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SPECTRAL EFFICIENCY ANALYSIS OF MUTI CELL OFDMA SYSTEM WITH SECTORING

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Abstract

This paper analyses the performance of the multi cell OFDMA system for the average spectral efficiency and the coverage probability. We form the Chunk by the grouping of the adjacent subcarriers by exploiting the correlation among them. Frequency band allocation is based on the chunk instead of the subcarrier in order to reduce complexity in the sub carrier based resource allocation. In order to mitigate inter cell interference; in addition with Fractional Frequency Reuse (FFR), the proposed scheme introduces 3 additional directional antennas to provide 120 degree sectoring. This method provides better spectral efficiency than FFR without including sectoring. We achieve the optimal radius ratio of 0.6 for this proposed resource allocation scheme. Through simulation, we validate the analysis.

Keywords:

FFR, OFDMA, Sectoring, Multi Cell

1. INTRODUCTION

In cellular systems, intra-cell and inter-cell interferences are a serious performance degrading problems due to the use of the same channel in multiple cells. To provide high data rate in cellular systems, (OFDMA) is a promising technique for downlink transmission in the next generation mobile communication systems [1][2]. Each sub-carrier bandwidth is smaller than system coherence bandwidth in OFDM, therefore the effect of inter-symbol interference (lSI) is reduced. Due to the orthogonality among sub-carriers, it mitigates the effect of sub-carrier interference (SCI) and also intra cell interference. However, inter-cell interference (ICI) or co-channel interference (CCI) is the major bottleneck with OFDMA, particularly for cell edge users. To mitigate this inter-cell interference, the same set of frequencies are not used in neighboring cells. This method leads to decrease the available channels within each cell. So, in order to improve spectrum efficiency, the fractional frequency reuse (FFR) concept is suggested.

In [3], the authors proposed and evaluated interference management FFR mechanism for OFDMA macrocell networks. Based on user throughput and user satisfaction, optimal FFR scheme was proposed. Interference avoidance scheme coupled with power control in multi-cell OFDMA environment was proposed in [4]. In order minimize the effect of inter-cell interference ICI, Adaptive FFR (AFFR) scheme is presented in [5]. They proved that this method improves usage of radio resources, and also provides fair radio resource allocation to Base stations (BSs). Inter-cell interference management scheme based on interference concentration, i.e. ICon was proposed for uplink in [6]. This method outperforms the common ICIC methods in cell edge user and also, it is simple to implement, easily adaptable. According to the traffic loads, the number of major subcarriers and transmit power for each cell can be varied for each cell. This information is shared only with adjacent BSs. So, this method provides decentralization in allocating resources [7]. Dynamic FFR resource allocation was proposed for irregular cell layout in [8].

In [9], authors described the ICIC techniques for multiuser OFDMA networks such as LTE and also compared the various resource allocation schemes such as reuse-1, reuse-3, FFR, and SFR considering uniform and non-uniform UE distributions. This work particularly focused the spectral efficiency and fairness index for comparison. From [3]-[9], authors considered the resource allocation in terms of subcarriers. In order to allocate subcarrier by subcarrier, complexity requirement is high. In order to reduce complexity, using correlation property of adjacent subcarriers in OFDM, the adjacent subcarriers are grouped to form chunk. Resources are allocated as Chunk instead of subcarrier by subcarrier.

In [10], the authors presented simplified chunk based algorithms for resource allocation for distributed antenna system. In [12], chunk is allocated according to Bit Error Rate (BER) constraint and also, adaptive modulation is adopted according to the channel condition to guarantee the average BER constraint within a chunk. In [13], in addition with chunk allocation joint power and bit allocation are considered according to the BER constraint. In [14], in order to reduce Peak to Average Power Ratio (PAPR), equal power is allocated to all subcarriers within chunk. In [10]-[14], the authors analysed the performance in single cell environment. In [15], the performance of FFR scheme with chunk allocation was considered in multi cell environment. The authors proved that the spectral efficiency performance is better at the optimal radius ratio of 0.7 i.e. the inner cell radius to the whole cell radius.

