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ORIGINAL ARTICLE

General expressions for downlink signal to interference and noise ratio in homogeneous and heterogeneous LTE-Advanced networks

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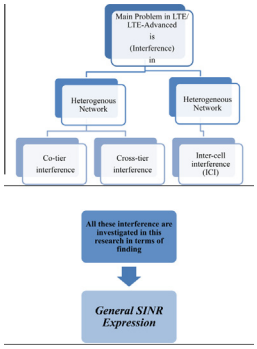
GRAPHICAL ABSTRACT



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ABSTRACT

The interference is the most important problem in LTE or LTE-Advanced networks. In this paper, the interference was investigated in terms of the downlink signal to interference and noise ratio (SINR). In order to compare the different frequency reuse methods that were developed to enhance the SINR, it would be helpful to have a generalized expression to study the

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performance of the different methods. Therefore, this paper introduces general expressions for the SINR in homogeneous and in heterogeneous networks. In homogeneous networks, the expression was applied for the most common types of frequency reuse techniques: soft frequency reuse (SFR) and fractional frequency reuse (FFR). The expression was examined by comparing it with previously developed ones in the literature and the comparison showed that the expression is valid for any type of frequency reuse scheme and any network topology. Furthermore, the expression was extended to include the heterogeneous network; the expression includes the problem of co-tier and cross-tier interference in heterogeneous networks (HetNet) and it was examined by the same method of the homogeneous one.

Introduction

Frequency reuse schemes are the most suited interference management techniques for the OFDMA based cellular networks wherein the cells are divided into separate regions with different frequencies [1,2]. The most famous technology using OFDMA is the Long Term Evolution (LTE). LTE was developed by the third Generation Partnership Project (3GPP) to complement the 3G technology with high data rate, low latency and high spectral efficiency. To further improve the network and set the requirements of the International Mobile Telecommunication-Union (IMT-U), 3GPP developed LTE-Advanced to be the 4G technology by using carrier aggregation, higher order MIMO and implementing low power nodes with the macrocells. However, using OFDMA results in a big problem which is the inter-cell interference (ICI) due to using the same frequency for all cells [1,2]. This results in performance degradation especially for the edge users. Fractional frequency reuse (FFR), soft frequency reuse (SFR) and the new hybrid frequency reuse (NHFR) are the most used interference management techniques that were generated to mitigate the ICI problem in LTE homogenous network [3,4].

In FFR, the whole system bandwidth is not used inside the cell, where the cell is divided into inner and outer regions; the inner regions use the same frequency (reuse factor = 1), but the outer regions use different frequencies (reuse factor > 1) as shown in Fig. 1 [5–7]. In SFR, the whole system bandwidth is used inside the cell. The cell is divided into inner and outer regions with different frequencies and different transmission powers (Fig. 2) using power control to mitigate the interference [5–7]. Signal to interference and noise ratio (SINR) is the most significant factor to measure the amount of ICI and to evaluate the performance of the proposed interference management technique.

In NHFR, the cell is not divided into inner and outer regions. But, the centre frequencies of the neighbouring base stations are changed to reduce the ICI as shown in Fig. 3 [3]. Changing these centre frequencies causes some overlapping

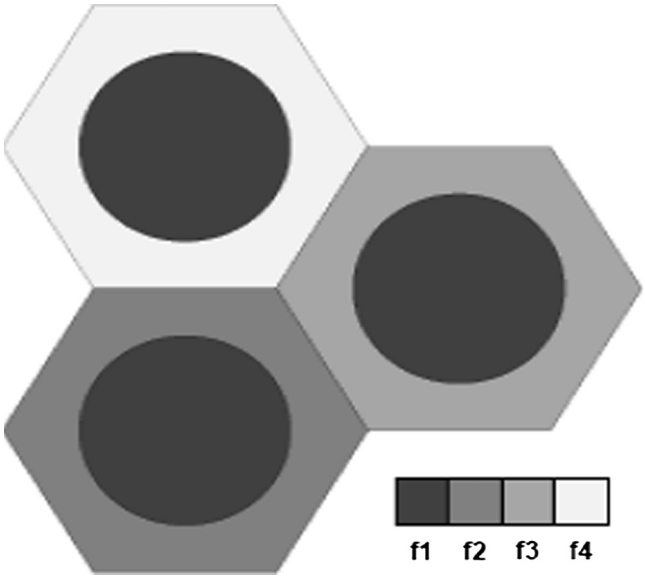

Fig. 1 FFR scheme.

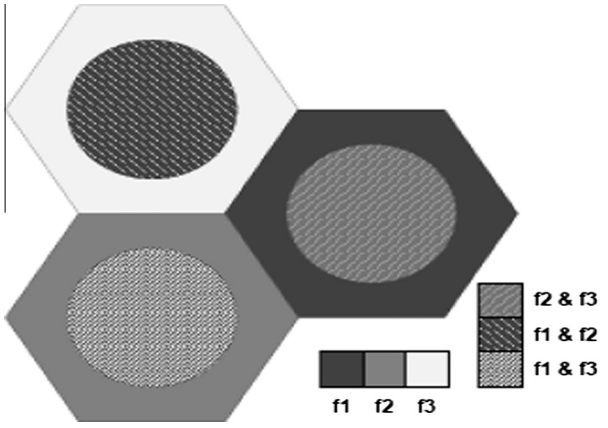

Fig. 2 SFR scheme.

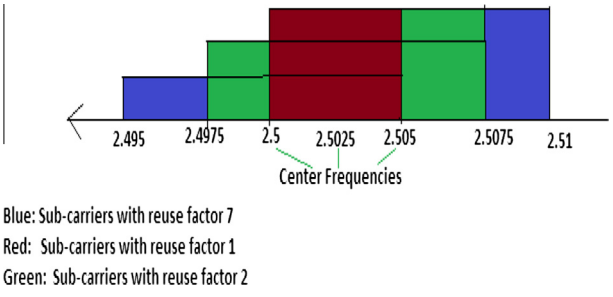

Fig. 3 NHFR scheme [3].