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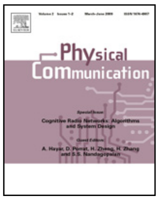

Full length article

Inter-cell spectrum efficiency improvement technology[☆]

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ABSTRACT

Improvement in inter-cell spectrum efficiency is a valuable research topic in mobile communication system, which affects cell edge user experience especially. According to current research results, there are three methods to deal with inter-cell interference to improve inter-cell spectrum efficiency, including inter-cell interference randomization, inter-cell interference cancellation and inter-cell interference coordination. This paper analyzes three important inter-cell spectrum efficiency improvement technologies, soft frequency reuse (SFR), uplink power control, and downlink coordinated multi-point transmission/reception (CoMP), and relative research progress.

1. Introduction

The rapid growth of the population of mobile users demands the fast development of mobile wireless communication and technology. The new trends in wireless telecommunications desire higher user bit rates and lower delay requirements. The wireless mobile system has to meet these requirements.

There are two performance measures that are crucial for wireless systems: average cell throughput and cell-edge user throughput [1]. Improving both of the performance measures becomes one of the major tasks of the next generation wireless communication systems. However, it is important to note that improving average cell throughput is a relatively easy task, while improving cell-edge user throughput becomes extremely demanding. This is because the average cell throughput can be improved using simple methods such as transmission power boosting. However, for cell-edge user throughput, these simple methods are not valid any more. Cell-edge users usually have relatively low received signal strength; furthermore, they do suffer from strong inter-cell interference. Transmission power boosting may increase the received signal strength, but it will also create stronger inter-cell interference to other cell's cell-edge users and hence reduce their throughput. Therefore, improving cell-edge user throughput becomes highly nontrivial. This is also part of the reasons why interference mitigation technologies for next generation wireless systems receive enormous attention in the standardization societies as well as in the research community [1–4].

How to improve inter-cell spectrum efficiency is getting more and more attention, mainly focus on inter-cell interference mitigation technology. Three approaches to inter-cell interference mitigation are currently being considered.

- Inter-cell interference randomization aims at randomizing the interfering signal(s) and thus to allow for interference suppression at the UE in line with the processing gain, such as cell-specific scrambling.
- Inter-cell interference cancellation devotes to interference suppression at the UE beyond what can be achieved by just exploiting the processing gain, such as spatial suppression by means of multiple antennas at the UE, interference cancellation based on detection/subtraction of the inter-cell interference [5].

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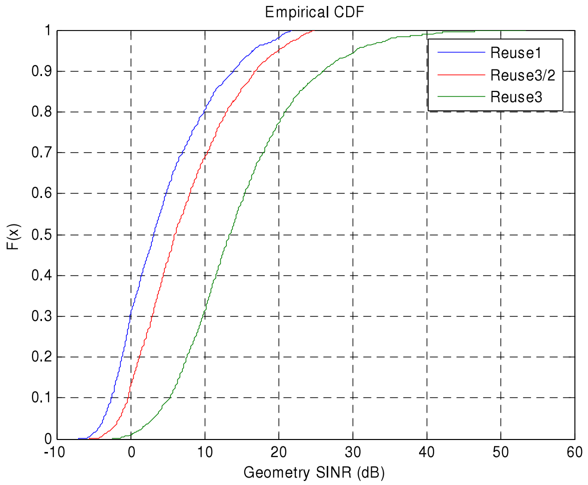

Fig. 1. Average SINR CDF of uniformly distributed MS in networks with different reuse factors.

- Inter-cell interference coordination/avoidance aims to apply a flexible schedule to the resource management in a coordinated way between cells, for example, soft frequency reuse (SFR), uplink power control, and downlink coordinated multi-point transmission/reception (CoMP).

Through the analysis of a large number of technical literatures, inter-cell interference coordination technology is a more effective technology to improve inter-cell spectrum efficiency, very worthy of study. So the remainder of the paper is organized as follows. In Section 2, we introduce methods based on soft frequency reuse technology. In Section 3, means on account of uplink power control to mitigate inter-cell interference is described. In Section 4, several approaches are introduced and potential gains by downlink CoMP are analyzed. Conclusions of the paper are summarized in Section 5.

2. Soft frequency reuse

2.1. Technology principle

The basic concept of frequency reuse is to reduce interference origin by dividing total frequency resource into several partitions and by exploiting only limited partitions per BS. Since, by doing this, the number of interference sources is decreased and distance of interference is increased, interference level could be far much reduced.

To improve the system spectrum efficiency, aggressive frequency reuse is highly desirable. However, the system with a reuse 1 network suffers from strong co-channel interference since the same frequency is reused by neighboring base stations. In particular, mobile stations which are located near cell edges receive the strong interference from nearby BS. From Fig. 1, it can be seen that in a reuse 1 network more than 30% mobile stations' average SINR is below 0 dB. In OFDMA systems, SINR below 0 dB makes it difficult to support fast and robust transmissions. Such users are typically at cell edge and will likely experience a poor network connection, low downlink throughput, and high probability of outage. Higher frequency reuse factors, such as 3, can significantly reduce the co-channel interference amongst neighboring cells/sectors in that 2/3 of the co-channel interference sources are eliminated compared with reuse 1 networks. This leads to greatly improved coverage and average SINR for cell edge users.

However, improvement in the downlink average SINR by using higher reuse factors is achieved at the cost of system spectrum efficiency, defined as the ratio of system throughput to occupied spectrum bandwidth, since higher reuse also requires more spectrum bandwidth.

To achieve better coverage, while still retaining the high system spectrum efficiency of reuse 1, SFR was introduced [6–9], also known as fractional frequency reuse (FFR).

Soft frequency reuse refers to the case where higher reuse factors are supported by restricting the interfering BS DL transmit power on certain subcarriers rather than turning them off, as shown in Fig. 2. On the contrary, conventional hard frequency reuse refers to the case where higher reuse factor is achieved by shutting off the interfering BS on certain subcarriers. Soft frequency reuse intuitively has capacity advantage when system load is high because physically there is no bandwidth loss caused by frequency planning, while hard frequency reuse is easier to deploy when the system load is light.

2.2. Research process

The key problem of SFR is to find the optimal channel segment for any user distribution, so we study a concrete way of implementing SFR, called adaptive-SFR (A-SFR).

When the system initially boots up, there is no information about user distribution or propagation environment. A pre-defined reuse segment is set to enable user to measure average SINR for different reuse segments and start the A-SFR adaptation procedure.

There are two steps in A-SFR, which are price adaptation and segment size adaptation.

2.2.1. Price adaptation

The price adaptation is a necessary step for A-SFR to adapt segment size later. The power loading level and segment size should be fixed during this adaptation.

An initial price is set for each reuse segment, for example, in the case of an A-SFR system with 4 segments (one reuse-1 segment and three reuse-3 segments). The price of segment with reuse-1 is always 1, while prices of the other three reuse-3 segments are subject to dynamic adaptation and broadcast to all users. The adaptation procedure starts with the initial price vector at BS and iteratively increases/decreases the price values if there are too many/few bandwidth requests from users for the corresponding channel segments. This procedure continues until the price converges to a stable value. In order to speed up the convergence, the adjustment value of one segment price can be set based on the number of bandwidth requests for the corresponding channel segments in every iteration.

This procedure to find the optimal price in a dynamic system is referred as "Market Price Iteration Algorithm"