MITIGATION OF CO-CHANNEL INTERFERENCE IN LONG TERM EVOLUTION USING FRACTIONAL FREQUENCY REUSE SCHEME

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Abstract **– Co-channel interference in Long Term Evolution (LTE) cellular network is caused due to usage of same frequencies between the neighboring cells at the same region. Here the term co-channel interference is otherwise known as inter-cell interference. It is important to mitigate co-channel interference at micro-cells in-order to improve the communication performance of the cellular network. In this paper, we propose a fractional frequency reuse approach for micro-cells to mitigate the co-channel interference. In this approach, the cell is partitioned into inner region & outer region and selects the optimal frequency allocation for each region in the cell to enhance the overall throughput and user satisfaction.**

Keywords: ***co-channel interference, long term evolution, microcells, fractional frequency reuse.***

I. INTRODUCTION

The Long Term Evolution (LTE) is a fourth generation wireless communication standard manipulated in mobile phones to achieve high data rate during mobility. This standard is developed by the 3rd Generation Partnership Project (3GPP) by re-designing the radio network and core network. Is the next major step in mobile radio communication and is specified as Release 8. LTE employs Orthogonal Frequency Division Multiple Access (OFDMA) for downlink data transmission [1].

Orthogonal Frequency Division Multiple Access (OFDMA) is a multi-user version of OFDM digital modulation scheme. Multiple-access is achieved in OFDMA by assigning subsets of subcarriers to individual users at a time. These subcarriers are assigned based on the demands of the users. This allows low data rate transmission from several users. OFDMA is a packet mode transmission with shorter delays. The key characteristic of a cellular network is the ability to reuse frequencies in order to increase both capacity and coverage. Fractional Frequency Reuse (FFR) is discussed in OFDMA based networks such as Long Term Evolution (LTE), to overcome the Co-Channel Interference (CCI) problems [2]. In FFR, the cell space is divided into inner region which is located close to the Base Station (BS) and outer region is located to the borders of the cell. The whole frequency spectrum is divided into several sub-bands and is assigned differently to the inner and outer region of the cell. By this the intra-cell interference is eliminated and the inter-cell interference is reduced [3]. Moreover, two new algorithms, Fractional Time Reuse (FTR) and Fractional Time and Frequency Reuse (FTFR), are proposed in [4] to cater for reduced capacity in the cell border area because of FFR. In [5], the author shows that the Soft Frequency Reuse (SFR) scheme is a good candidate to enhance the cell edge throughput without sacrificing the average cell throughput.

This paper proposes a Fractional Frequency Reuse mechanism for OFDMA based mico-cell networks. The optimal FFR scheme is deliberated through the mechanism based on two parameters such as: (i) user throughput and (ii) user satisfaction. For every iteration, this mechanism checks the inner cell radius and the inner cell frequency. Also for each user it estimates the Signal to Interference plus Noise Ratio (SINR) and throughput with the corresponding inner cell radius and allocated frequency. These values are then been used to compute the cell mean throughput and the user satisfaction. Finally, through this mechanism the optimal FFR scheme is selected that is used to either maximizes the cell mean throughput or the user satisfaction. By tuning either the frequency allocation assigned to each region or the transmit power of each subcarrier the interference can be combated upto a particular levels. This paper also offers several simulation scenarios.

The rest of the paper is composed of theoretical background of co-channel interference in Section II. Section III describes the system model & mechanism layout. The performance analysis of the LTE system is illustrated in section IV. Section V: Conclusion.

II. CO-CHANNEL INTERFERENCE

In cellular mobile communication (GSM & LTE Systems), the frequency resource is partitioned into non-overlapping spectrum bands and is assigned to each region of the cell. Co-channel interference (CCI) is the type of interference that exists between any neighboring cells in LTE cellular networks due to the sharing of same channel. Here this type of interference is a serious issue as it degrades the performance of the system in terms of data rate and spectral efficiency particularly at cell edge. Actually to improve the efficiency of spectrum the frequency reuse methods are adopted. But on the other hand this method leads to co-channel interference as the same set of frequency is used by several cells in the network. The term co-channel interference is also known as inter-cell interference (ICI).

It is not possible to mitigate the co-channel interference by increasing the power of the transmitter. As this increased transmitter power might increase the interference among the neighboring co-channel cells. To mitigate co-channel interference there exist several simple approaches that is by physically separating the co-channel cells with minimum distance and by using the cell sectorization in the seven-cell system. The co-channel interference can also be controlled by cell planning, cell selection, modulation schemes, dynamic channel allocation and power control. By mitigating these co-channel interferences (CCI) the link quality and throughput for cell edge users can be improved.

