

An Efficient Femto-cell Channel Assignment Scheme

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ABSTRACT— Femto-cell technologies have been successfully used to extend the cellular network capabilities by providing a better coverage and a remarkable less power consumption. However, there are some factors that threat its Quality of Service (QoS). One of them is that the frequency assigned to the Femto-cell shall prevent any interference which might reduce the QoS. This paper discusses a simpler method for efficient Femto-cell frequency assignment to prevent the interference as it also studies the traffic intensity and the graphs of the number of user that the system can support after implementing the scheme. The results are shown in a Matlab Graphical User Interface (GUI) simulating the GSM900 environment to enhance the performance of the cellular systems when implementing the technology of the Femto-cell in the system to optimize the frequency spectrum.

Keywords— Femto-cell, Channel assignment, Frequency spectrum, traffic intensity

I. INTRODUCTION

Over time humans have developed various ways to communicate to each other in different locations. And it is quite challenging when facing the growing requirements for the individuals and the technology itself, such as mobility and the availability of resources at least when it is needed. Starting from the 'telegraph' up to a border term that gained quite attention and widely spread in the industry of telecommunication as a subset of the known macro-cell 'Femto-cell' the customers are connected together in the various locations in the planet. Customers got the benefit of these terms in potentially improved voice quality and

extended battery life, as well as improved coverage capabilities.

Femto-cells are smaller size and low power cellular base stations manufactured only for private indoor usage, connected to the service provider via a broadband connection. Femto-cells are implemented to be an attractive method to increase coverage and capacity for the service providers, in terms of long battery life, improved voice quality and guaranteed coverage and network resources for individual mobile users. It is also applicable for all standards such as Global System for Mobile Communication (GSM), Code Division Multiple Access (CDMA), Worldwide Interoperability for Microwave Access (WiMAX), Fourth Generation Long Term Evolution (4G LTE) etc.

Although Femto-cell has various advantages; there are some other factors that threat the efficiency of this method, such as handoffs, interference issue, access method, time synchronization etc. which will also threat the macro-cell feasibility.

The interference has always been introduced as the setback of all wireless systems regardless the type the system. Less interference levels will be detected when the Femto-cells are using a separate carrier frequency as compared to the surrounding macro-cell network for the cellular telecommunication system. More complicated scenarios may arise when the Femto-cells are using the same carrier frequency with the surrounding macro-cell network. This scenario also provides the greatest level of spectrum efficiency, but also the greatest challenges in-order to maintain the interference levels.

Previous researches and works proposed many scenarios to solve the interference issue by reserving dedicated channels for Femto-cells (guard channels) in-case of a sudden initiation of a Femto-cell, or include the Femto-cell in the Dynamic Channel Allocation area. Somehow, it was successful in reducing the interference but on the other hand it is either wasting the spectrum or increasing the interference at other locations. This

scheme is trying to avoid the interference while insuring the perfect utilization of the frequency spectrum.

Main interference scenarios are detailed below [1]:

- A. *Femto-cell to Macro-cell base station interference when using the same frequency:* When the same frequency channel is shared between the Femto-cell and the Macro-cell base station, it will create a level of interference in which will degrade the overall performance by increasing the interference level.
- B. *Two Femto-cells interfering each other due to distance factor:* The distance is an important factor to be considered if the two Femto-cells are placed close by each other with the same frequency. In this scenario, some sort of background noise will affect and reduce the sensitivity of both Femto-cells.
- C. *More than one base station receiving a high power transmitted by a user equipment:* There are some buildings that were built or constructed using materials that blocks or reduces some signals levels; so indoor signals (Femto-cell coverage) will sometimes reach base stations in a way that it will also degrade the overall performance by increasing the level of noise that will be received by the base stations.

To initiate a Femto-cell, it has to go through some stages which will be discussed in Section 2 while the core of this paper will be discussed in Section 3. Section 4 will discuss the results of the experiment showing two different cases as well as some graphs of the network capacity and the traffic intensity after implementing the Femto-cell. The conclusion of the experiment will be shown in the last Section of the paper; section 5.