In order improve the spectral efficiency further; sectoring may be used in conjunction FFR chunk resource allocation method. In order to utilize the maximum bandwidth and reduced overall call blocking probability, sectoring concept was considered. The main contribution of the paper is to embed the sectoring in addition to FFR chunk allocation. Numerical result shows that the optimal radius ratio is achieved at 0.6 instead of 0.7 when only FFR with Chunk allocation was considered in [15] and also, improvement in spectral efficiency is achieved.

The paper is organized as follows. The systems model describes in section 2. Simulation result describes in section 3. Section 4 concludes the paper.

2. SYSTEM MODEL

Consider the multi cell OFDMA system with 19 cells. As [15], the two tier interference with two layer model is considered. FFR resource allocation scheme with sectoring is proposed in this paper. First whole available bandwidth is divided into 4 frequency bands such as f_1, f_2, f_3 and f_4 as shown in Fig.1.

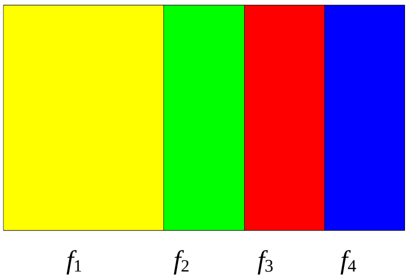

Fig.1. Frequency Band Separation

In FFR, users in each cell are classified into the inner cell area users and the outer cell area users according to their location. Frequency band f_1 is allocated to the all the inner cell area users and remaining three frequency bands are allocated to the outer cell area users of adjacent base stations. So, the frequency reuse factor is one for the inner cell area users and 1/3 for the outer cell area users. Through this resource allocation scheme, the spectral efficiency improvement as well as the outer most cell user's performance can be improved.

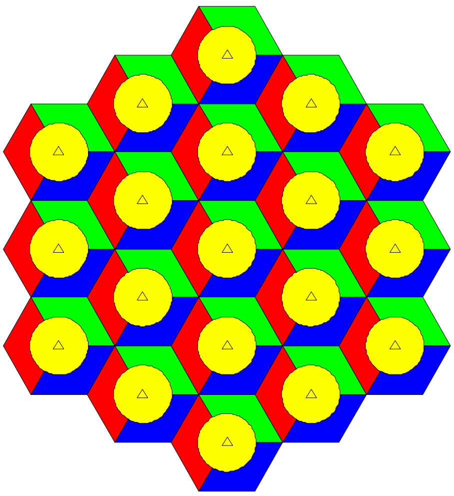

Fig.2. Two Tier Multi Cell with FFR Sectoring Resource Scheme Allocation

In sectoring with FFR, f_1 is allocated to all the inner cell area users. But, remaining three frequency bands are also allocated to all the outer cell users according to 120 degree sectoring. Frequency band f_2 is allocated to the users lies in the outer cell area users within 0 to 120 degree. Frequency band f_3 is allocated to the users lies in the outer cell area users between 120 to 240 degree and the frequency band f_4 is allocated to the users lies in the outer cell area users within 240 to 360 degree, as shown in Fig.2. Users in the inner cell area receive interference from all the base stations. But, the users in the outer cell area receive the interference from only the base station which radiates the power in the same direction. So, this method improves still the spectral efficiency and the outer most user performance. The center of the cell in this cellular layout is assumed as the reference cell.

In OFDMA system, Rayleigh fading is assumed for each sub channel between any base station and the user of reference cell. Moreover, noise is an Additive White Gaussian Noise (AWGN) with double sided power spectral density of $N_0/2$. The frequency response, $g_{k,n,l}$ of the l^{th} sub channel between the base station (BS) k, and the n^{th} user can be defined by the combination of path loss, fading, and phase. It is given by

$$g_{k,n,l} = d_{k,n}^{-\alpha/2} \cdot h_{k,n,l} \cdot e^{j\psi_{k,n,l}} \tag{1}$$

where α is the pathloss exponent, $h_{k,n,l}$ is the magnitude of the channel fading of l^{th} sub channel between BS_k and n^{th} user, and is independent identically Rayleigh distributed with unitary mean square, $E(h^2_{k,n,l})$, for all k,n. $\psi_{k,n,l}$ is the channel phase and is assumed to be uniformly distributed.

