Interference Management in Multi-Antenna Lte HetNets

Saroj Dogra¹, Garima Saini²
ME Scholar, Assistant Professor ECE Department NITTTR Chandigarh, Panjab University

Abstract-In modern cellular networks, heterogeneous networks (HetNets) come out as one of the most emerging development to meet out the raising target specifications like high capacity, high performance, power efficient end user devices of Long Term Evolution(LTE) networks. In this paper for such networks Dynamic Fractional Frequency interference mitigation technique along with Radio Resource Distribution (RRD) scheme and widely accepted. Orthogonal Frequency Division Multiple Access (OFDMA) technology is used to increase throughput and user satisfaction of the cellular network. The proposed mechanism divides the cell area into two, the inner and outer area and in addition the outer cell area is further divided into six subbands or sectors, and selects the optimal size as well as optimal frequency distribution between these areas with main target to maximize the user satisfaction metric.

Keywords – LTE, 3GPP, HetNets, FFR, RRD, Cellular Network, OFDMA.

1. INTRODUCTION

Conventional cellular networks can no longer promote the recent, rapidly growing demand for high-speed multimedia applications such as Internet surfing, online Games, voice over Internet protocol (VoIP), video streaming, etc., due to their limited capacity and data rate. This direct the 3rd Generation Partnership Project (3GPP) to construct the Long Term Evolution (LTE) cellular system, to achieve higher data rates and superior capacity to support those multimedia applications [1],[2]. LTE is based on Orthogonal Frequency Division Multiple Access (OFDMA) technology to achieve higher data rates and enhanced spectral efficiency [3]. Here the frequency and time resources are allocated to users in orthogonal manner.

LTE systems need to adopt an extra scalable and flexible approach that is advantageous to both operators and end users, not only to increase the coverage area and network capacity of the cell, but also advances the broadband user experience within the cell cost-effective manner [4]. Therefore 4G wireless networks like LTE adopt hierarchical layering of cells with macro base station in first tier and small powered cells known as femtocells in second tier, thus forming a new communication network model known as heterogeneous networks (HetNets). Due to smaller coverage area same licensed frequency band is efficiently reused many times within the second tier of the HetNet and thus improving network capacity and spectral efficiency.

OFDMA technique significantly helps in overcoming challenges like limited bandwidth, limited power resources and achieving high data transmission rate. Therefore LTE system has widely used OFDMA technique to overcome above challenges. Although, intercell interference can adversely influence OFDMA systems, hence an efficient radio resource distribution (RRD) technique is deployed. OFDMA divides the wideband frequency selective channel into a set of narrow band channels known as sub-bands or sub-channels and these sub-channels are orthogonal to each other [5]. OFDMA multi-carrier nature provides enormous opportunities for dynamic resource allocation strategies, thus allows efficient management of multiuser diversity in the system, great spectrum efficiency and flexible frequency allocation to users [6]. But, in LTE networks the system performance is severely hindered by the Inter-Cell Interference (ICI) and co-channel interference (CCI) due to the frequency reuse. Fractional Frequency Reuse (FFR) is discussed in OFDMA-based femtocell networks to mitigate the CCI and ICI problems [7, 8, 9]. The FFR is one of the solutions to reduce inter-cell interference in macrocell system, especially for the cell edge users [10]. FFR also result in reduction of CCI and ICI to large extent [11].

FFR is an interference mitigation technique where cells are partitioned into regions with different frequency reuse factors [12]. The cell surface is partitioned into two distinct geographical regions in FFR scheme: the inner cell region and outer cell edge area. The outer cell area is further partitioned into a group of N regions and each sub-region is assigned with different frequency sub group, a frequency reuse factor of 1 to the center region and an FRF of N to cell edge area. Thus, a entire number of (N + 1) subgroup is required [13].

Early work on maximizing total network throughput or spectral efficiency of the network and interference mitigation issue for femtocell system have been discussed using optimal static fractional frequency (OSFFR) technique in [14]. The proposed technique observed that the total network throughput is increased if the central cell radius is increased to half of the total macrocell radius and three-fourth of the frequency resources are allocated to the central region. The mechanism overcomes interference.
between macrocell and femtocell by assigning spectrum orthogonally. The HetNets chooses a subband that is not used in the macrocell sub-region and each femtocell uses subbands in arbitrary manner. Like this the intracellular cross-tier interference is reduced to a large extent and also due to sectoring, the intercell cross-tier interference is reduced.

