Interference Mitigation Optimal Dynamic Fractional Frequency Reuse (OD-FFR) Scheme in LTE Networks

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ABSTRACT
Fractional Frequency Reuse is an interference mitigation technique well suited for OFDMA system where the cell region is partitioned into two: inner cell region and outer cell region. In this paper we proposed an interference mitigation technique in LTE OFDMA femtocell system using Fractional Frequency Reuse (FFR) also system in order to improve performance of the system resource allocation is used. Using FFR scheme, femtocells chooses the sub-bands under the macrocell allotted frequency band that are not used in the macrocell sub-region to avoid interference. System simulation are done to evaluate and compare the effects of changing inner cell shape and selects the optimal size as well as optimal frequency allocation between inner and outer regions with key target to maximize throughput and user satisfaction. Simulation results show that the proposed scheme enhances the throughput especially for cell edge users.

Keywords
OD-FFR, 3GPP, 4G, HetNets, femtocells, OFDM, OFDMA, FFR

1. INTRODUCTION
Heterogeneous Networks (HetNets) within the 3rd Generation Partnership Project (3GPP) are measured to increase demand for data traffic and bandwidth. Heterogeneity and network densification comprises of a macro base station in the first tier and small, low range, low power base stations like femtocells in the second tier [1], [2]. HetNets are expected to become foundation stone for 4G cellular mobile networks aimed to achieve significantly improved indoor coverage, higher data rate services and maximum spatial reuse [3]. Due to the small coverage area, same license band of frequency is efficiently reused multiple times within the second tier resulting in improved indoor network coverage, high data rates, quality of service (QoS) and spectral efficiency per unit area of the cellular network in cost effective manner [4]. Femtocell is a base station (BS) with low transmission power with direct high-speed internet connection. Its key purpose is to cover small isolated areas with inadequate macrocell coverage, providing an access point to users at home or small office that can be benefited from high signal to interference ratio due to the closeness of the femtocell BS [5], [6].

Also the budding demands on cellular communication networks to support data applications at higher throughputs and spectral efficiencies has motivated to develop Orthogonal Frequency Division Multiplexing (OFDM) based 4th generation (4G) networks, together with WiMAX and 3GPP Long Term Evolution (LTE). The main objective regarding deployment of OFDM 4G networks is to utilize Fractional Frequency Reuse Technique (FFR) as an interference mitigation technique. Due to transmit power limitations in 2G and 3G cellular mobile terminals, a requirement to achieve higher data rate throughputs for users not only near the base station, but also for cell edge users, a higher value of frequency reuse technique is used in 4G cellular networks [7]. The cellular spectral efficiency is restricted due to the cell edge user interference, thus cell-edge user throughputs suffers the most. Mitigating cell edge interference is thus a immense challenge to improve throughput performance, especially at cell edge. Fractional frequency reuse (FFR) an interference mitigation technique used in OFDMA based cellular networks where the cells are partitioned into regions with different frequency reuse factors, frequency Reuse of 1 at the centre of cell and a higher frequency reuse of N in the outer or cell edge [8], [9]. To reduce intercell interference in macrocell system, especially for the cell edge users, FFR is one of the solutions [10], [11]. The key feature of a cellular system to increase network capacity and coverage is the ability to reuse frequencies. Optimal Static Fractional Frequency (OSFFR) scheme have been discussed to maximize total network throughput and interference mitigation in OFDMA based femtocell system in [12]. Here the cell region is partitioned statically into, the inner and outer regions also division of spectrum statically into different geographical regions. The proposed mechanism experiential that the networks total throughput is increased if the radius of the central cell is increased to half of the total cell radius and three-fourth of the frequency resources are allocated to the central region.

Moreover to increase User Satisfaction metric, Optimal Fractional Frequency Reuse (Optimal-FFR) schemes is discussed in [13]. Here the frequency and resources are allocated dynamically.

This paper proposes an Optimal Dynamic Fractional Frequency Reuse (OD-FFR) technique for OFDMA based cellular networks. The proposed scheme is calculated through the mechanism based on two parameters, user throughput (UT) and user satisfaction (US). For each iteration, this technique checks the inner cell frequency and the inner cell radius. Thus throughout this mechanism the optimal FFR scheme is selected that is used to increase either the cell mean user throughput or user satisfaction.

