Low Complexity Graphical Framework and Power Optimal Solution for Resource Allocation in LTE Network

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Abstract: ***The objective of the proposed project work is Downlink resource allocation for OFDMA-based next generation wireless networks subject to inter-cell interference (ICI). The main aim of the project is balanced performance improvement between cell edge and cell centre users. The resource allocation scheme consists of radio resource and power allocation, which are implemented separately. To achieve radio resource allocation, the low complexity heuristic algorithms are proposed, where graph based frame work and fine physical resource block PRB assignment are performed to mitigate ICI and improve the network performance. The power allocation performs to optimize the performance of cell edge users under the condition of the desirable performance of cell centre users.***

Keywords: OFDMA, SINR. RRM, ICIC, Resource allocation

1. Introduction

The Main aim of next generation wireless networks is to achieve high data rates, efficiency resource usage and economical deployment of network. But generally radio resource is becoming a scarce resource in wireless communication, the orthogonal frequency division multiple accesses (OFDMA) have been proposed as a air technology to enable high spectrum efficiency and effectively combat frequency selective fading. Due to its feature OFDMA adopted in many cellular systems such as Long term Evolution (LTE) [2] and IEEE 802.16m [3].

A good Radio resource management (RRM) scheme, including subcarrier allocation, scheduling and power control, is crucial for guarantee high system performance. Generally most published work concentrate on the single-cell scenario where resources are allocated to deliver a local performance optimization [5]-[8]. But in multi cell scenario, inter-cell interference (ICI) has become a major issue for modern OFDMA-based cellular networks, due to the same spectral usage in adjacent cells. So, developing RRM schemes with an emphasis on ICI reduction in the multi cell scenario is of significant interest to recent research work [9]-[11]. Generally the RRM can aware of ICI by formulated as a global performance optimization problem by considering SINR instead of SNR. But finding the optimal solution for global optimization problem is too hard. So this problem is known as a mixed integer programming (MIP) [12], [13]. In the literatures this work has been analysed from different perspectives and consequently can be separated in to two categories. The first category aim is to mitigate ICI and improve system performance by intelligent subcarrier allocation scheme this is known as ICI coordination (ICIC). By using heuristic algorithms can achieve sub carrier allocation. In [13] semi distributed radio resource allocation scheme where the radio network controller (RNC) coordinated ICI and then each base station (BS) makes its own channel assignment decision, In [14] here two level resource allocation was proposed with ICI graph theory. ICIC usually do not provide any precise power allocation solution.

The second category, here mainly concentrated on maximizes the network throughput by using power allocation. A Lagrange dual method and geometric programming has been proposed to such optimization problems.

2. System Model

A multi-cell OFDMA-based downlink network is considered in this paper. One example of the network layout with seven hexagonal cells is displayed in Fig. 1, where a BS equipped with an Omni-directional antenna is placed at the centre of each cell to serve users who are randomly distributed within the cell. In OFDMA systems, the frequency resource is divided into subcarriers while the time resource is divided into time slots. The smallest radio resource unit that can be allocated to transport data in each transmission time is termed as traffic bearer in general. As specified in the LTE standard, the traffic bearer is defined as a physical resource block (PRB), which consists of twelve consecutive subcarriers in the frequency domain and one slot duration (0.5 msec) in the time domain. In other words, the PRB is a group of subcarriers that can be coherently allocated to users in a given time. For consistency, thus, from now on we will use the term PRB to represent the single unit of radio resource for allocation in the OFDMA-based network. In addition, the following fundamental assumptions are made throughout the remainder of this project.

1) In each cell, users are classified as either cell-centre or cell-edge users depending on their current geographic locations and straight-line distances to the serving BS. The boundary that separates the cell centre and cell edge

region, as shown in Fig.1, can be adjusted as a design parameter. The geographic location information can be reported to the BS by users periodically via the uplink control channels.

2) In every transmission time interval (TTI), each BS has to make a decision on PRB assignment to its served users. The duration of TTI is equal to one time slot of the PRB. We also assume that BSs can have perfect knowledge of channel state information updated periodically via feedback channels for every TTI. BSs in the network are given the same maximum transmission power.

3) To any cell, only interference from its adjacent cells is regarded as the effective ICI. In particular, to any cell-edge user there is a dominate interference that usually comes from its closest adjacent cell (i.e., in Fig. 1 cell 2 is considered as the dominant interfering cell to the cell-edge user in cell 1). In addition, cell-edge users may have at most two dominant interfering cells when they are located at the corner of serving cells and thus have nearly equal distances with both neighbouring cells (i.e., in Fig.1 both cell 1 and cell 4 are dominant interfering cells for the cell-edge user in cell3).