Optimal FFR scheme to increase user satisfaction US metric have been discussed in [15]. The author here consider strict FFR scheme where all the distribution of the Resource Blocks (RBs) can be used everywhere in the cell without any specification of user’s location. For moving users, update of inner cell region radius and frequency distribution is done which leads to lower total throughput but a higher US.

The major goal in this paper is to introduce an interference mitigation, Optimal Dynamic FFR scheme and optimizing the cell edge region fractional reuse factor (FRF), the cell centre region radius, and the distribution of frequency resources in centre and edge region mobile user equipment and better full the goals like high spectral efficiency, better cell edge coverage, high throughput and US.

II. PROPOSED SCHEME

A. Illustration of the Proposed Scheme

To maximize user satisfaction metric (US) and the total network throughput, at least amount of data rate requirement for the users in the presence of heterogeneous networks, an Optimal Dynamic FFR (OD-FFR) scheme is proposed.

In OD-FFR scheme, the macrocell coverage region is divided into two: the central region and the outer cell edge region having six sectors. The inner region is allocated with subband A and the rest of available subchannels are divided into B, C, D, E, F and G (six subbands) and each of these are allocated to each edge zone sectors individually as in figure 1(ii). In this proposed scheme, the central region FRF of 1 and FFR of 6 is applied to the cell edge region as shown in figure1(iii).

B. System Model

OFDMA based LTE system utilizes a 10MHz of bandwidth, in additional which is divided into 25 RB. A group of 12 subcarriers consists of one RB. Therefore a total of 10 MHz frequency is divided into 300 subcarriers each having 30KHz of frequency. Now using the FFR scheme these resource blocks are divided in sectors, but these effects in restricting the maximum throughput available to the users as doing this whole bandwidth is not used. For fully utilization of bandwidth and interference mitigation, an OD-FFR scheme is proposed which divides time and frequency resource among the subcarriers or the resource blocks [16]. The dynamic mechanism selects FFR scheme is based on the comparative throughput of the user in contrast with the throughput of all the users in same cell. The proposed method utilizes an algorithm that partitioned the cell region into two regions: the inner and outer area and calculates the User Satisfaction (US) for consecutive combinations of the inner region radius and frequency allocation. For each combination, in addition to the US metric, the algorithm calculates per-user as well as cell total throughput. After all calculations the proposed method selects FFR that maximize the user satisfaction metric.

The proposed method consists of the topology that contains a grid of cells and a number of multiple users that are randomly distributed through the topology. A network size of 16 cells which are arranged in 6 columns×3 rows and a total of 360 users out of which 24 users/cells are chosen as shown in fig 2. And it is assumed that the user of one cell may not enter into the other cell. The frequency distribution is examined in terms of RBs.
Frequency Distributions (FDs). The case of the frequency allocation for the proposed mechanism is graphically presented in Figure 1(ii). This process is frequently repeated in order to take into account user’s mobility, US, per user throughput and cell total throughput and are calculated periodically at each time, the FFR scheme that utilize the above parameters is selected. This process is known as Adaptation.

C. Performance Formulation

We consider a theoretical approach to calculate SNR, US metric, throughput. Overall network is assumed to be composed of M adjacent cells and each cell contains a number of users in the hunt for sharing a cluster of subcarriers. Here there is no restriction on the number of users in the inner and outer region of the cell. It is assumed that equal power is transmitted to all base stations. SNR in an OFDMA based cellular network where a user, who is served by a base station \( b \) on subcarrier \( m \) is given by the equation.

\[
SNR_{i,m} = \frac{G_{b,l} \cdot P_{b,m} \cdot h_{b,l,m}}{\sigma^2_m + \sum_{l=1}^{L} G_{d,l} \cdot P_{l,m} \cdot h_{i,l,m}} \tag{i}
\]

and

\[
\sigma^2_m = N_c B \tag{ii}
\]

Where in equation (i), the transmitted power of the base station on subcarrier \( m \) is \( P_{b,m} \), path loss component associated with channel between base station \( b \) and user \( l \) is \( G_{b,l} \), exponentially distributed fast channel fading power is \( h_{b,l,m} \) and Additive White Gaussian Noise (AWGN) channel is given by \( \sigma^2_m \) symbols (\( t \)) and (\( i \)) represents a set of all interfering base stations that are using same sub band as user \( l \). The coefficient \( h_{i,l,m} \) is replaced by its mean value (\( h_{i,l,m} = 1 \)). And in equation (ii), \( N_c \) the power spectrum of density of AWGN and \( B \) is the bandwidth of each sub band divided by the number of users that share the specific sub band. Then the corresponding charge to user average SNR is given by Shannon formula for channel capacity [17].

