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Sector Based Resource Allocation for MIMO-OFDMA System

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Abstract— **Inter Cell Interference (ICI) avoidance and attaining overall throughput by effective resource utilization are the major goals while choosing any frequency reuse scheme in multi cell Multiple Input Multiple Output- Orthogonal Frequency Division Multiplexing Access (MIMO-OFDMA) systems. The users present at the edges in the coverage area of a respective Base-station (BS) undergo signal degradation due to fading and neighboring interfering signals using the same resources. This limits the overall system throughput and capacity attained. This scenario indicates that the cell edge users contribute maximum for the reduced performance in a cellular region. It is possible to attain an enhanced overall throughput only if the edge users attain similar metric as cell center users. In order to minimize ICI and to attain higher throughput, the system must incorporate an efficient allocation of radio resources (subcarrier and power). In this paper we propose sectored frequency planning involving appropriate subcarriers and power allocation to cell center and edge users, that provides higher throughput.**

Index Terms — **Frequency reuse, throughput, LTE, User Satisfaction.**

I. Introduction

Resource management in cellular system is a domain which needs continuous upgrading as the traffic load and user requirements keep changing each day. OFDMA adopted in LTE systems encourage dynamic resource management, as the system performance is highly deteriorated by Inter-Cell Interference (ICI)[1].The signals transmitted by the base station degrade as the distance of end-user increases. Hence it is necessary to keep up the signal to a minimal threshold [2]. The region over which the strength of the radio signal remains above or almost the minimal specified value is considered to be the coverage area of the base station. This region is usually circular but considered hexagonal for simulation as it tends to cover the complete area and avoids any overlapping. Once the coverage area is known, allocating the bandwidth to this region to achieve higher capacity and spectral efficiency is a discerning task. Further to avoid any super-imposition of channels, frequency reuse technique is preferred prior to allocation.

In frequency reuse, the radio signals are partitioned and allocated such that they are reused in a regular pattern in the given coverage area without overlapping [3][4]. If the repeating regular patterns happen to be same at the boundaries of the cell then this will lead to interference which is called Inter-cell Interference (ICI) [5]. Another terminology called Intra-cell Interference is caused by the interference of signals from neighboring end user devices. This interference is considered during the computation of signal-to-interference-plus-noise ratio (SINR). However with the mercurial rise in the figure of mobile users, the service providers need to pursue good strategies which assure effective bandwidth utilization in conjunction with user satisfaction [6]. With an elevated throughput and flat interference being the primary objective, a good frequency reuse scheme is crucial in achieving an economical allocation[7].

II. System Framework

Multiuser OFDMA (MU-OFDMA) adds multiple access to OFDM by allowing a number of users to share an OFDM symbol. Resource allocation is done by two techniques namely fixed resource allocation and dynamic resource allocation. In a fixed resource allocation, for each user the dimensions such as sub channel or time slot are assigned independently by using FDMA or TDMA. Due to the varying channel conditions this fixed resource allocation scheme is not optimal. But for the dynamic resource allocation in [9], for the users the dimension such as, channel gain, are allocated adaptively. Due to the time-varying nature of the wireless channel, dynamic resource allocation makes full use of multiuser diversity to achieve higher performance [8]. The resource allocation problem of the MIMO-OFDM system is divided into three stages; user separation, subcarrier allocation and power allocation stage.

For the system framework, we consider OFDMA cellular system where a large number of user are functioning in the downlink. These users are spread out randomly in the coverage area and each one is served by the respective base station. The received Signal to Interference Plus Noise Ratio (SINR) for the particular user in the downlink is estimated as

$$SINR_y = \frac{P_x h_{xy} G_{xy}}{\sigma^2 + \sum_{z \epsilon Z} P_z h_{zy} G_{zy}} \tag{1}$$

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Where P_x is the transmit power of the base station, h_{xy} is the exponentially distributed channel fading power, and G_{xy} is the pathloss associated with the channel between user y and base station x, and σ^2 is the noise power. The set Z represents all the interfering base stations, i.e. base stations that are using the same sub-band as user y. In this paper we consider the pathloss and small scale fading for simulation and in future work this will be extended to consider large scale fading as well.

