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# Self-organized dynamic resource allocation using fraction frequency reuse scheme in long term evolution networks ☆

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A B S T R A C T

Inter-Cell Interference (ICI) from neighboring cells is the major challenge that degrades the performance of Orthogonal Frequency Division Multiple Access (OFDMA) cellular mobile systems, particularly for cell edge users. An efficient technique to mitigate ICI is the interference coordination. The most commonly ICI Coordination (ICIC) technique is the Fractional Frequency Reuse (FFR), which effectively mitigates ICI by applying different reuse factors to Users' Equipments (UEs) situated in different regions in each cell. This paper presents a novel Self-Organized FFR Resource Allocation (SORA) scheme that automatically selects the optimal RA to inner and outer regions of the cell, based on coordination between neighboring evolved NodeBs (eNBs), through a message passing approach over Long Term Evolution (LTE)-X2 interfaces. The performance of the proposed scheme is evaluated using MATLAB and compared with different combinations of RA as well as with frequency reuse-1 and reuse-3 schemes. Simulation results show that the proposed scheme improves the cell-edge performance and achieves high degree of fairness among UEs compared to reference RA schemes.



## 1. Introduction

Transmission over wireless channels endures random fluctuations in signal level known as fading and co-channel interference [1]. Recently OFDMA has gained increasing interest. Due to its ability to combat the Inter-Symbol Interference (ISI) resulting from frequency selective fading, OFDMA is widely considered as a key multiple access technique for various types of wireless communication systems, including next generation cellular mobile systems such as IEEE 802.16 m Worldwide Interoperability for Microwave Access (WiMAX) [2], LTE [3], and LTE-Advanced (LTE-A) [4]. OFDMA is a form of Orthogonal Frequency Division Multiplexing (OFDM), which is the underlying technology. In OFDMA, the frequency selective wideband channel is divided into number of non-frequency selective parallel orthogonal narrowband sub-carriers. The orthogonally of the OFDMA narrowband sub-subcarriers ensures that the ICI can be avoided. However, Co-Channel Interference (CCI) from neighboring cells is considered as the major challenge that degrades the performance of OFDMA based cellular mobile systems, particularly for cell edge users. For next generation cellular mobile systems, the effective reuse of the available frequency resources can highly improve system capacity. With a smaller Frequency Reuse Factor (FRF), more resources are available for each cell. However, the usage of FRF-1 results in heavy ICI, especially near the cell

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edge, and this degrades the system performance in terms of cell coverage and system capacity. The conventional method to figure out this problem is by increasing co-channel distance using higher cluster size, which can mitigate the ICI efficiently. However, increasing cluster size decreases the available frequency resources for each cell which results in restricted data transmission rate and lower system spectrum efficiency in general. In order to improve cell-edge performance while retaining system spectrum efficiency of reuse-1, several approaches for interference mitigation are recommended by LTE standard [3]; i.e., ICI cancelation, ICI randomization, adaptive beam forming and ICI avoidance/coordination (ICIC) [5–8]. Interference reduction using ICIC achieved by applying restrictions to resource management in a coordinated way among network entities. Resources for coordination can be (time/frequency and/or transmit power). In order to effectively mitigate the ICI, the 3rd Generation Partnership Project (3GPP) introduced the use of FFR for cellular mobile systems. The FFR effectively mitigating ICI by applying different FRFs to UEs situated in different regions in each cell [9,10]. The FFR scheme statically divides each cell in the cellular mobile system into two geographical regions; i.e., inner and outer regions. The UEs situated in the inner region with the best received signal quality can use a lower FRF, whereas UEs located in the outer region with low received signal quality use higher FRF compared to UEs in the inner region. Self-Organizing Network (SON) is an automation technology designed to make the planning, configuration, management, optimization and healing of mobile radio access networks simpler and faster. In order to improve the network performance and reduce the capital expenditures (CAPEX) and operational expenditures (OPEX) for operators, SON concepts have been introduced in the LTE standards starting from the first release of the technology (Release 8) and expanding in scope of subsequent releases [11]. The 3GPP has defined a set of LTE SON use cases and associated SON functions. Among the proposed SON use cases, the management of ICI is of utmost importance. FFR schemes have been rather well studied using both theoretical analysis and system level simulations. In [12], a theoretical capacity and outage rate analysis of an OFDMA cellular system assuming FFR and proportional fair scheduling has been presented, where the users are classified as cell-center users and cell-edge users based on the geographical location. The optimization of design parameter (distance threshold or SINR threshold) of FFR has been studied using graph theory in [13], and convex optimization in [14]. It has been shown in [14] that the optimal frequency reuse for the cell-edge users is reuse-3. The average cell throughput in FFR system is derived in [15] as a function of the distance threshold for both Round Robin (RR) and Maximum SINR (MSINR) scheduling strategies. The authors in [16] introduced an analytical optimization technique to configure FFR solution for the downlink of LTE cellular system. In [17], the authors proposed a mechanism that selects the optimal size of the inner and outer region for each cell as well as the optimal frequency allocation between these regions that either maximizes the mean user throughput or the user satisfaction. Extensions and variations of the basic FFR scheme have been examined in a number of recent articles. In order to overcome the limitations of standard FFR and to address the performance of FFR in large-scale networks with irregular cell structure, the authors in [18] presented a Generalized Fractional Frequency Reuse (GFFR) scheme for flexible resource allocation. The GFFR scheme based on optimizing sub-band allocation and power assignment, the scheme adapts the utilization of the spectrum and power resource to the level of interference sensitivity of each cell-edge zone. 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. The authors in [19] evaluated the downlink performance of FFR in LTE networks employing a metric combining throughput and fairness. They considered different scenarios combining FFR with two different scheduling algorithms (round robin and proportional fair). Their results showed that if the fairness of the UE throughput distribution is to be maintained, FFR offers no gain if proper scheduling is employed. The authors in [20] proposed a dynamic mechanism that selects the optimal FFR scheme based on a custom metric, which is called User Satisfaction (US). Their proposed mechanism divides the cell into

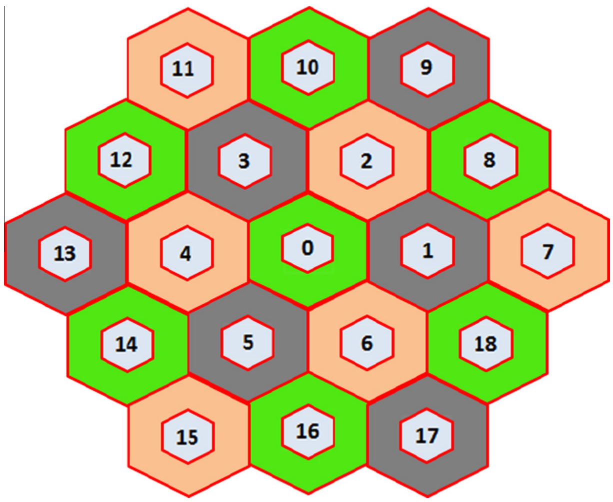


**Fig. 1.** System model under investigation.