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Improved Channel Capacity and Interference Reduction in ML-SFR for Wireless Communication Systems

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***Abstract* - In this paper a new method using Particle Swarm Optimization (PSO) has been proposed to reduce the Inter Cell Interference. We formulated the work using the model presented in the base paper. Then we investigated the cell edge spectrum efficiency and Inter Cell Interference in the ML-SFR. After investigation we searched for the different algorithms to reduce the interference and increase the channel capacity. After that we proposed a Swarm Intelligence based Inter Cell Interference reduction algorithm. This has optimized the power of each cell with the adaptive resource allocation technique, which was the limitation of base paper and also this algorithm is adaptive with network traffic and path loss model. MATLAB has been used for the simulation of cell edge spectral efficiency and interference. The results have shown that the cell edge spectrum efficiency is increased by 23% of that ML-SFR.**

***Index terms* - ML-SFR, PSO, ICI, OFDM**

I. INTRODUCTION

To deal with the increased users endorsement of the new wireless communication services, the Third Generation Partnership Project (3GPP) has presented the Carrier Aggregation (CA) concept as one of the Long Term Evolution-Advanced (LTE-A) features in order to fulfill the 5th Generation (5G) requirements. The CA technology permits the aggregation of multiple LTE-supported carriers, known as component carriers, to form a greater carrier. This aggregation should be in a backward compatible way such that both LTE-A a capable user equipment (UE) and legacy LTE release 8 UE are served simultaneously.

One of the restraining factors that disturb the performance of the cellular LTE orthogonal frequency division multiplexing (OFDM) system is the inter-cell interference (ICI) between users in different cells being assisted in the same physical resource block. Although the aggressive spectrum reuse achieves the highest system capacity, it causes the largest degradation in signal-to-interference-plus-noise ratio (SINR) due to ICI, especially at the cell edge. This causes the difference to widen between the performance of cell-center and cell-edge users. Several interference management solutions are made to improve the cell edge throughput including the frequency reuse concept which reduces the interference levels significantly at the expense of the reduction in the available bandwidth. To strike a balance between the need of a high system throughput and sufficient cell edge spectral efficiency, the concept of soft frequency reuse (SFR) is presented. Using this concept, some of the available physical resource blocks are assigned to the cell-center users, whereas the rest are divided between the edge users of the adjacent cells. An ML-SFR scheme is introduced in that divides the resources between the cell-center and the cell-edge region not only by frequency sub-bands but into multi-level power density. The performance of SFR in communication networks under different load and power setups will be discussed in. In the presence of multiple carriers and users with different capabilities, CA deployed as a capacity-boosting.

Orthogonal frequency division multiplexing (OFDM) is a popular multi-carrier modulation scheme. It provides exemption to intersymbol interference and frequency selective fading by separating the frequency band into a group of mutually orthogonal subcarriers, each having a much lesser bandwidth than the coherence bandwidth of the channel. In a multi-user environment, multiple access of OFDM can be achieved by employing Time Division Multiple Access (OFDM-TDMA) or Code Division Multiple Access (OFDM-CDMA). Orthogonal Frequency Division Multiplexing (OFDM) is introduced as one of solutions to enable bandwidth efficiency and robustness due to intersymbol interference (ISI) in the consequence of multipath fading environment. The principle of OFDM is dividing high rate data stream into parallel low rate data streams using Fast Fourier Transform (FFT).OFDM is combined by modulation with more bits per symbol to increase data transmission throughput. OFDM is multiplexing scheme which divide data stream became more narrowband data channel to share the bandwidth available. Narrowband channel is called subcarrier which transmit phase or amplitude modulated data signal. Different with Frequency Division Multiplexing (FDM), OFDM have subcarrier that orthogonally. This orthogonally can reduce interference between subcarrier and increase spectrum efficiency utilization. OFDM receiver requires frequency synchronization to combat Inter-Carrier Interference (ICI).This interference occurs caused by Doppler shift due the mobile device movement and multipath channel. Frequency reuse has become one of most important enablers for wireless system especially based on the orthogonal frequency division multiplexing (OFDM), to achieve high data-rate communications. In frequency reuse, a power density upper limit (PDL) curve is defined for each cell. The actual power density of the transmitted signal should be lower than the PDL. Frequency reuse is an important concept of cellular communication system which allows the user in different geographical area to use the same frequency band. By reusing the frequency bands over and over again a cellular network provider can serve a large number of users simultaneously, therefore increasing the capacity of the system. While reusing the frequency, proper planning is required to overcome the effect of interference which is caused due to same frequency used in neighboring cells. SFR given bandwidth is divided in three parts, higher power density level frequency band, that is also called primary band which is used at cell edge and other two bands with low power density level are called secondary bands. At the cell centre whole available bandwidth is used and at cell edge high power density frequency bands are used. As primary bands are orthogonal to each other so interference at cell edge is minimum that will increase the overall throughput of system. In SFR γ which is the ratio of PDLs of secondary to primary band, is an important factor.