III. SYSTEM MODEL & MECHANISM LAYOUT

A. System Model

The available entire frequency spectrum (i.e., 10MHz) is partitioned into four uneven spectrums as *f1*, *f2*, *f3* and *f4* as shown in figure 1. In-order to increase the percentage of coverage and capacity of a network the size of the cell has to be reduced. i.e., the larger cell is partitioned into number of smaller cells.

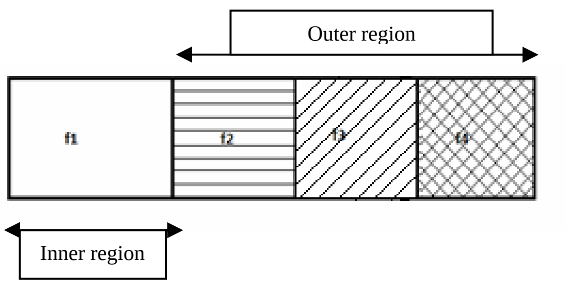

Figure 1: Partition of frequency spectrum

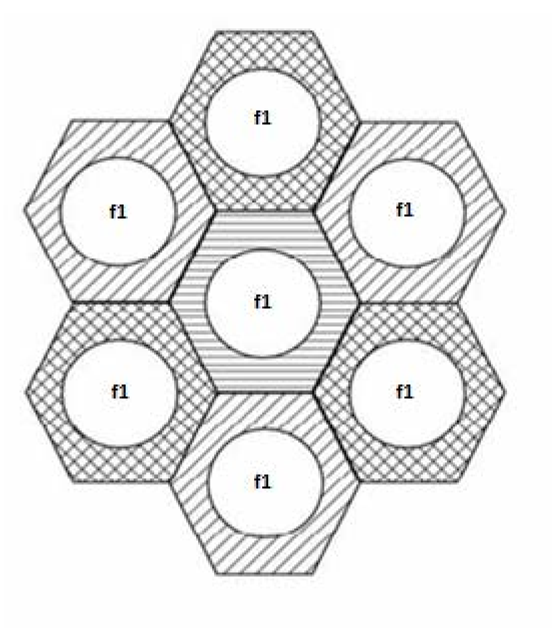

Figure 2: System topology using FFR scheme

The main objective of this mechanism is to combat the Co-Channel interference in LTE cellular network. Through this mechanism the frequency is allocated to each region of microcell. The one of the successful method to enhance the capacity of the system is by using frequency reuse over small cells (i.e., microcell). The region of each microcell is divided into: cell center (inner region) with reuse factor of 1 and cell edge (outer region) with reuse factor of 3 as shown in figure 2.

Here we consider two base stations where one base station serves the users of cell center over the same sub-band as user x and the other base station serves the users of cell edge over the same sub-band as user x.

Each cell holds number of users and who tries to share the available resource (i.e., subcarriers). The SINR of the user x who is served by the base station b on sub-carrier n is equated as [6]:

$$SINR_{x,n} = \frac{G_{b,n} P_{b,n} h_{b,x,n}}{\sigma_n^2 + \sum_{j}^{k} G_{j,x} P_{j,n} h_{j,x,n}} \quad \ldots(1)$$

Where in equation (1), $G_{b,n}$ is the path loss associated with the channel between user x and base station *b*, $P_{b,n}$ is the transmit power of the base station on subcarrier *n*, $h_{b,x,n}$ is the exponentially distributed channel fast fading power and σ_n^2 is the noise power of an Additive White Gaussian Noise (AWGN) channel. Symbols *k* and *j* refer to the set of all the interfering base stations (i.e. base stations that are using the same sub-band as user x). Their physical meaning is that *j* is the cell index and *k* the number of co-channel cells. In our analysis, we assume that equal transmit power is applied, $P_{b,n} = P$ for all base stations. The coefficient $h_{b,x,n}$ is replaced by its mean value ($h_{b,x,n}$ = 1)

Next the throughput of the user x is calculated with the known values of user x's capacity and assigned bandwidth. The capacity of the user x over subcarrier n is equated as [7]:

$$C_{x,n} = \Delta f . \log_2(1 + SINR_{x,n}) \qquad \ldots(2)$$

Where, Δf refers to the available bandwidth for each subcarrier divided by the number of users that share the specific subcarrier.

Thus, the throughput of the user *x* can be expressed as follows [8]:

$$T_x = \sum_n \beta_{x,n} C_{x,n} \qquad \ldots(3)$$

Where, $\beta_{x,n}$ represents the subcarrier assigned to pico user x. When $\beta_{x,n}$ *=1*, the subcarrier *n* is assigned to pico user x. Otherwise, $\beta_{x,n}$ = 0.

The user satisfaction (US) is based on the subcarrier allocation at the cell regions where both are indirectly proportional to each other. The term user satisfaction is used here to indicate the performance of the proposed system. Thus the user satisfaction is given as [8]:

$$US = \frac{\sum_{x=1}^{X} T_x}{\max\_user\_throughput * X} \qquad \ldots(4)$$

The value of US ranges between 0 and 1. If the US ranges to 1 then the throughput of each user can be parallel to each other. There might exists a huge difference in each cell's throughput of the user while US=0.