II. INITIATING A FEMTO-CELL

At the startup stages, the Femto-cell shall be able to [2][3]:

- *Sense the surrounding environment* so it can measure the signal levels of the neighboring macro-cells. This radio sensing mechanism has some major elements such as the listening mode and the message exchange.
- *Self organize* to avoid the interference issues and to provide a more reliable environment.

III. THE PROPOSED SCHEME

This scheme is simulating the reality scenario by initiating a Femto-cell at a random location chosen by

the user; the Femto-cell has to be connected to the network through the existing broadband connection in the initiation location.

The proposed scheme relies on some prior steps to stages to assign the frequency. The first stage is that while a Femto-cell being initiated, the Visitor Location Register (VLR) has to validate the location of the initiated Femto-cell by checking if any other Femto-cell exists at this location or not. It is to insure that there will not be any duplication of the same frequency at this location. If it exists, the frequency to be assigned will be different from the one to be assigned when it does not exist.

Figure 1 is showing a simple system module for initiating a Femto-cell and validating its location.

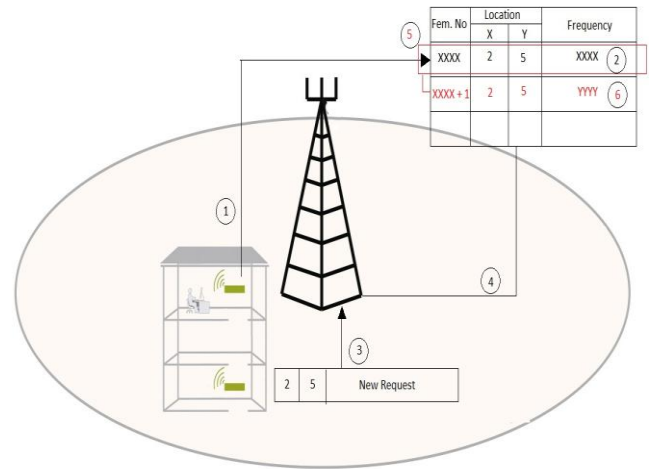


Fig. 1 System model

It is also important to know the distances between the Femto-cell and each other macro-cell in the cluster as their locations are pre-defined to the system. Since all locations are there in the database it is easy to calculate the distance as in Figure 2.

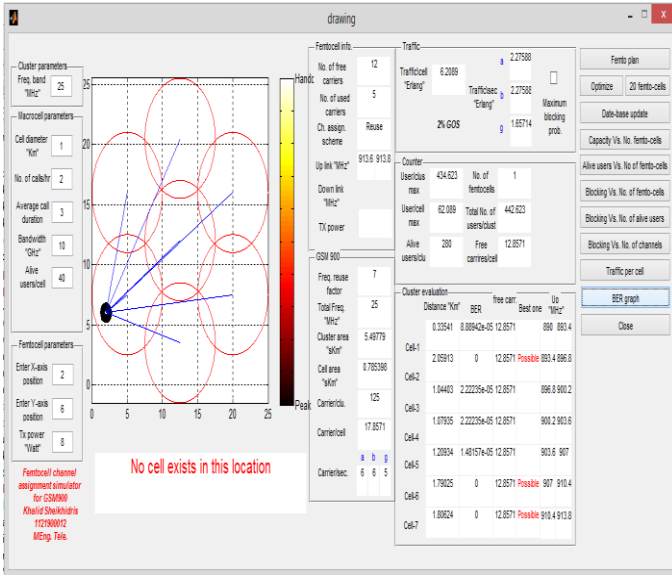


Fig. 2 Distance calculation

Femto-cell location has to be determined with respect to the surrounding Macro-cells in the cluster; this system supports seven cells per cluster. The model used to calculate the distance between the two transmitters is:

$$d = \frac{\sqrt{(x_2-x_1)^2 + (y_2-y_1)^2}}{\sqrt{(y_2-y_1)^2}} \quad (1)$$

- x_1 = X-axis of the initiated Femto-cell.
- x_2 = X-axis of the designated Macro-cell.
- y_1 = Y-axis of the initiated Femto-cell.
- y_2 = Y-axis of the designated Macro-cell.

