained by subtracting a Cell's capacity utilization value from the capacity utilization threshold which is set at 60%. A cell with a high lending potential will have a low borrowing affinity and borrowing need.

$$LP = CU\ (i) - CUT \qquad (12)$$

Borrowing Need (BN) is the factor that determines the claim for a Cell or region to borrow channels from neighbor Cells. It is obtained by assigning priority to each Cell based on the value of its CU and that of the LP. Cells whose CU values are less than the threshold cannot borrow but can lend Channels to Cells in need of them. Priorities are set with 1 being the highest priority and 5 the least. A Cell with high LP will have a low BN and vice versa.

Borrowing Potential/Ability (BP) considers the capability of a cell to borrow cells even when the LP value is low. Cells with their CU values above the threshold are able to borrow and are assigned numbers one (1) while those with CU values less than 60% is such that they have very minimal borrowing ability hence, they have BA values of zero (0). There is need to calculate the various capacity utilization values for each Cell in order to set up the values of the capacity utilization table (CUT).

The range of CU values for each region is 60-100% for the Hot Region, 30 – 59% for the Warm Region and 0 – 29% for Cold Region.

For Cell A, we have the CU value calculated thus:

A = $\left(\frac{18}{21} * \frac{100}{1}\right)$ = 85.7 % Hot Region

B = $\left(\frac{15}{21} * \frac{100}{1}\right)$ = 71.4% Hot Region

C = $\left(\frac{17}{21} * \frac{100}{1}\right)$ = 76.2 Hot Region

D = $\left(\frac{7}{21} * \frac{100}{1}\right) = 33.3$ Warm Region

E = $\left(\frac{9}{21} * \frac{100}{1}\right) = 42.8$ Warm Region

F = $\left(\frac{5}{21} * \frac{100}{1}\right) = 23.8$ Cold Region

G = $\left(\frac{3}{21} * \frac{100}{1}\right) = 14.3$ Cold Region

The borrowing decision will depend on the values of a CU table. The table amongst other information, will reveal the Cell with the highest potential to lend Channels, this is inadvertently the Cell with the highest value of LP (in this case is Cell G) with the value of 45.7 which is approximately equal to 46. This will be directly followed by Cell F with LP value of 36.2. This implies that Cells F6 and G have approximately 36 and 46 free Channels' capacity respectively to lend to any neighbor in need. The table also shows that these two Cells have higher potentials or ability (in this case 1, where 1 is the maximum) to lend out free Channels when compared to other Cells in the Network. It is worthy to note that both Cells F and G are members of the Cold Region hence; they are in the right state to lend to demanding neighbors from any region but in this case, most likely the Hot Region.

Table 3. Cell capacity utilization

Cells	Call activity rate	Capacity Utilization (%)	Lending Potential/Ability (LP) (60 – CU)	Borrowing Need (BN)	Borrowing Potential/Ability (BP)
F1	18	85.7	- 25.7	1	1 Can Borrow
F2	15	71.4	- 11.4	2	1 Can Borrow
F3	16	76.2	- 16.2	3	1 Can Borrow
F4	7	33.3	26.7	4	0 Can't Borrow
F5	9	42.8	17.2	5	0 Can't Borrow
F6	5	23.8	36.2	6	0 Can't Borrow
F7	3	14.3	45.7	7	0 Can't Borrow

Adaptive Channel Borrowing Scheme (ACBS) has the following processes to its algorithm execution:

1. The arrival of a new call triggers the Base Station controller (BSC) to calculate the Capacity Utilization (CU) values for each of the three specified regions, Hot, Warm or Cold.
2. If the calculated CU value is above the set threshold of 60% in any of the Regions;
   - (i) More new incoming Calls should be assigned to this Region until it reaches a maximum capacity of 100% utilization.
   - (ii) Else, the CU table should be updated accordingly and the next step initiated.
3. When the Region is filled up to its maximum capacity, the CU table is used to determine the Region where the borrowing process is to be initiated. This is the Region with the least Capacity Utilization (CU), Borrowing Potential (BP) and threshold value less than 30% but with the highest Lending Potential value of 6 on the average as seen in Tables 3.3 and 4.2.
4. Process number three is repeated until the entire system is at its maximum capacity before new calls can be blocked. This is a very rare occurrence since calls always drop at its completion

