Performance of fractional frequency reuse (FFR) in 4G cellular networks

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Background

All standard proposals targeting 4G and Beyong 4G service requirements (WiMAX 802.11e, LTE, LTE-Advaced) coincide in relying on a physical layer based on orthogonal frequency division multiple access (OFDMA), owing to its superior capabilities in terms of spectral efficiency and flexibility [1]. In sharp contrast with single-cell deployment technologies such as IEEE 802.11b/g/n/ac systems (*aka* WiFi), cellular architectures must implement some form of interference control to prevent performance degradation among users in neighbouring cells [2]. In the context of OFDMA systems, one of the most important mechanisms to control interference is the so-called fractional frequency reuse (FFR) [3, 4]. Unlike full frequency reuse, where each subcarrier is assigned in all cells thus potentially creating interference if the corresponding users are nearby, in FFR not all subcarriers can be assigned in the whole cell of all cells. Different reuse factors/patterns result in different amounts of interference and it is up to the system designer to decide the most appropriate one. To further complicate this landscape, 4G systems will surely be heterogeneous: the classical architecture where a single base station (BS) is in charge of the users in the cell will now be supplemented by other infrastructure elements (relays, femtocells) and cooperation among neighbouring BS will also be possible [5, 6]. This more complex network topology further complicates the application of FFR concepts, thus opening several interesting research questions.

Keywords: Interference, fractional frequency reuse, OFDMA, 4G Cellular systems, base station cooperation.

Objectives

The main aim of this project is to evaluate the performance of FFR in the context of an OFDMA-based network defined in accordance with 4G/B4G requirements (e.g. LTE/LTE Advanced). Two different scenarios will be considered depending on whether BSs are allowed to cooperate or not. To this end, a simulation environment will be developed in Matlab implementing a cellular layout with its corresponding wireless channel models, user distribution processes and FFR designs. The performance assessment will typically focus on the computation of the overall network throughput although other metrics such as user fairness might also be considered. Apart from the FFR design itself, it will also be important to consider the number of users in the system and the user-allocation policy. Over the course of this project (or potentially two projects) we aim to answer the following questions:

1. What are the effects of interference on the different FFR reuse factors/patterns?
2. What is the relation between the antenna sectorisation at the BSs and the FFR design?
3. How the user scheduling policy affects overall throughput?
4. What are the consequences of having BS cooperation in the FFR design?

To fulfill this goal, student are expected to:

- Acquire a reasonable amount of knowledge on some state-of-the-art wireless topics such as multicarrier and interference mitigation and also on state-of-the-art standards such as 3GPP-LTE Advanced.
- Understand in detail the technique of fractional frequency reuse.
- Derive throughput/capacity expressions for the different scenarios defined in accordance with 3GPP-LTE/LTE-Advanced specifications.
- Become competent in the use of Matlab.
- Develop the corresponding Matlab simulation environment.
- Write a technical report describing the work done.
- Prepare an oral presentation highlighting the main points of the project.

Tools: Search engines for literature review (*scholar.google.com, www.ieeexplore.org*), Matlab for programming, LaTEX for report writing.

Pre-requisites: general knowledge of communication theory and mobile communication networks.

Bibliography

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