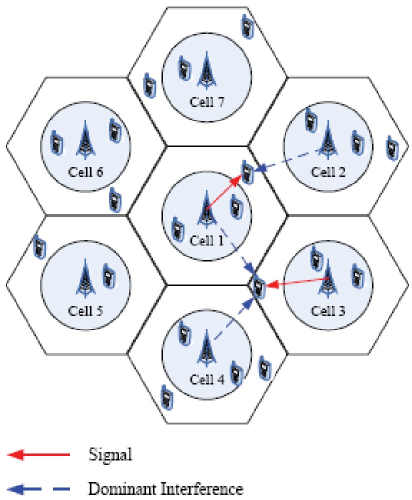

Figure 1: An example of an LTE network with inter-cell interference

2.1 Problem formulation

Optimization goal is to maximize the overall throughput of cell edge users while maintaining the required throughput for cell centre users. As a result, a balanced performance improvement between cell edge and cell-centre users is expected to be achieved in the multi-cell systems. The reason behind this is that cell-centre users usually do not suffer from heavy ICI and relatively high performance is easy to be obtained for these users even in a network without optimization, whereas cell-edge user's performance is much more vulnerable to ICI and their performance improvement has to strongly rely on optimization schemes.

- Cell edge users suffer from several interference due to the shorter distances to the adjacent BSs.
- Users within the same cell are mutually connected.
- For any cell-edge user, the connection is only pair wise established with other cell-edge users of its dominant interfering cells.

3. Resource Allocation Schemes

The work is formulated as an optimal joint resource allocation optimization problem for the multi-cell OFDMA-based downlink network. Unfortunately, there is no time-efficient algorithm that can optimally solve this type of problems and directly finding the optimal solution (even by exhaustive search) will be computationally prohibitive when the number of user's and PRBs is large in the network. Therefore, a feasible suboptimal resource allocation scheme is proposed in this work. The resource allocation scheme is divided into two steps in order to reduce the complexity radio resource and power allocations.

3.1 Radio resource allocation

In radio resource allocation is done in two phases, first phase is ICIC scheme using a simple but effective graph-based framework. The second phase is PRB assignment.

3.1.1 Radio resource allocation

In first phase of radio resource allocation using effective graph based framework. Our objective is to construct a graph that reflects major interference occurring in the real time network environment. According to the graph theory, the corresponding interference graph is denoted by G = (V,E), where V is a set of nodes each representing a user in the network, and E is a set of edges connecting users that can cause heavy mutual interference when they are allocated the same PRB.

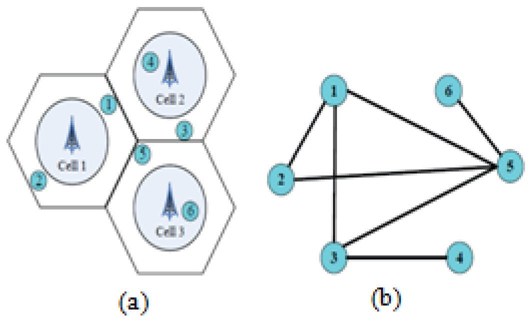

Figure 2: An example of the graph-based framework. (a) 3cell scenario. (b) Interference graph construction

Let $\mathbb{D}_m$ denote the set containing indices of dominant interfering cells to cell-edge user m. Thus, an illustrative example is given by Fig. 2. Fig. 2 (a) presents a simple 3-cell network case, where user 1, 2, 3 and 5 are cell-edge users of each cell and $\mathbb{D}_1 = \{1\}$,$\mathbb{D}_2 = \emptyset$,$\mathbb{D}_3 = \{3\}$,$\mathbb{D}_5 = \{1, 2\}$, respectively.Then the corresponding interference graph is constructed in Fig.2(b). The concept of this graph-based framework is that simultaneous transmission on the same PRB is forbidden for users who are connected by edges, and thus both intra-cell interference and major ICI can be avoided in the network.

3.1.2 PRB allocation

In this phase of the work concentrate on PRB allocation based on the interference graph. This work is also known as the color mapping problem in general graph theory by marking those directly connected nodes with different colors. To reduce complexity, a heuristic algorithm is proposed here to perform a fine PRB allocation by taking account of the instantaneous channel quality.

(a) Block Diagram Description

The figure 3 represents a theoretical model of the proposed PRB allocation. After Interference connection graph is constructed between the users of the same cell (Intra-cell connections) and cell-edge users of the neighbouring cells (inter-cell connections). The graph so generated serves as the input to a heuristic algorithm that produces a resource allocation matrix as output.