2. SYSTEM MODEL
The total spectrum of LTE network of 10MHz, for interference mitigation is partitioned FFR scheme into two major regions: inner region using frequency reuse of 1 and outer cell region into six sectors with a frequency reuse of N. As a result of this the co-channel interference is reduced and the channel or the system capacity increases.

In this section a theoretical approach to calculate signal to noise ratio (SNR), throughput and user satisfaction are discussed. SNR for a typical OFDMA cellular network for a user x who is served by a base station b on n subcarrier is given by equation [14].

$$SNR_x = \frac{P_b h_{bx} G_{bx}}{\sigma^2 + \sum_{Z \in \mathcal{Z}} P_z P_{zx} G_{zx}} \qquad \text{(i)}$$

In (i) G_{bx} is the pathloss associated with the channel between the base station b and the user *x*, P_b is the transmitted power of base station, h_{bx} is the exponentially distributed channel fading power and σ^2 is the noise power. Set Z represents all interfering base station that are using same subbands as user x.

Throughput of user x is expressed as

$$\mathrm{T}_x = \sum \beta_x C_x \qquad \text{(ii)}$$

Where

$$\beta_x = \begin{cases} 1 & \textit{when subcarrier is assigned to the user x.} \\ 0 & \textit{otherwise} \end{cases}$$

and

$$C_x = \Delta f * \log_2(1 + SNR) \qquad \text{(iii)}$$

in (ii) represents the subcarrier assigned to the user x, C_x represents the capacity user x and Δf in (iii) represents the available bandwidth for each subcarrier divided by the number of users that shares the particular subcarrier.

User satisfaction is based on the subcarrier allocation at the cell regions and is given by:

$$US = \frac{\sum_{i=1}^{X} T_x}{max.user\ throughput * X} \qquad \text{(iv)}$$

Where X represent total number of users.

A. Cell Partitioning and Resource Allocation

Optimal Dynamic FFR (OD-FFR) scheme is proposed to maximize the total network throughput and user satisfaction (US) at least amount of data rate requirement for the users in the HeNBs. Here the total macrocell coverage area is divided into, the central region with a frequency reuse of 1 and the outer cell edge region consisting of six sectors where, subband A is assigned to the central region and subbands (B, C, D, E, F and G) are assigned to remaining six subbands, as shown in fig 1.

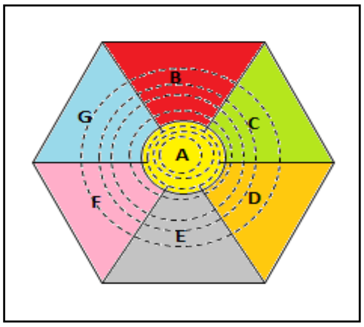

Fig 1: Optimal Dynamic FFR scheme

Here a band of 10 MHz utilized by OFDMA based LTE system is divided into 25 resource blocks (RBs), where a set of 12 subcarriers constitute of one RB. OD-FFR scheme an interference mitigation technique is used to fully utilize the available bandwidth and to divide time and frequency resources several resource sets where each resource set is assigned with a certain frequency. At the initial stage the complete 25 subcarriers are assigned to the inner part of the cell and no subcarrier are assigned to the outer part of the cell or cell edge. During every iteration the subcarrier allocated at inner part of the cell is reduced and finally becomes 0 at the end of the iteration. Consecutively the subcarrier allocation is increased for cell edge users at each iteration. Thus the outer part of the cell is assigned with complete 25 subcarriers. For every frequency allocation, the proposed scheme calculates per user and then cell total throughput for each successive inner cell radius dynamically as shown in fig 1. The process is repeated periodically for every inner region radius and out of these selects the FFR scheme that maximizes throughput. This periodic procedure is known as adaption.

3. SIMULATION RESULTS

Since we examine an LTE-based cellular system for all the performance requirements, and system simulation parameters like BS transmit power, Cell radius and Power Noise Density according to 3GPP specifications [15]. In detail, LTE system with 10MHz is considered, here 2000MHz frequency is set for the macrocell base-station. And we calculate the path loss according to Hata Costa Model. Simulation is performed on the bases of two parameters i.e with and without adaption process.