$$G_{xy} = 46.3 + 33.9log10(f_c)13.28log10(h_b)a(h_m) + b \quad (2)$$

where $a(h_m)$ is computed as,

$$a(h_m) = (1.1(log(f_c) - 0.7)h_m - (1.56(log(f) - 0.8))$$

$$b = \begin{cases} 0dB & \text{for medium cities and suburban areas} \\ 3dB & \text{for metropolitan} \end{cases}$$

Considering the obtained SINR, we can estimate the capacity of the end user y on subcarrier k as ;

$$C^p_{y,k} = \Delta f log_2(1 + \beta SINR^p_{l,k}) \quad (3)$$

The constant for target bit error rate (BER), given by;

$$\beta = \frac{1.5}{\ln(5BER)} \quad (4)$$

The overall throughput of the serving cell(p) is estimated using the practical capacity as;

$$T^p_{l,k} = \sum_{l=1}^{L}\sum_{k=1}^{K} \rho_{l,k} C^p_{y,k} \quad (5)$$

where $\rho_{l,k}$ indicates the assignment of subcarrier k to the user.

$$\rho_{l,k} = \begin{cases} 1 & \text{if subcarrier k is allotted to user l} \\ 0 & \text{otherwise} \end{cases}$$

III. Methodology

A multicell MIMO-OFDMA based downlink system is considered in this paper. A base station equipped with an antenna is placed at the center of each cell to serve users who are who are randomly distributed within the cell. This paper implements Fischer algorithm for subcarrier and power allocation. To avoid ICI, the frequency band is divided into three sectors. The Fischers algorithm allocates subcarriers according to the gain of each user. The channel condition of each user is found earlier in the form of SINR which is further taken as a metric for deciding number of subcarriers to the particular user. The specifications followed here are as per LTE standards. For comparative analysis, we have made an attempt to allocate resources by two methods.

1. Allocating resources without differentiating between Cell Centre Users and Cell Edge Users.
2. Allocating resources after differentiating between Cell Centre Users and Cell Edge Users. Frequency Reuse- 1 is applied to the centre while Frequency Reuse-3 is applied to the edge.

In the first method the users in the cell are not categorized as cell centre and cell edge users. The resources are allocated considering the individual gains, irrespective of the type of user. The throughput of this method is reduced as because of the throughput reduction of the edge users. Hence it is needed to bifurcate the users as edge and centre and adopt a technique for allocating the radio resources.

In the second method of allocation, users are classified as either cell centre or cell-edge users depending on the threshold set using z-distribution table. The categorization of users is done by using distance as criteria. We assume that BSs have perfect knowledge of channel state information updated periodically via feedback channels. The transmission power is allowed to be independently allocated on each subcarrier. Hence, dynamic resource allocation is performed on the sectored frequency schemes. The sum of the overall allocated power in each cell does not exceed the maximum transmission power of the BS. We assume that all BSs in the network are given the same maximum transmission power. To any cell,only interference from its adjacent cells are regarded as the effective ICI. To avoid ICI, subcarrier indexing is taken care and an algorithm is used for subcarrier and power allocation which attains the fairness metric.

Initially, the power is equally distributed among all the users. Since, the users at the edge of the cell do not have sufficient power to have a cooperative communication; Lagrange multiplier is used to overcome this drawback. To both center and edge users, we allocate the subcarriers by using Fischer algorithm, with reduced iterations. For the edge users who do not have sufficient power are allotted with subcarrier by using this algorithm and the power is re-allocated by using Lagrange Multiplier, which satisfies the users need to have a minimum data rates. With this we attain User Satisfaction with the increased capacity and minimum complexity.