Using correlation among adjacent subcarriers, consecutive L_1 sub channels are grouped together to form chunk in the chunk-based resource allocation. The channel fading of the chunk is defined by the average channel fading of all sub channels within the chunk, and is given by,

$$\hat{h}_{k,n,l} = \left(\frac{\hat{g}_{k,n,q} \cdot \hat{g}^H_{k,n,q}}{L_1} \right)^{1/2} \tag{2}$$

where, $(\cdot)^H$ stands for the Hermitian conjugate and $\hat{g}_{k,n,q}$ represents q^{th} chunk of n^{th} user in the k^{th} cell.

A constant transmit power is allocated to all the subcarriers within a chunk to avoid large peak to average power ratio in practical OFDMA systems, [14]. The transmit chunk-power per subcarrier for the inner cell area is denoted as P_i, and that for the outer cell area is denoted as P_0. If the q^{th} chunk is allocated to the n^{th} user in the reference cell, the power of the received desired signal is given from [15],

$$P_{S_n} = \begin{cases} P_i \cdot \hat{h}^H_{1,n,q} \cdot x_n^{-\alpha} & \text{inner cell area} \\ P_0 \cdot \hat{h}^H_{1,n,q} \cdot x_n^{-\alpha} & \text{outer cell area} \end{cases} \tag{3}$$

where x_n is the distance between BS_1 and n^{th} user.

From Fig.2, if the q^{th} chunk is allocated to the inner cell area of the reference cell, the same chunk is allocated to inner cell area of all base stations. If the q^{th} chunk is allocated to the outer cell area of the reference cell, according to the color the same chunk is allocated to the corresponding areas. Through the base stations coordination, this chunk allocation information is shared among all the base stations.

Since all the users in the cell receive interference from more than six base stations, the total co-channel interference from other base stations can be approximated as a Gaussian random variable, [15]. The variance of the total received co-channel interference component is given by,

$$\eta^2_{I_n} = \begin{cases} \sum_{i=1}^{18} P_i \cdot d_{i,n}^{-\alpha} & \text{inner cell area} \\ \sum_{i \in I} P_0 \cdot d_{i,n}^{-\alpha} & \text{outer cell area} \end{cases} \tag{4}$$

where $d_{i,n}$ is the distance between the n^{th} user and i^{th} interfering base station.

The chunk allocation is not a fixed one. Irrespective of the user position, considering fairness among the user the chunk is allocated to the user. Therefore, the instantaneous SINR, $\gamma_{n,q}(x_n,\theta_n)$, can be given as,

$$\gamma_{n,q}\left(x_n,\theta_n\right)=\frac{P_{S_n}}{\eta_{I_n}^2+\eta^2} \quad (5)$$

where η^2 is the variance of the noise component at the output of the receiver, which is same for all the users. From the SINR calculation, the average spectral efficiency and coverage probability are found through simulation.

3. SIMULATION RESULTS AND DISCUSSION

In this section, the performance of the multi cell OFDMA system with FFR sectoring for the average spectral efficiency and coverage probability are analyzed using MATLAB and also compared with FFR without sectoring. The simulation parameters are tabulated in the Table.1.

Table.1. Simulation Parameters [26]

Parameters	Value
Bandwidth	100MHz
Number of subcarriers	1024
Subcarrier spacing (Δf)	100MHz/1024=97.7KHz
BER Constraint (β_0)	10^{-3}
Coherence bandwidth	$5\cdot\Delta f$

The channels fading between all the users and the base station for each subcarrier are normalized. Rayleigh fading distribution assumption is used and it is having unitary mean square as illustrated in system model. As described in Table.1, the coherence bandwidth, f_C, five times of Δf, i.e.488.5KHz. The transmit power in the inner cell area and outer cell area are assumed as same, i.e. $P_i = P_0$.