$$\gamma = \frac{PDL\ of\ secondary\ band}{PDL\ of\ primary\ band}$$

It can be seen that when we increase the γ it will decrease the capacity of the cell edge user and increase the capacity of cell center user and vice versa.

In the multi-level frequency reuse, it also defines a network-level framework for resource allocation in each cell. Generally, a UE can be assigned the resources in the frequency band that covers it. However, allocating resources is suggested to user equipment in the bands with the possible smallest coverage to optimize the system performances. First of all, a coverage area is determined for each of the frequency bands according to their PDLs. The relationship between the PDL and coverage is an implementation problem which operators would optimize based on the realistic scenarios.

II. LITERATUREREVIEW

In this paper, Philippe Godlewski, et al.[1] proposed the FFR and TLPC schemes with appropriate settings of inner region radius and power ratio provide the best performance when a scheduler fair in throughput is assumed. Syed Hussain Ali, et al. [2] proposed small to mediumcell and large grid sizes, the proposed scheme outperforms the traditional schemes. In this paper, the notion of difference-set with sectorization technique has been presented by AbdelhalimNajjar [3]. The FFR of 3/7, 4/7 and 2/3 have been applied and considered as a powerful technique to enhance the channel quality in the cell edge. In this paper, Mustafa M. M et al. [4] proposed the Reuse 3 scheme increases substantially user cell-edge performance, and is more immune to the increase of system loading when compared to a reuse 1 scheme. In this paper, A.K.M Fazlul Haque1 et al. [5] proposed the performances of frequency reuse schemes in mobile cellular environment have been simulated and evaluated. In this paper, Martin Taranetz et al. [6] proposed the compared to a conventional Reuse-1 scheme; simulation results show significant improvements in terms of average- and peak performance, while achieving a cell-edge performance comparable to a conventional Reuse-3 scheme. In this paper, Lei Chen et al. [7] proposed the For highly interference-sensitive cell edge zones, interference is minimized by sub-band isolation or power reduction, whereas for the other cell-edge zones more bandwidth is allocated if this leads to better performance. In this paper, ZhengXie et al. [8] proposed an enhanced frequency reuse scheme, the EFFR scheme, for ICI mitigation in OFDMA networks is developed and evaluated and obtained results show that significant cell capacity gains and increases at cell edge can be achieved with the deployment of the proposed EFFR scheme. In this paper, Chandra Thapa et al. [9] proposed the FFR provide better probability of coverage and probability of acceptance rate than Traditional frequency reuse 1 and reuse. In this paper, Xuezhi Yang et al. [10] proposed the ML-SFR methodology can achieve better interference pattern than SFR-2, further improving the cell edge and overall data rate. It can be used in the current LTE system and would be a candidate key technology for future 5G systems. Lei, Haipeng [12] In this paper, a novel frequency reuse scheme has been presented for multi-cell orthogonal frequency division multiplexing access (OFDMA) systems for co-channel interference reduction. Simulation results show that this scheme can bring higher system throughput and lower CCI, and it also can increase the data rate at the cell edge. Interference aware scheduling has been presented by Doppler, Klaus et al. [13]. This scheduling scheme is used for soft frequency reuse. In this paper M. Bohge [14] investigates the performance of different power mask configurations against the optimal case, in which a central entity optimally distributes power and resource blocks among the users of the network. Bin. Fan et al.[15] present a dynamic resource allocation algorithm, termed Dynamic Major group Allocation (DMA), based on Soft Frequency Reuse (SFR) which is an efficient method to mitigate inter-cell interference (ICI) in Orthogonal Frequency Division Multiple Access (OFDMA) systems.Simulation results demonstrate that the proposed DMA algorithm carries superior throughput performance of CEU over the traditional two-level resource allocation scheme (TLA) which simply combines SFR with PF.