Table I
SIMULATION PARAMETERS FOR THE SYSTEM MODEL

PARAMETERS	VALUES
Number of End User Devices	100
Radius of the Cell	500m
Channel Bandwidth	10MHz
Carrier Frequency	2GHz
Number of Subcarriers	600
Subcarrier Spacing	15kHz
Noise Spectral Density No	-174dBm/Hz
Target BER	106
Path loss Model	Cost 231 Hata Model
Height of Transmit Antenna	40m
Height of Receiver Antenna	1m

IV. Algorithm

1) Load the LTE Specifications as mentioned in the Table-I.
2) Randomly distribute the users in the network.

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3) Bifurcate the users as edge and centre users based on the threshold identified.
4) Consider a section of Sub-bands out of the entire bandwidth for centre and edge users.
5) Divide the edge Sub-bands into three sectors.
6) Set initial Maximum User Satisfaction =0
7) do
8) for i do=1:numberofusers
9) Allocate subcarriers and respective power using Lagrange Multiplier.
10) Calculate the capacity of the cell.
11) Calculate the average User Satisfaction.
12) end for
13) end do while(User Satisfaction >Maximum User Satisfaction)
14) go to step 1
15) Plot the results
16) end

The algorithm loads the transmission power and assigns the pathloss model according to LTE standards. As the users get randomly distributed, their respective gains are calculated using (1). Here the correlation factor b is considered zero. The algorithm utilises the distance parameter of every user while bifurcating the users as centre user and edge user. It further considers the SINR parameter for subcarrier and power allotment. The Fischer algorithm allocates subcarriers maximising capacity and adapts power accordingly.

Here the user which the least gain tends to get amount of resources which makes an effective contribution towards attainment of overall throughput. The algorithm is run separately to the network which involves no bifurcation of users as cell centre and edge and to the network with bifurcation. The first method involves lesser computation compared to the second as the thresholding calculation and division of sub-band for edge and centre is eliminated.

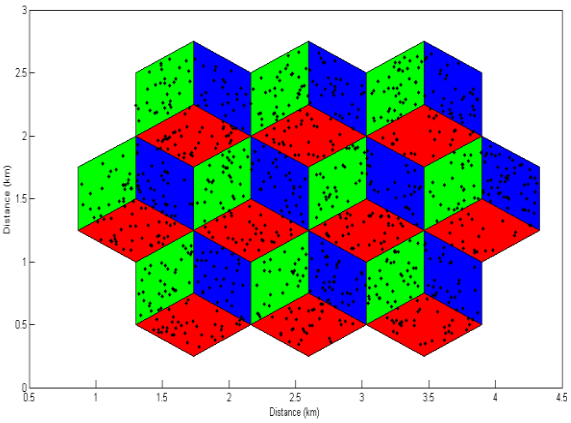

Figure 1: Cellular layout where the users are randomly spread in the entire cell area with nine cells. There is no separation of users as cell center and edge.

V. Discussion Of Results

In this paper we have compared both allocation methods using Fischer algorithm for resource allocation. It is observed that the algorithm allocates

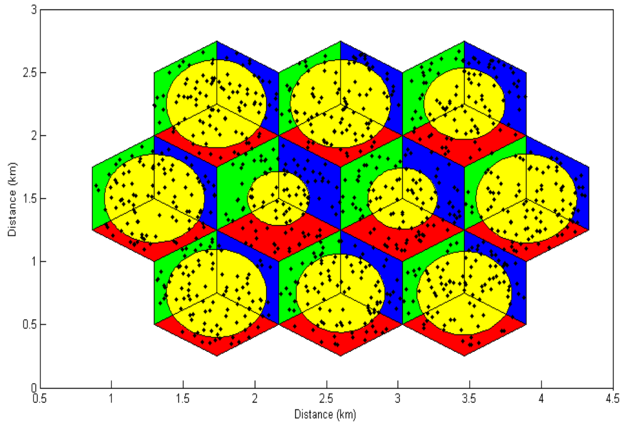

Figure. 2. Cellular layout where the users are randomly spread in the entire cell area with nine cells. There is separation of users as cell centre and edge indicated by a varying circular structure.