After calculating the distance, the second stage is to calculate the E_b/N_0 from each Macro-cell to the Femto-cell using the path-loss equations (Friis transmission equation)

$$\text{Path loss} = -10 * \log \frac{\lambda^2}{4\pi^2 * d^2} \quad (2)$$

$$\lambda = \frac{C}{f} \quad (3)$$

- λ = The wave length.
- C = speed of light '3*10⁸'.
- f = frequency.
- d = distance between Femto-cell and macro-cell base stations.

The third stage is to choose the least Bit Error Rate (BER) using the calculated E_b/N_0 by injecting it into a Gaussian Minimum Shift Keying (GMSK) modulator and demodulator since the system is testing it under GSM.

After applying the GMSK modulation and demodulation the BER has to be evaluated according to Equation (4).

$$\text{Bit Error Rate} = \frac{\text{No. of error bits}}{\text{No. of transmitted bits}} \quad (4)$$

The BER helps the system to propose a suitable and a safe frequency to be assigned. The system chooses the least BER with most far distance macro-cell's frequency to be assigned and highlight it with an indicator. As shown in Figure 3.

	Cluster evaluation		free carr.	Best one	Up "MHz"
	Distance "Km"	BER			
Cell-1	0.33541	8.88942e-05	12.8571	890	893.4
	2.05913	0	12.8571	Possible	893.4 896.8
Cell-2	1.04403	2.22235e-05	12.8571	896.8	900.2
	1.07935	2.22235e-05	12.8571	900.2	903.6
Cell-4	1.20934	1.48157e-05	12.8571	903.6	907
	1.79025	0	12.8571	907	910.4
Cell-6	1.80624	0	12.8571	910.4	913.8

Fig. 3 The proposed frequency after BER evaluations

IV. RESULTS AND DISCUSSION

Case 1: The first Femto-cell to be initiated in the cluster

Figure 4 shows the final results of the system after evaluating all the factors discussed in the previous sections. The frequency assigned will not interfere any Macro-cell that uses the same frequency because at the location of the Femto-cell the BER value is zero.

After assigning this frequency, the VLR will be updated that this frequency is reused at this location with this Femto-cell, thus when another Femto-cell is initiated at this location, another frequency will be assigned since this location is being served by another Femto-cell. While Figure 5 shows that the system indicated this Femto-cell as the first one in this location and the assigned frequency is totally new, meaning that it has not been used by any other Femto-cell.

Femtocell info.

No. of free carriers: 12

No. of used carriers: 5

Ch. assign. scheme: Reuse

Uplink "MHz": 893.4 893.6

Downlink "MHz":

TX power:

Fig. 4 Assigned frequency

Existing Femto-cell: Yes No

Frequency assigned: New Used by close by Femto-cell

Fresh Femto-cell

Fig. 5 Femto-cell indication

Case 2: Initiating a Femto-cell at the same location of another

Typically when a Femto-cell is initiated at any location the system will follow the same stages as before to assign the frequency. However, when two Femto-cells were initiated at the same location, both of them are supposed to have a unique frequency than the other one. Moreover because the Femto-cell is at the same location of another one, the system will propose the same frequency to be used but Figure 6 shows the indication of the system categorizing the Femto-cell as a duplicate at the same location and the frequency to be assigned will not be unique. Thus, the system has to go for the

second best frequency as it is shown in Figure7 which is unique from the previous one.

Figure 8 is showing the proposed frequency to be used.

Cluster evaluation					
	Distance "Km"	BER	free carr.	Best one	Up "MHz"
Cell-1	0.33541	6.66706e-05	12.8571		890 893.4
Cell-2	2.05913	0	12.8571	Possible	893.4 896.8
Cell-3	1.04403	7.40785e-06	12.8571		896.8 900.2
Cell-4	1.07935	2.96314e-05	12.8571		900.2 903.6
Cell-5	1.20934	0	12.8571		903.6 907
Cell-6	1.79025	0	12.8571		907 910.4
Cell-7	1.80624	0	12.8571		910.4 913.8

Fig. 6 Second Femto-cell proposed frequency

Existing Femto-cell: Yes No

Frequency assigned: New Used by close by Femto-cell

Femto-cell exists & using the same frequency

Fig. 7 Second Femto-cell indication

Femtocell info.