III. METHODOLOGY

ML-SFR Algorithm

1) Start Design of ML-SFR.
2) Consider a cellular system contains 13 cells with the radius r. In this, ML-SFR scheme can be used the primary band of the Cell 0 which has also primary band of the Cell 7-12, and secondary band of Cell 1-6.

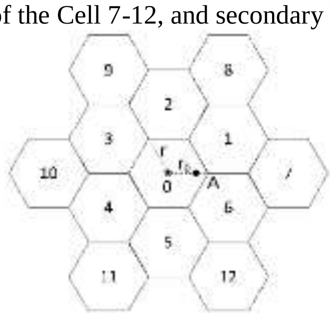

Fig 1. Cellular system including 13 cells

3) A UE is located in Cell 0 and their place is restricted on straight line between base station and point A, intersection of Cell is 0,1, and 6. So, represent distance between UE and base station as

$$r_0 = \beta_0 r, \quad \text{where } \beta_0 \text{ is coefficient within } (0,1]$$

4) Consider the SFR-2 scheme in downlink and assume p_n is the transmit power density of base station of the Cell n, which is expressed by

$$p_n = k_n N_0, \quad n = 0,1,\ldots\ldots\ldots,12,$$

There, N_0 can be the power density of the white noise in UE receiver. Suppose bandwidth is B.

Let N_0 = -169 dBm/Hz, p_0= 50/20 dBm/MHz,

5) Consider power of noise in UE receiver is

$$\sigma_A^2 = N_0 B,$$

6) Consider the distance between base station of the Cell n and UE as d_n and L(d) the path loss model, then received power of UE from serving cell is

$$\sigma_B^2 = \frac{p_0 B}{L(d_0)} \sigma_Z^2,$$

Where $L(d) = 128.1 + 37.6 \log_{10}(d)$

7) Interference power from the other cells is

$$\sigma_C^2 = \sum_{n=1}^{12} \frac{p_n B}{L(d_n)} = \sum_{n=1}^{12} \frac{k_n}{L(d_n)} \sigma_A^2,$$

8) Let $k_n = \gamma k_0$, $n = 1,2,\ldots.6$, $k_n = k_0$ $n = 7,8,\ldots\ldots,12$

Where $\gamma = \frac{\text{PDL of secondary band}}{\text{PDL of primary band}}$

It means transmit power of all the primary bands is p_0B, and all the secondary bands is γp_0B, then

$$\sigma_C^2 = \left[\gamma \sum_{n=1}^{6} \frac{k_0}{L(d_n)} + \sum_{n=7}^{12} \frac{k_0}{L(d_n)}\right] \sigma_A^2, [10]$$

SWARM OPTIMIZATION

9) Define Parameters.
10) maximum iteration *(T*max*)* = 40 where t =1, 2, . . . , Tmax;
11) swarm size *(N)* = 50 where i = 1, 2, 3, . . . , N;
12) initial velocity $vi,d(0)$ = 0;
13) initial position $xi,d(0) = Pf \sim 2+U[0, 1]$;
14) inertial weight w= 0.01;
15) initial personal best position *p*Best *i,d= xi,d*;
16) acceleration constant c1=c2=0.7
17) Calculate *p*Best.
18) Calculate *g*Best.

For each iteration, the following parameters are evaluated:

19) $v_i(t) = w * v_i(t) + c_1 * r_1 * (pbest_i(t) - p_0) + c_2 * r_2(gbest(t) - p_0)$
20) $p_0 = p_0 + v_i(t)$
21) $k_0 = \frac{gBest}{N_0},$
22) Calculate optimized interference power

$$\sigma_P^2 = \left[\gamma \sum_{n=1}^{6} \frac{k_0}{L(d_n)} + \sum_{n=7}^{12} \frac{k_0}{L(d_n)}\right] \sigma_A^2,$$

23) Considering the intra-cell interference which is efficiently eliminated in OFDM systems, according to the Shannon's law of the channel capacity, the increased spectrum efficiency can be expressed as

$$\eta(\gamma, \beta_0) = \mathrm{B} \log_2\left(1 + \frac{\sigma_B^2}{\sigma_P^2 + \sigma_A^2}\right),$$

This is a function of γ and β_0.

24) Plot the variation of spectral efficiency as a function of γ.
25) Plot the variation of spectral efficiency as a function of β_0.
26) END

IV. RESULTS

The results for the experiment are as shown further. The graphs show the channel capacity with respect to the distance parameter and gain. The red color line shows the base model and blue color line shows the proposed model.