B. Mechanism layout

In this mechanism we assume that the system topology consists of large number of multicast users. And the users are distributed uniformly. After estimating the throughput and user satisfaction for the allocated subcarriers, the optimal FFR scheme is determined by partitioning the cell into two regions such as: inner region with frequency reuse factor of 1 and outer region with frequency reuse of 3.

Table.1 describes the subcarrier allocation in the mechanism of the system. At the initial stage of the mechanism the entire 25 subcarriers are allocated to the inner part of the cell and there exists no subcarrier allocation for the outer part of the cell. During every iteration the subcarrier allocated at inner part of the cell is reduced and finally becomes 0 at the end of the iteration. Simultaneously the subcarrier allocation for the outer part of the cell is been increased at every iteration. And thus the entire 25 subcarriers are allocated to the outer part of the cell. The optimal FFR scheme is chosen by determining the maximum mean throughput and US. At every iteration the user's throughput and user satisfaction are determined for every consecutive inner cell radius.

Table 1: Subcarrier Allocation

ITERATION	REGION	SUBCARRIER ALLOCATION
1	Inner	25
	Outer	0
2	Inner	24
	Outer	1/3
3	Inner	23
	Outer	2/3
.	.	.
.	.	.
.	.	.
25	Inner	1
	Outer	24/3
26	Inner	0
	Outer	25/3

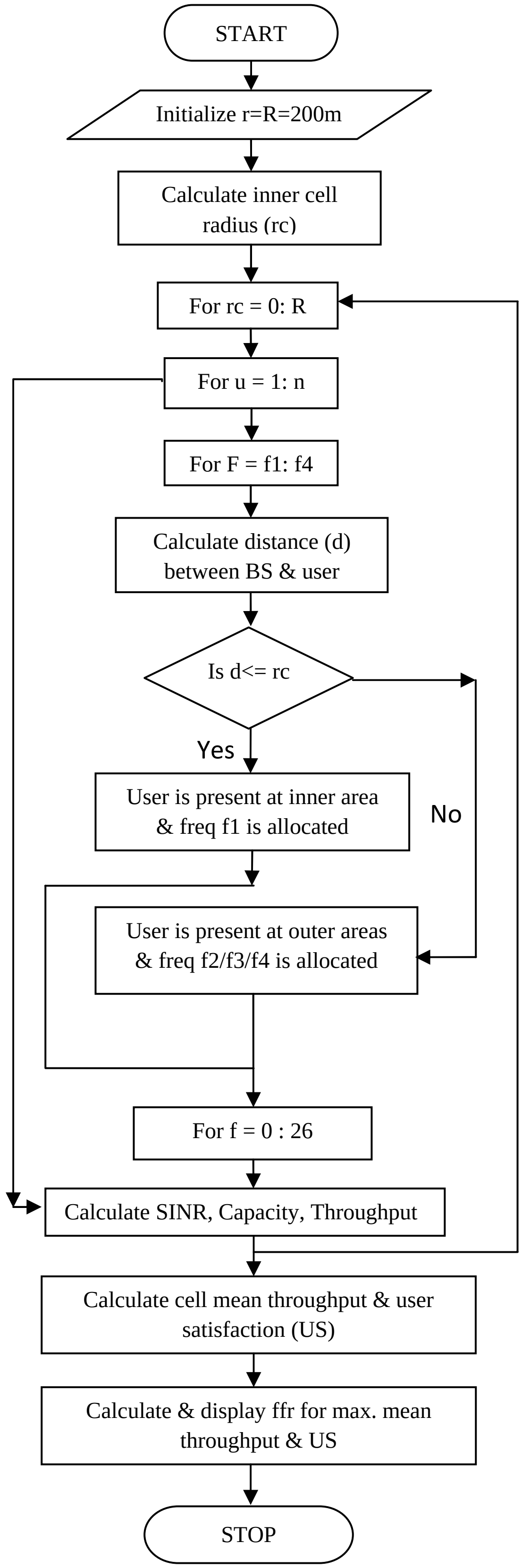

Figure 3: Mechanism Flow

IV. PERFORMANCE ANALYSIS

The simulation parameters are listed in the Table 2. Here we consider LTE system with 10 MHz bandwidth and which is partitioned into 25 subcarriers. The system behavior is investigated based on the suburban scenario with COST 231 walfish-Ikegami channel model.