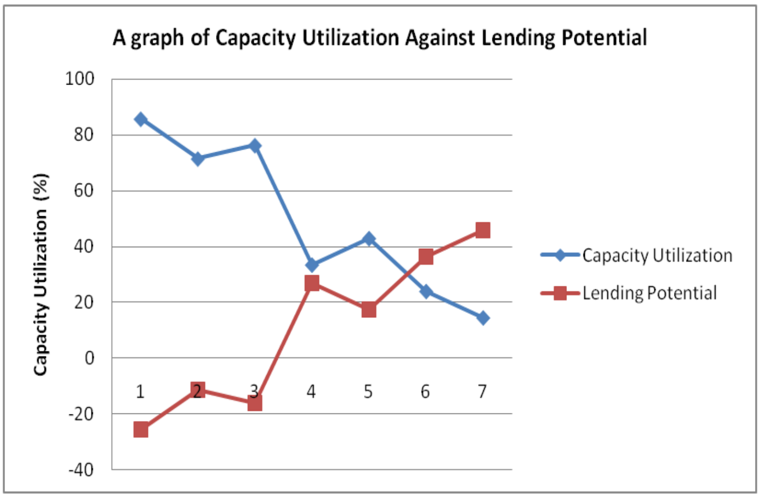

Fig. 3. A graph of Capacity Utilization against Lending Potential

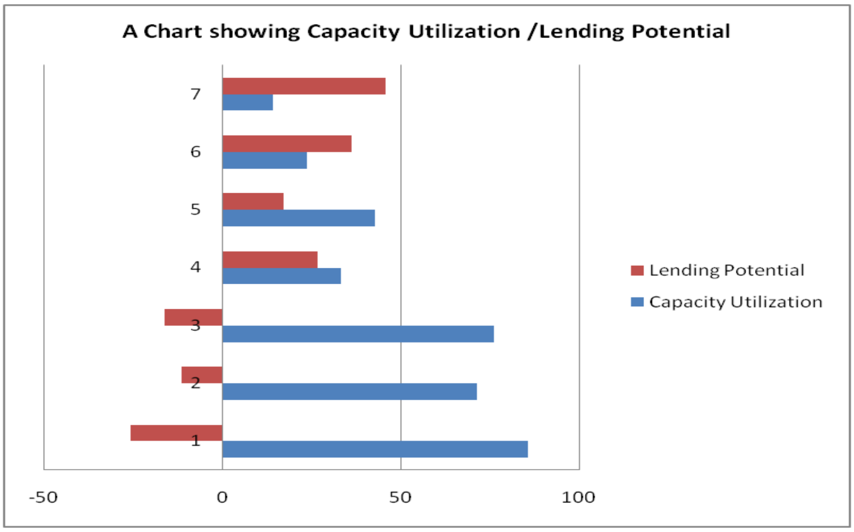

Fig 4. A Bar Chart showing the relationship Between Capacity Utilization and the Lending Potential of the system