\[
I_{i,m} = B \cdot \log_2 (1 + SNR_{i,m}) \tag{iii}
\]

The Throughput of user \( l \) is given by:

\[
T_l = \sum_m \beta_{l,m} \cdot I_{i,m} \tag{iv}
\]

Where, \( \beta_{l,m} \) represents the subband assigned to the user \( l \) and

\[
\beta_{l,m} = \begin{cases} 1 & \text{the subband } m \text{ is assigned to the user} \\ 0 & \text{Otherwise} \end{cases}
\]

User Satisfaction (US) metric is defined as the summation of the user’s throughput divided by the product of maximum user’s throughput and the entire number of users \( N \) in the cell and is expressed as:

\[
US = \frac{\sum_{l=1}^{N} T_l}{User \; Throughput_{\text{max}} \cdot N} \tag{v}
\]

US have been chosen as recital metric since it leads to a fairer overall network behaviour. The value of US varies between 0 and 1. If US approach to 1, then the throughput of each user in the subsequent cell experience similar throughput, whereas as US approaches 0, there is a big dissimilarity in the throughput achieved by the users in the cell. US metric expresses the comparative throughput of single user as compared to the throughput of the users in the same cell and it physically presents how close is the user’s throughput to that of maximum throughput in a specific region.

III. PERFORMANCE ANALYSIS

The simulation parameters are listed in table 1.

<table>
<thead>
<tr>
<th>PARAMETERS</th>
<th>VALUES</th>
</tr>
</thead>
<tbody>
<tr>
<td>System bandwidth</td>
<td>10MHz</td>
</tr>
<tr>
<td>Resource Blocks</td>
<td>25</td>
</tr>
<tr>
<td>Subbands</td>
<td>300</td>
</tr>
<tr>
<td>Subband’s bandwidth</td>
<td>30KHz</td>
</tr>
<tr>
<td>Macro BS frequency</td>
<td>2000MHz</td>
</tr>
<tr>
<td>BS transmit power</td>
<td>46dBm</td>
</tr>
<tr>
<td>Cell radius</td>
<td>240m</td>
</tr>
<tr>
<td>Correlation distance</td>
<td>40m</td>
</tr>
<tr>
<td>User’s speed (Pedestrian)</td>
<td>3Km/h</td>
</tr>
<tr>
<td>Channel model</td>
<td>3GPP Typical urban</td>
</tr>
<tr>
<td>path loss model</td>
<td>Hata costa 231 Model (in dB)</td>
</tr>
<tr>
<td>Power noise density</td>
<td>-174dBm/Hz</td>
</tr>
</tbody>
</table>

Here LTE system with a bandwidth of 10MHz is considered which is partitioned into 25 RBs. Each RB has 12 subband of 30KHz each the system behaviour is investigated based on dense urban scenario, according to Hata Costa 231 Model, which illustrate the maximum path loss in urban areas.
Figure 3 illustrate user satisfaction using optimal US for the proposed scheme. For the range 0 to 50m when the number of users is low, US are high and are constant value. Further as the number of users increases the value of US goes on decreasing upto 150m and then again US starts on increasing. This shows that the proposed scheme provides significant improvement in the coverage of cell edge users and ensures better QoS to the users.

Figure 4 shows US when optimized using optimal throughput. Initially US for both adaption and without adaption process is very low of approximately equal to 0.02 from time 0 to 175sec and after that US value suddenly increases to a large extent and reaches to its maximum value of 0.6 and remain constant for without adaption case whereas US for with adaption remains a very low value.

US at cell center over time when optimized using US is shown in figure 5. Initially the value of US both for adaption and without adaption is 0.69. US without adaption increases and reaches to its maximum value of only 0.73 at time equal to 30sec. and after that the value goes on decreasing with time. Whereas US with adaption increases with time and reaches its maximum value of 0.76 at 90sec. and after that its value decreases to min value of 0.7 at 200sec. but after that its value increases.

As the users move throughout the cell, the proposed scheme adapts the range and resource block (RB) or subcarrier allocation of the inner cell area in order to ensure that all the users in the cell experience similar value of throughput and a high value of US.