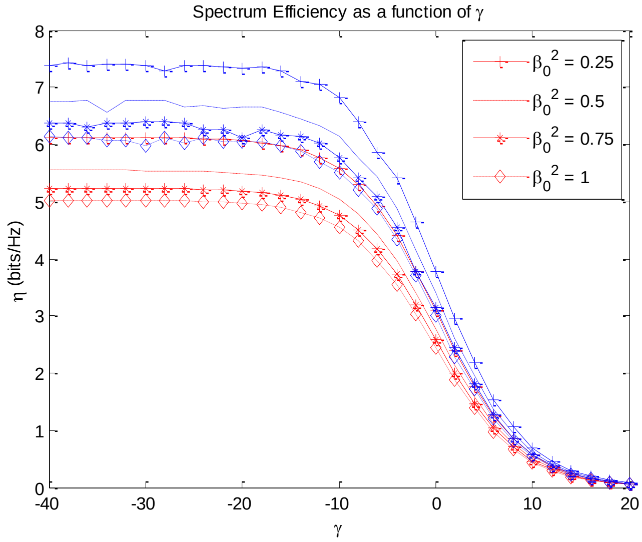

Fig 2. Spectrum efficiency as a function of gamma (γ)

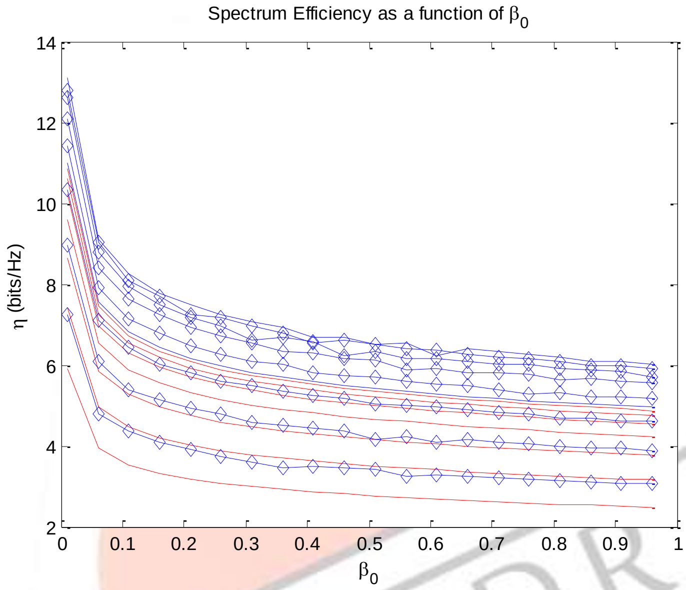

Fig 3. Spectrum efficiency as a function of beta (βo)

The cell edge spectral efficiency as in the SFR-8 base method is found to be 2.475 dBm/Hz and for that of the proposed method, it is 3.057 which is a 23% improvement from the base method.

V. CONCLUSION

In this work, a new method for optimizing the Inter Cell Interference (ICI) to increase the channel capacity of the system or the throughput has been proposed. The proposed algorithm has higher channel capacity than the previous method without optimized inter Cell interference. This is because the proposed algorithm optimizes the loads into consideration when allocating resources to different cells and maximizes system throughput by reducing the effective interference. However, in SFR, the subcarrier and power allocation in each cell is pre-determined beforehand and not adapted to the changes in network traffic. This is because the proposed algorithm effectively reduces ICI by dynamically adjusting the major and minor subcarriers' transmit power in each cell while in SFR-8 both inner and outer cell users experience the highest interference from adjacent cells. The results shown that the cell edge user performance of the two schemes. The proposed algorithm guarantees cell edge user data rate requirement when allocating resources. It adjusts the number of major subcarriers and transmit power according to cell edge data rate requirements. However in other scheme, the resource allocated to each cell region is predefined. When the cell edge traffic load is high the achieved system throughput in each iteration of the proposed algorithm for each cell region may not be enough to serve all its users which will lead to the outage of cell edge users. Therefore, the proposed can be a better option in order to reduce the ICI.

The future work may involve the reduction in the complexity of the system. This is because the current system based on PSO may be a bit complex in terms of implementation because of the algorithm's iterative structure. Hence, a further research can be to reduce the complexity and improve the timing performance of the algorithm.

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