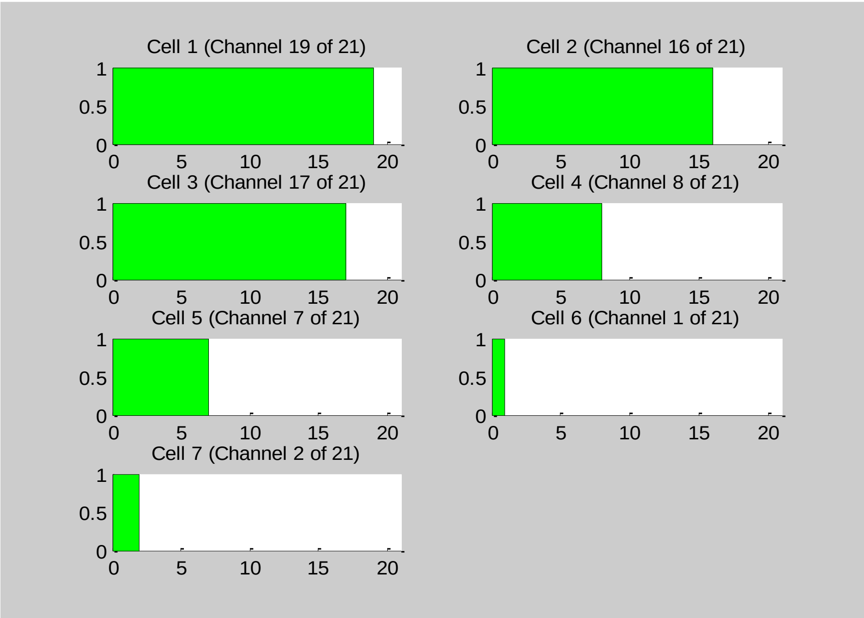

Fig. 5. The initial state of the Cells when launched

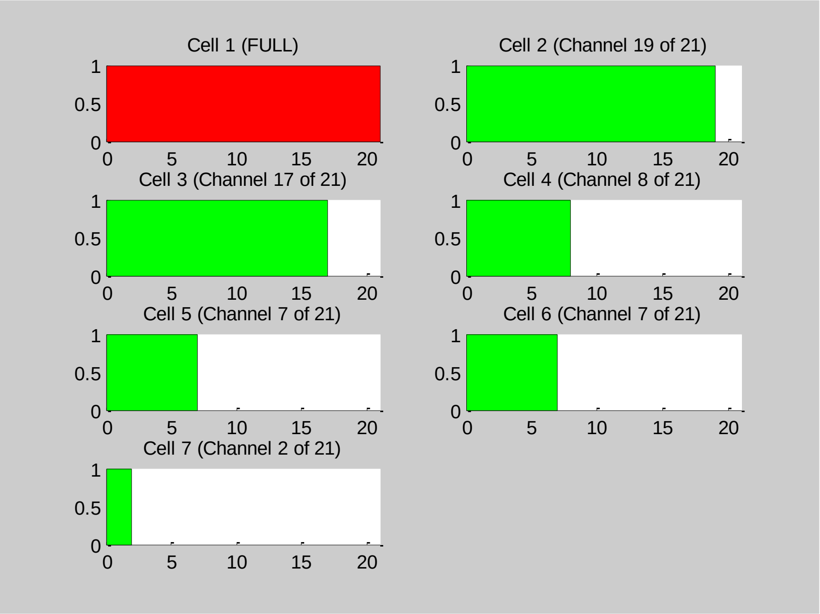

Fig 6. Cell 1 completely filled and more Channels borrowed from free Channels in the Region