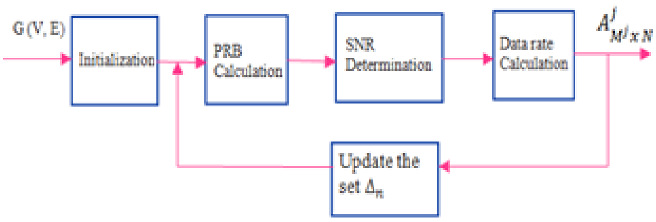

Figure 3: Block diagram of PRB allocation

Based on the above algorithm the subcarriers are allocated to each user of the network and the user set as well as the available subcarrier/PRB set are updated periodically till the user set is exhausted. Allocation of the spectrum completes category one of the Resource allocation problem and the process reduce to individual cell problem. The power allocation being the second phase of the resource allocation process is carried out on individual sub-channel for individual user of the reference cell.

3.2 Power allocation

The radio resource allocation, the power allocation is decided individually in each cell and subsequently performed by BSs in a distributed manner. Therefore, a distributed power allocation approach is proposed in this section with an emphasis on performance optimization for cell-edge users.

3.2.1 Total Power Distribution

The overall transmission power of each cell into two parts: total power for cell-edge users and cell-centre users. Let P_E^j and P_C^j denote the total power allocated to cell edge users and cell-centre users in cell j, respectively, and $P_E^j + P_C^j = P_{max}$ .Note that P_{max} is assumed to be the same for all BSs in the network.

$$\begin{cases} \frac{P_C^j}{P_E^j} = \alpha \frac{B_C^j}{B_E^j} \\ P_E^j + P_C^j = P_{max} \end{cases} \quad (1)$$

Where B_C^j and B_E^j denote sets of total PRBs occupied by cell-centre and cell-edge users in cell j, respectively, and α ($0 < \alpha < 1$) is a proportional factor indicating that a higher weight is given to cell-edge users for power allocation.

3.2.2 Power Allocation for Cell-centre Users

The objective is to conditionally maximize the performance of cell-edge users and there is no optimization for cell-centre users, though protection of their performance is stated as an important constraint. Thus, we simply determine the power allocation to cell-centre users by evenly distributing the total power for cell-centre users among their used PRBs in each cell.

3.2.3 Power Allocation for Cell-edge Users

Given the fixed PRB allocation and power allocation of cell centre users, the original optimization problem becomes a convex function of power of cell-edge users and can be decomposed into parallel sub-problems, where the optimal power allocation to cell edge users is solved locally by each BS of the network. Where only mutual interference between cell edge and cell-centre users is taken into account. The Maximum power is allocated to cell edge user, constant power is allocated to cell centre users.

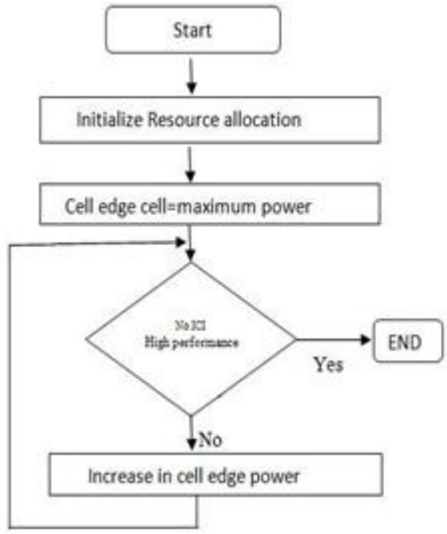

Figure 4: Flow chart for power allocation

4. Results and Discussion

Table 1: Main Simulation Parameters

Parameter	values
Number of cells	7
Cell radius	1000m
Bandwidth	5 MHz
Carrier frequency	2 GHz
Cell-edge area ratio	1/3 of the total cell area
Total number of PRBs	24
Frequency spacing of a PRB	180 KHz
Total transmission power per cell	43 dBm
LOS path loss model	103.4 +24.2 log10(*d*) dB, *d* in km
NLOS path loss model	131.1 +42.8 log10(*d*) dB, *d* in km
Shadowing standard deviation	8 dB
Channel model	Rayleigh multipath model
Thermal noise	-174 dBm/Hz

The performance is further evaluated with respect to the average throughput achieved by cell-edge and cell-centre users of the reference cell under various numbers of users per cell, respectively. As shown in Fig 5 is graph based frame work of Interference graph construction. Our objective is to construct a graph that reflects major interference occurring in the real time network environment. In Fig 6 shows that PRB allocation based on Interference graph. As seen in Fig 7. (a) And (b) the proposed schemes can consistently improve performance of cell-edge users and at the same time maintain desirable performance for cell-centre users. In particular, the proposed scheme with [*we* = 4, *wc* = 1] achieves nearly balanced performance improvement between cell-edge and cell-centre users. However, Fig. 7(b) shows that the proposed

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schemes perform slightly worse or even better in terms of average throughput for cell-centre users when the user density increases. This observation indicates that our scheme can provide not only consistent performance improvement to cell-edge users but also better performance protection for cell-centre users especially when high ICI is experienced in the network.