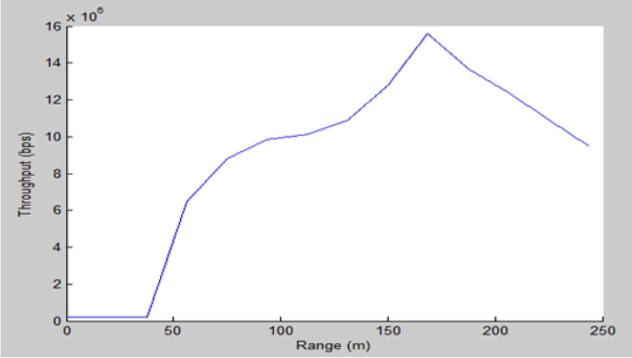

Fig 2: Throughput at points starting from cell centre to cell extreme when optimized using optimal throughput.

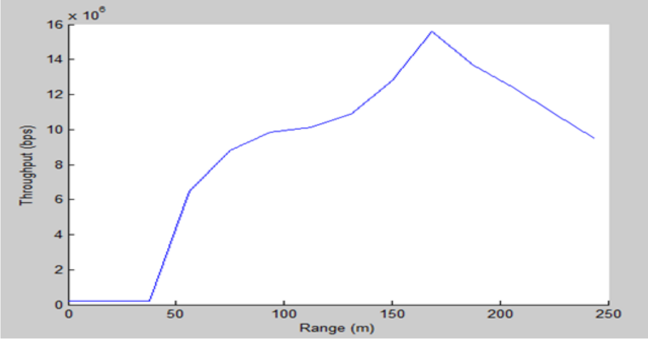

Fig 3: Throughput at points starting from cell centre to cell extreme when optimized using optimal User Satisfaction.

In both fig 2 and fig 3 throughput is calculated once by optimizing throughput and other by optimizing user satisfaction. In both figures initially when the radius of the inner cell is less than 50m, as the number of users are less so the throughput is approximately zero. As the inner cell radius goes on increasing also the number of users in the cell increases, throughput increases rapidly. When the inner cell radius is around 165m throughput attains its maximum value and after that with the increase in the radius the throughput goes on decreasing.

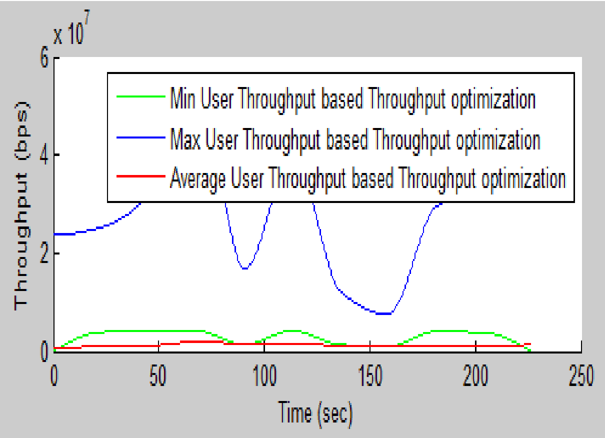

Fig 4: Throughput at cell center over time when the system is optimized using -min, max and average user based throughput

Fig 4 depicts that throughput is optimized using min, max and average user based throughput and results in better throughput optimization when average user throughput is considered.

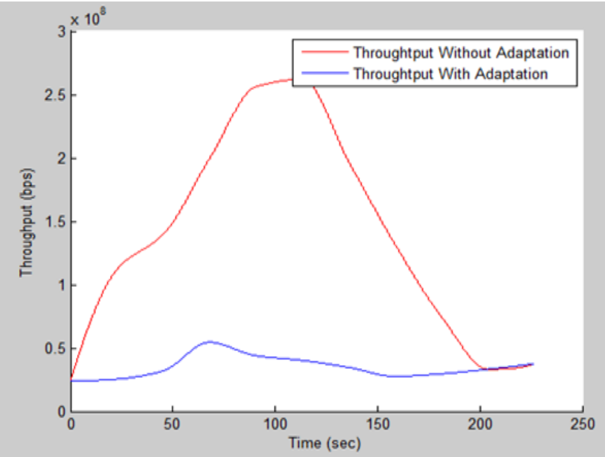

Fig 5: Throughput at cell center over time when optimized using optimal throughput.