Subcarriers according to the respective gain of the user. Figure 1 and Figure 2 represent the two methods in which the subcarriers and power are allocated to the users. Special care is taken while allocating the frequency bands to the respective sectors. Every resource block carries its own Identity which is indexed in such a way that avoid ICI. Figure 3 and Figure 4 represent the average capacity (or throughput) and average user satisfaction attained while simulating both the methods of resource allocation. From the Fig.3, we find that the capacity is attained more when the allocation of subcarriers is done after user separation using thresholding technique. From the Fig.4 we find that the User Satisfaction is attained more when the allocation of subcarriers is done without opting user separation method. Though both the methods have their own advantage and disadvantage, it is left to the user to prefer the method based on the requirements.

In both the cases, the overall power allocated is very feasible hence this algorithm is chosen for frequency allocation. Moreover the performance gap is found to be decreasing with the increase in SNR. This indicates that our proposed method is more effective for any kind of channel and any distribution of users. Attaining high spectral efficiency, high reliability and good transmission quality during bad channel state is more important than during good channel state. So, our proposed are valuable in practice.

VI. Conclusion

A Sectored Frequency Planning Scheme incorporating Fischer algorithm is presented in this paper. This algorithm is tested in two different ways in order come up with an optimal method. From the simulation results, it is clear that the method involving user separation promotes higher capacity at the cost of User Satisfaction. Hence it over performs the latter which achieves higher user satisfaction at the cost of capacity. The new power

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allocation method boosts the performance with only a slight increase in complexity in both the cases. For reliable applications, the trade off is definitely worth the extra effort. In addition, the cases reflect amount of subcarrier allocation and power allocation followed to achieve the targeted user satisfaction and capacity.

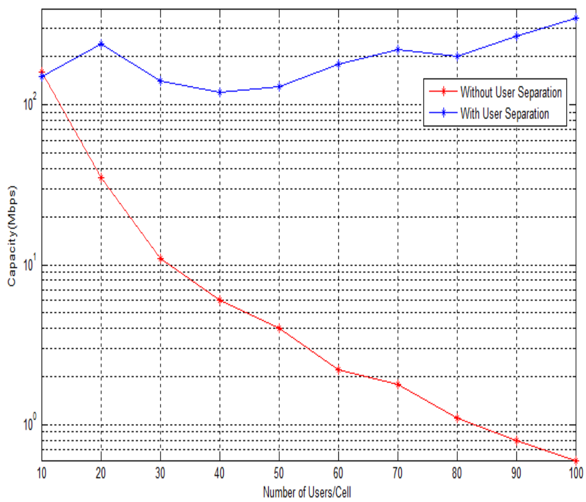

Figure. 3. A plot for the average cell throughput versus number of users considering cell radius as 450m and users ranging from 10-100 users.

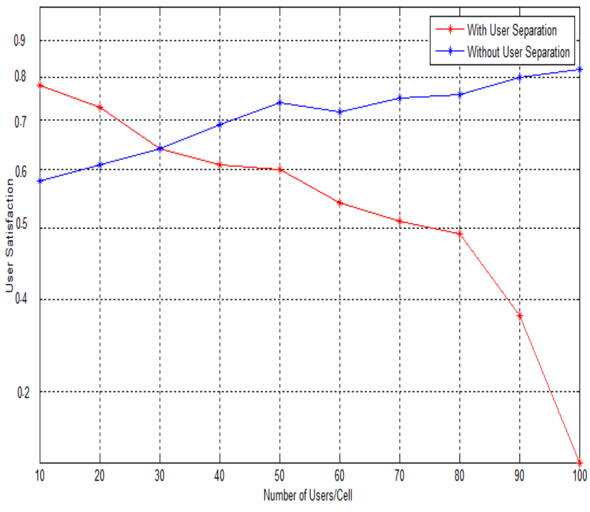

Figure. 4. A plot for average User Satisfaction for respective throughput, number of users considering cell radius as 450m and users ranging from 10-100 users.

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