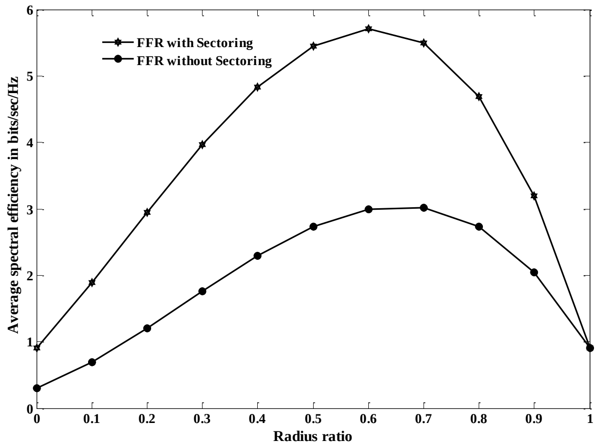

Fig.3. Average Spectral Efficiency Comparison of FFR Resource Allocation with and without sectoring

The Fig.3 shows the comparison of FFR resource allocation with and without introducing sectoring concept. As expected, the average spectral efficiency performance is better with sectoring than without sectroing. Since all the available frequency bands are used in all the cells, the spectral efficiency is better in FFR with sectoring. At the same time the edge user performance is better in FFR with sectoring. As [15], the average spectral efficiency performance is compared with respect to the radius ratio between the inner cell radius to the whole cell area. Radius ratio increase the average spectral efficiency also starts increases as in [11]. After the particular point, the average spectral efficiency starts decreasing. That point is called as the optimal point. The optimal radius ratio acheived in the proposed scheme is 0.6. but in FFR without including sectoring is 0.7. Also the tremendous improvement in the average spectral efficiency is observed in proposed scheme than without including sectoring. This occurs due to the efficienct utilization of all the available frequency bands in all the cells. The Fig.4 shows the coverage probability comparison between FFR with and without including sectoring methods. The coverage probability with sectoring is inline with without including sectoring.

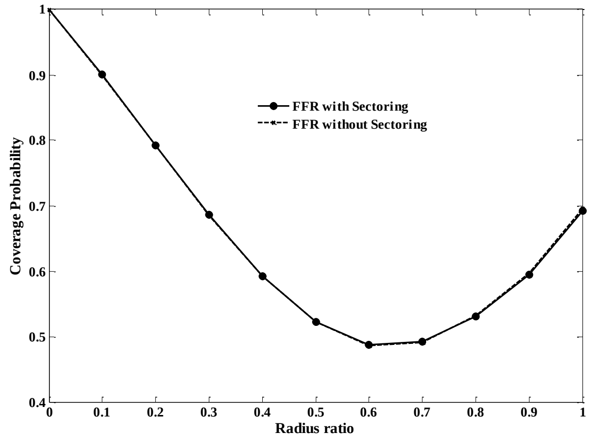

Fig.4. Coverage Probability Comparison of FFR Resource Allocation with and without sectoring

4. CONCLUSION

In this paper, in addition with FFR resource allocation the sectoring has proposed in the multi-cell OFDMA environment still to improve the spectral efficiency performance. The proposed method has also implemented with chunk-based resource allocation. The average spectral efficiency and coverage probability performance analysis have illustrated for this proposed method and also compared with existing FFR resource allocation scheme. The optimal radius ratio of the inner cell area to the whole cell area is around 0.6 in this proposed method instead around 0.7 in existing. Through the simulation result, it is confirmed that the proposed resource allocation performance is better than FFR based resource allocation alone, when the spectral efficiency is considered. Coverage probability performance for these schemes is same. The average spectral efficiency performance achieved for this proposed method at the optimal radius ratio was 5.71bits/sec/Hz. But, in exiting resource allocation without including sectoring with FFR, it was 3.02 bits/sec/Hz. But the performance gain is achieved at the additional complexity of providing three antennas instead of Omni directional antenna.

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