Fig 5 shows the throughput graph for with and without adaption process when throughput is optimized and it is observed that, initially for both cases throughput is 0.3×10^8(bps) but as the time increases throughput increases to max value of 2.6×10^8(bps) for without adaption case and is very high as compared to other.

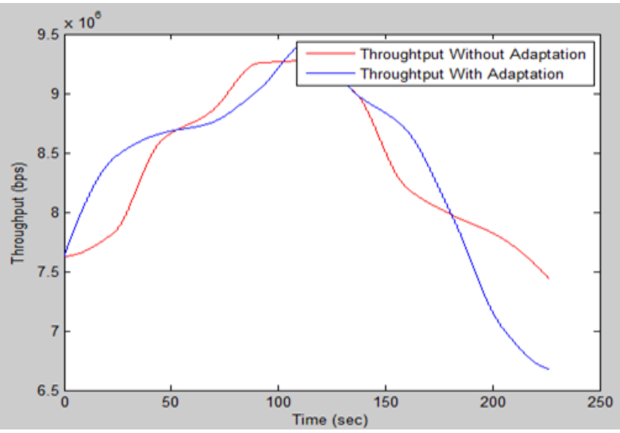

Fig 6: Throughput at cell center over time when optimized using optimal US

Fig 6 shows the throughput graph for with and without adaption case when US is optimized. Initially the throughput is high for both the cases and is 7×10^8(bps). With the increase in time at 80sec the throughput is maximum of 9.2×10^8(bps) attains constant value for 140sec and then the value of throughput goes on decreasing. Whereas for without adaption process the throughput increases and attains a maximum value of 9.45×10^8(bps) at 120sec and after that the value of throughput goes on decreasing.

Comparing fig 5 and fig 6 it is observed that optimizing US results in high throughput.

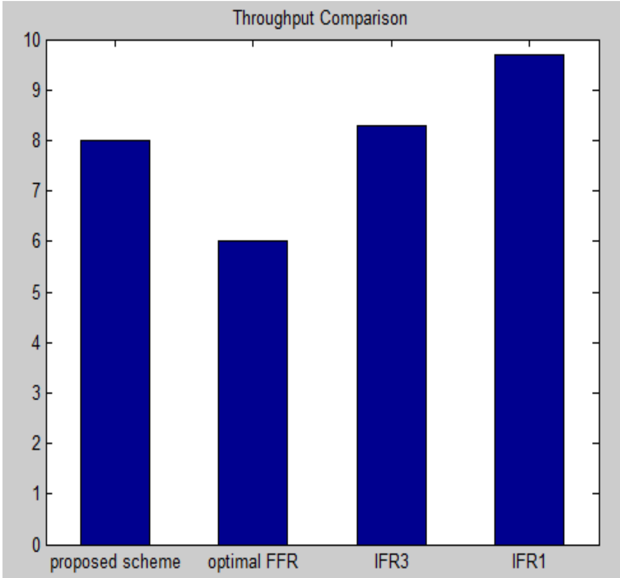

Fig 10: Per-user throughput for different schemes.

Table1: Throughput with adaption for the proposed and optimal FFR scheme

Range (in m)	Optimal FFR (Mbps)	Proposed Scheme(Mbps)
0	0.38	0.1
50	0.38	2
100	0.44	10
150	0.36	13
154	0.35	15.8
200	0.34	13
240	0.24	10

The values in the table clearly show that proposed scheme results in high throughput as compared to the optimal FFR scheme.

4. CONCLUSION

Interference mitigation in OFDMA based LTE system through intelligent resource allocation is a technique to improve overall system capacity. Thus using Optimal Dynamic Fractional Frequency Reuse (OD-FFR) scheme the SNR, per-user capacity, user satisfaction and throughput is calculated after these calculations the mechanisms selects the FFR scheme that maximizes the throughput. During adaption process US, pre-user throughput, cell total throughput are calculated periodically ensuring that each time the selected FFR scheme maximizes the throughput. The result indicates that the adaption process results in enhanced performance as allows inner cell radius and frequency allocation update. Moreover the comparison between optimal FFR, IFR3 schemes with the proposed scheme results in higher value of throughput. The overall observation is that the proposed scheme distributes the available bandwidth between inner and outer cell region in fairer way, ensuring that all users in the cell experience same throughput.

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