During adaption process the mechanism updates the frequency or bandwidth allocation and inner region radius so as to take user’s mobility into account. Without adaption process, assumes that inner region frequency and radius are calculated once and remain constant during the whole scenario. Whereas adaption process updates the inner region and resource block allocation so as to achieve high value of US.

In figure 6(a), subcarrier allocation of inner cell area based on throughput for both with and without adaption is high i.e. 26 RBs are allocated to inner cell, but such a high value of RB result in very low US approximately 0.02 as shown in figure 4 for both cases. Whereas bandwidth allocation of inner cell...
area based on US both for with and without adaption is very low. As from figure 6(a) only 5 RB are allocated for without adaption process and 5 or less than 5 RBs for with adaption, but both results in high value of US as shown in figure 5. Also US with adaption is high as compared to without adaption process and attains a maximum value of 0.76 at 96sec.

The range (Radius) of inner cell area based on throughput in figure 6(b) for with adaption is 100m and for without adaption case is 100 or less, both results in lower value of US i.e. 0.02 as in figure 4, although US for without adaption increases drastically at 170 sec to a higher value and remains constant. Whereas radius of inner cell area based on US optimization, without adaption is 200m and that with adaption lies between 100-200 m, for both cases initially US is high i.e. 0.69 as in figure 5 and after that with passage of time US metric for with adaption increases to maximum value of 0.76 at 90 sec which is a higher value as compared to the without adaption process.

Table 2: Comparison of US of different schemes with and without Adaption.

<table>
<thead>
<tr>
<th>Time (in sec)</th>
<th>US(Optional-FFR) without Adaption</th>
<th>US(Optional-FFR) with Adaption</th>
<th>US(Proposed Scheme) without Adaption</th>
<th>US(Proposed Scheme) with Adaption</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0.685</td>
<td>0.72</td>
<td>0.685</td>
<td>0.685</td>
</tr>
<tr>
<td>40</td>
<td>0.638</td>
<td>0.69</td>
<td>0.618</td>
<td>0.713</td>
</tr>
<tr>
<td>80</td>
<td>0.648</td>
<td>0.703</td>
<td>0.618</td>
<td>0.755</td>
</tr>
<tr>
<td>120</td>
<td>0.68</td>
<td>0.702</td>
<td>0.638</td>
<td>0.743</td>
</tr>
<tr>
<td>160</td>
<td>0.392</td>
<td>0.663</td>
<td>0.7</td>
<td>0.716</td>
</tr>
<tr>
<td>200</td>
<td>0.166</td>
<td>0.74</td>
<td>0.708</td>
<td>0.695</td>
</tr>
</tbody>
</table>

Comparison of different FFR schemes at different time intervals is shown in the Table 2. On comparing US for without adaption for both the schemes, proposed scheme results better. Also overall performance of US with adaption for both scheme shows that proposed scheme results superior.

Graphically Figure 7 shows comparison of user satisfaction for different schemes, it is observed that the proposed scheme shows higher value of US as compared to the other schemes.

IV. CONCLUSION

In this paper, we proposed an interference management technique in OFDMA based LTE femtocell systems using FFR scheme. The general approach followed to avoid interference is dynamic FFR scheme that calculate the per-user SNR, capacity throughput and US. After that above calculations the mechanism selects the FFR scheme that maximizes the US metric. User’s mobility is checked for two cases: with adaption process, the process when the parameters like inner cell radius and frequency allocation are varied and periodically per-user throughput, cell total throughput and US are recalculated ensuring that at each interval, the FFR scheme that maximizes the US is selected. And other is without adaption process where per-user throughput, cell total throughput and US are calculated when inner cell radius and frequency allocation are selected once.

The result indicates that adaption process using the proposed scheme result in improved performance and higher US metric when US is calculated based on US optimization. Also we have compared the performance of the proposed scheme with dynamic strict FFR, FFR3, FFR1 schemes and observed that the proposed scheme results in higher value of US metric compared to all these schemes. The overall observation is that the proposed scheme distributes the available bandwidth between two regions: the inner and outer region in fairer way, ensuring that all the users in the cell will experience similar throughput and a higher value of US.

Acknowledgment

Author would like to thank to Dr. M. P. Punia, Director NITTTR Chandigarh, Dr. Maitreyee Dutta, HOD-ECE NITTTR Chandigarh without whose valuable guidance and support things would not have been practically implemented. Lastly we would like to thank our colleagues for giving their endless support.

REFERENCES