No. of free carriers: 12

No. of used carriers: 5

Ch. assign. scheme: Reuse

Uplink "MHz": 893.6 893.8

Downlink "MHz":

TX power:

Fig. 8 Second Femto-cell assigned frequency

The proposed scheme will later on evaluate the traffic as well as the number of users that can be supported by the system.

The cluster is having a dedicated traffic intensity in which it cannot be increased due to the limited resources. Since the Femto-cell is expected to have an independent traffic, the traffic per cluster is somehow enlarged when adding a Femto-cell to it. Figure 9 shows the cluster's traffic after been enlarged with the Femto-cells.

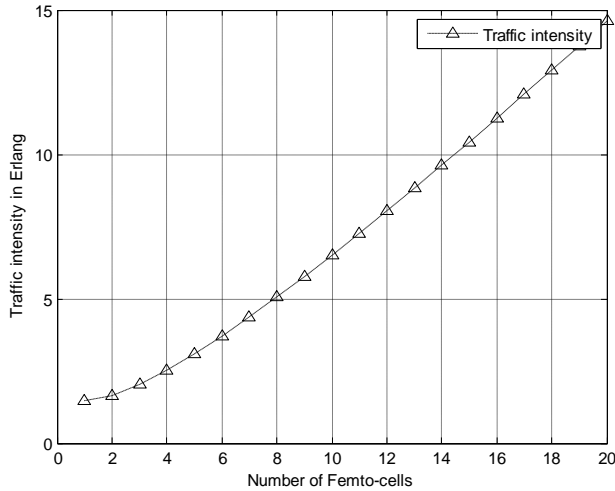


Fig. 9 Traffic per cluster

The traffic per user is calculated using Equation 5.

$$A_u = \lambda/h \quad (5)$$

$A_u =$ Traffic per user.

$\lambda =$ Average No. of calls "user input".

$h =$ Average call holding time "user input".

Since the number of channels is dedicated, then it is easy to import the total traffic per cell from erlang-b table. Hence, multiplying the traffic per cell by the number of cells will give the total traffic per cluster as shown in Equation 6.

$$A_{cluster} = A_{cell} * N \quad (6)$$

$A_{cluster} =$ Traffic per cluster.

$A_{cell} =$ Traffic per cell.

$N =$ Number of cells per cluster.

The Femto-cell also can support up to seven alive users if we assumed that it handles up to one carrier. As

a Time Division Multiple Access (TDMA) frame contains eight time slots; one of them is used for control channels. This indicates that with every Femto-cell initiated, the system will be capable of supporting seven extra users using the resources at the same time. Figure 10 shows the alive users graph.

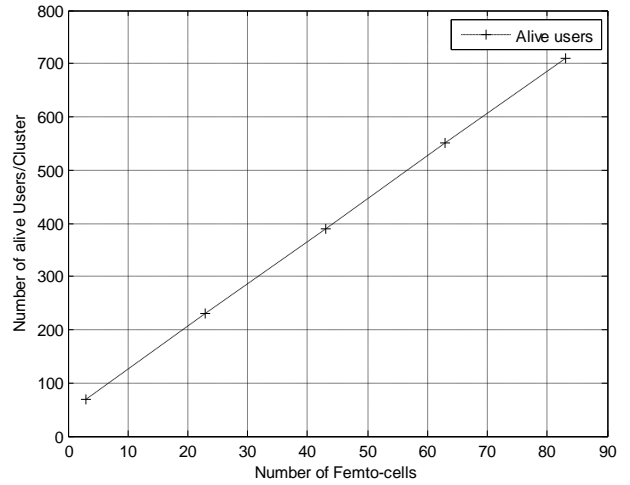


Fig. 10 Alive users graph

V. CONCLUSION

Using the Matlab software to simulate the behaviours of the cellular system offers an advantage of an easier and successful evaluation and testing the system under different circumstances. The proposed scheme had successfully assigned a unique frequency in which it contributes in reducing the interference and extending the system capabilities to support more users by offering more traffic. The proposed scheme is open for further researches to check the capability of the system to support more Femto-cells. Since this scheme is tested under the GSM, other systems such as CDMA, 4G LTE etc have to be tested as well.

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