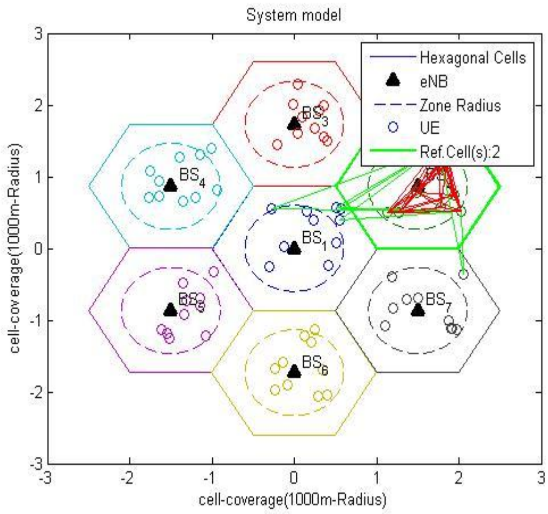


Figure 5: 7 cell scenario and Graph based frame work

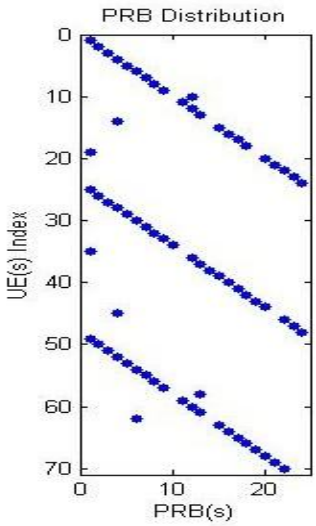
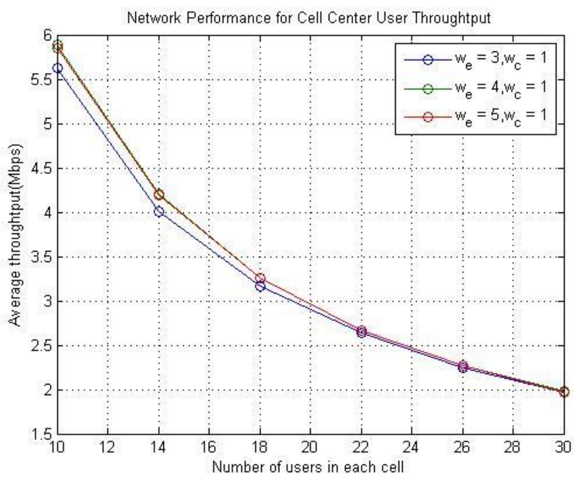
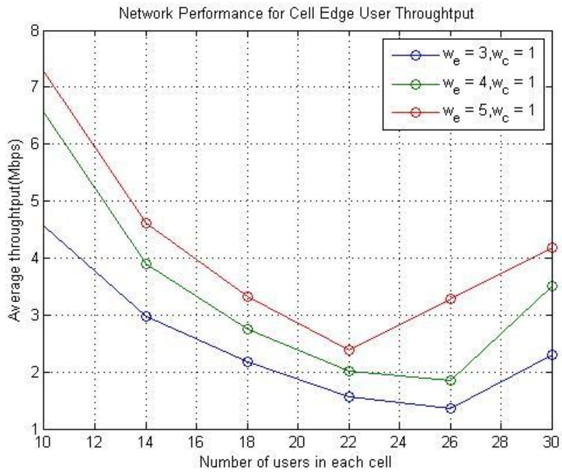


Figure 6: PRB allocation



(a)



(b)

Figure 7: Network performance for (a) cell centre user throughput (b) cell edge user throughput

5. Conclusion

In this Project, Simulation results show that the proposed scheme can achieve significant performance improvement for cell-edge users and desirable performance for cell centre users. The resource allocation scheme has been proposed for downlink multi-cell OFDMA networks. The scheme includes radio resource and power allocations, which are implemented separately to address the formulated problem with reduced complexity. For radio resource allocation, the graph-based framework combined with fine-scale PRB assignment algorithms are proposed to effectively manage ICI and improve performance of the network in a centralized manner. Given the solution of radio resource allocation, the optimal power allocation is performed independently in each cell to maximize performance of its own cell-edge users under the condition that performance of cell-centre users of adjacent cells are not degraded much. The optimal solution is obtained by the Lagrange method. Therefore, the proposed resource allocation scheme can yield balanced performance between cell-edge and cell-centre users, which allows for future wireless networks to deliver consistent high performance to any user from anywhere.

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