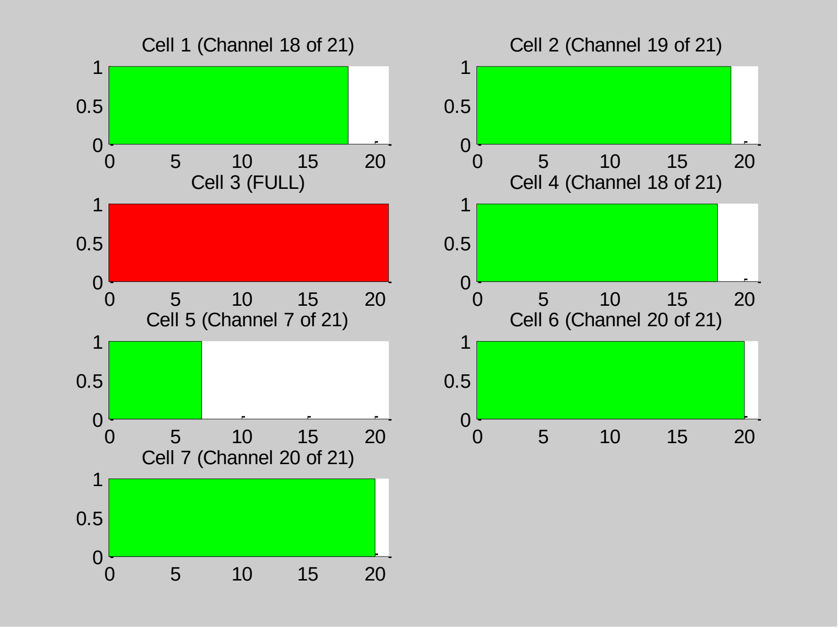

Fig 7. Calls that ended can be dropped from any of the initially busy Cells

6 Conclusion

This work presented an adaptive Channel Borrowing Scheme in wireless cellular networks with a 7-Cell cluster arrangement. The developed algorithm maximizes the network's resources by ensuring that each Cell fills up to full capacity before it is fit to borrow channels from Cells with available or free Channels. This algorithm provides enabling environment for the entire system's capacity to be fully utilized without jeopardizing the quality of service offered. This was achieved by ensuring that the Signal to Interference Ratio (SIR) value obtained from this study stayed within the approved acceptable range as shown in Equation 15.

This channel borrowing algorithm is important because it borrows channels available from neighboring cells where capacity is available to cells where capacity is needed to meet traffic demands. The algorithm is adaptive in the sense that it re-allocates the channels allocated to different cells (with complete awareness of the nature of their regions) based upon the dynamic traffic pattern demands from the users. Hence, in hot regions, channels are borrowed from cold regions to meet increasing demands for capacity while decreasing calls blocking or dropping probabilities. The algorithm essentially has several functions that try to switch calls to available channels in order to minimize the call blocking probability, while in the meantime maintaining the SIR requirements of each call within an acceptable threshold. The simulation results show some importance of this algorithm. This include the increase in network efficiency as more calls can be accepted for the same amount of resources, the quality of service provided by the network is enhanced as SIR did not exceed the set threshold.

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References

1. Rappaport, T.S., *Wireless communications: principles and practice*. Vol. 2. 1996: prentice hall PTR New Jersey.
2. Kahwa, T. and N. Georganas, *A hybrid channel assignment scheme in large-scale, cellular-structured mobile communication systems.* IEEE Transactions on Communications, 1978. **26**(4): p. 432-438.
3. Elnoubi, S.M., R. Singh, and S.C. Gupta, *A new frequency channel assignment algorithm in high capacity mobile communication systems.* IEEE Transactions on Vehicular Technology, 1982. **31**(3): p. 125-131.
4. Zhang, M. and T.-S. Yum, *Comparisons of channel-assignment strategies in cellular mobile telephone systems.* IEEE Transactions on Vehicular Technology, 1989. **38**(4): p. 211-215.

5. Lindsey, W.C. and M.K. Simon, *Telecommunication systems engineering*. 1991: Courier Corporation.
6. Angus, I., *An introduction to Erlang B and Erlang C.* Telemanagement, 2001. **187**: p. 6-8.
7. Dunlop, J., *Telecommunications engineering*. 2017: Routledge.
8. Baiocchi, A., et al., *The geometric dynamic channel allocation as a practical strategy in mobile networks with bursty user mobility.* IEEE Transactions on Vehicular Technology, 1995. **44**(1): p. 14-23.
9. Nesargi, S. and R. Prakash, *Distributed wireless channel allocation in networks with mobile base stations.* IEEE transactions on vehicular technology, 2002. **51**(6): p. 1407-1421.