Table 2: Simulation Parameters

PARAMETER	VALUE
System bandwidth	10 MHz
Subcarriers	25
Subcarrier's bandwidth	375 KHz
Carrier frequency	2000 MHz
Cell radius	200 m
Path loss	COST 231 Walfish-Ikegami
BS transmit power	46 dBm
Power Noise Density	-175 dBm/Hz

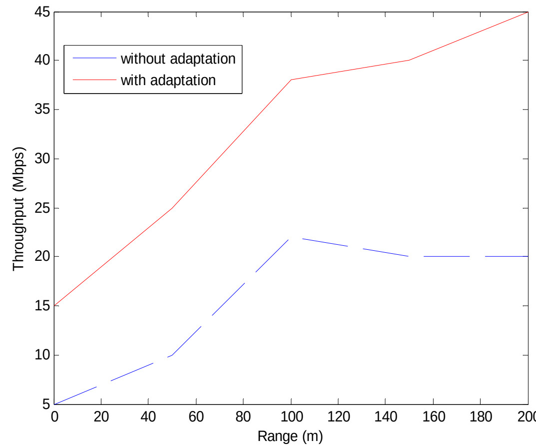

Figure 4: User's throughput

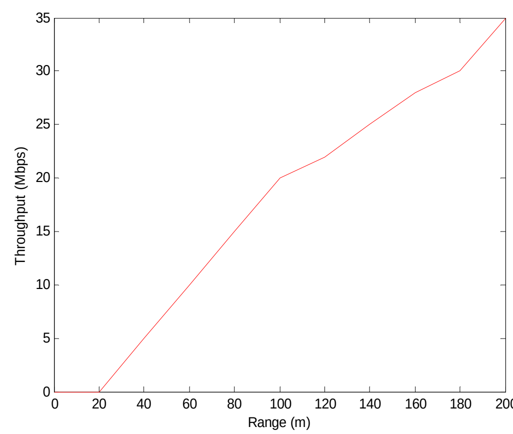

Figure 5: Optimal average throughput

A. Throughput

The Figure 4 represents the throughput value for with and without adaptation of FFR scheme. In which by using the FFR scheme the highest throughput and the mean throughput value for the inner cell radius of 90m is obtained. Figure 5 present the average throughput for an optimal throughput.

B. User Satisfaction

Figure 6 represents the user satisfaction value for with and without adaptation of FFR sheme. And in the topology the users are distributed uniformly. In this experiment at each microcell 15 users are accomodated. To which the maximum user satisfaction is observed within the 10 MHz bandwidth by using the FFR scheme. Figure 7 presents user satisfaction for an optimal user satisfaction.

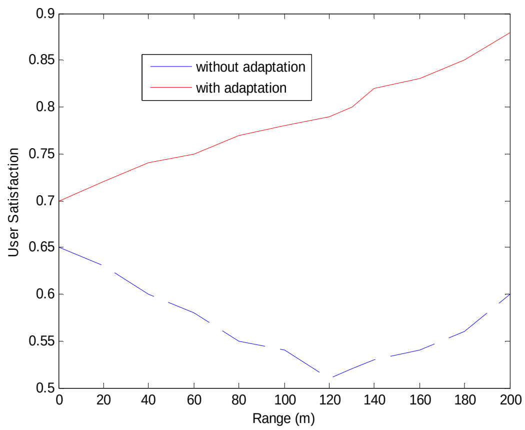

Figure 6: User satisfaction

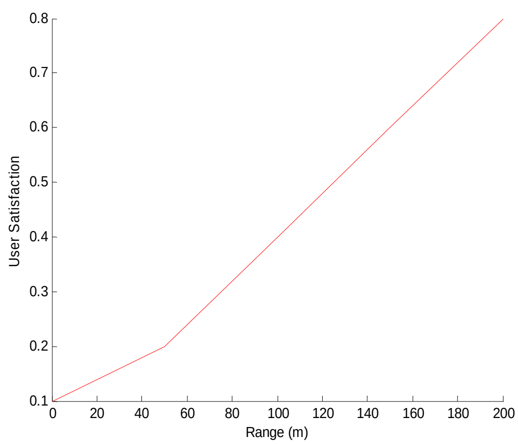

Figure 7: Optimal user satisfaction

V. CONCLUSION & FUTURE SCOPE

Thus by using the Fractional Frequency Reuse (FFR) scheme the throughput, SINR and user satisfaction of each user in the topology is calculated. And with these values the optimal mean throughput and user satisfaction is determined. In the microcell network the frequency is reused efficiently than any other cells and also the throughput & SINR of the users can be enhanced. The microcell uses a power control to limit the radius of its coverage area. Hence by which the interference from the nearby cells using the same set of frequencies can be combated. Also it requires only minimum power for the process of transmission in the network.

The idea suggested for the extension of this paper could be increment of co-channel reuse ratio, Q=D/R=sqrt(3N) for hexagonal cells and by reducing the antenna height at base station the level of co-channel interference can be reduced.

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