Chapter 15
Best–M Feedback Technique in 4G–LTE Systems

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ABSTRACT

The feedback load is an important parameter with a large impact in Orthogonal Frequency Division Multiple Access (OFDMA) techniques, as a feedback over each one of the subcarriers will induce a non-acceptable signaling load in the system, so that some optimization and feedback reduction strategies are required to meet practical systems demands. The decision over the best strategy for feedback optimization highly depends on the number of available users in the system. The authors obtain the users’ effect on the system through a feedback strategy over a subset of the subcarriers showing the best channel conditions, where a closed form expression of the obtained data rate is formulated to exactly indicate the effect of the number of users, the operating SNR, and/or the available number of feedback bits in the system. Quality of Service (QoS) is also obtained using the Symbol Error Rate (SER). The performance of the presented scheme is compared to the one-bit feedback strategy, where interesting conclusions are obtained.

1. INTRODUCTION

One of the most interesting techniques for modern broadband communications is the Orthogonal Frequency Division Multiple Access (OFDMA); Hoshyar et al. (2010) mentioned that efficiently converts a broadband frequency selective channel into a set of flat fading sub channels (subC) that are easily equalized. Its low complexity and high performance has pushed it into commercial standards as 3GPP LTE 4th generation for cellular communication systems (European Telecommunications Standards Institute, 2011). A further advantage of OFDMA in comparison to its predecessor OFDM is its suitability for Multiuser scenarios, as it can provide service to several users at the same time, where each user will be allocated a bundle of subCs, while in OFDM all the subCs are awarded to a single user. Commercial systems require resources distribution among the customers, so that the OFDMA option was the implemented option in the standards. For any multiuser wireless scheme to be efficient, adaptation to the channel conditions must be accomplished, where Chen et al. (2012) stated the opportunistic scheduling is an efficient approach to select the best user for each one of the subCs. The Adaptive Coding and Modulation (ACM)
strategy is another helpful tool to adapt the transmitted signal to the channel conditions (Simon & Alouini, 2004). The challenge of employing any adaption to the channel characteristics is that the transmitter must know information about the channel before the transmission starts, and this is done through feedback from the receiver to the transmitter.

Modern wireless communication standards are characterized by being dynamic, where several options are available within the same standard. The most typical example is related to the Multiple Input Multiple Output (MIMO) techniques within the LTE technology (Hoshyar et al., 2010), where up to 13 different options are allowed in the standard, and each operator can choose the most suitable option for its implementation. This is a very interesting and challenging paradigm in modern wireless systems, as each operator must have an internal R&D department, where the engineers must be in charge of doing applied research for their scenario conditions, user’s profiles and service characteristics, among others. This also opens the door for the research groups across the Globe to propose new techniques and strategies to improve the current wireless systems, by adapting the proposals to each operator demands. This is a very important characteristic in comparison to the rigid standardization process of GSM for example, where a single option is envisaged and the possibility to have some impact on the standard changes is minor for their search community.

In OFDMA this is a major handicap as each subC has a different performance, so that the transmitter must be aware about the channel quality from all users and over all the subCs, representing a feedback load that is prohibitive in practical systems. Based on the large amount of required feedback (Changhee & Shroff, 2009), some proposals targeted random users and subCs selection (Zorba et al., 2009), while others developed a single bit feedback to indicate an ON-OFF state over all the subCs (Sanayei & Nosratinia, 2007). But in order to extract the gain from OFDMA systems, channel information is required and thus, the solution seems to be through feedback reduction techniques. Trivellato et al. (2009) mentioned each user is allowed to feedback over one subC, the one showing the highest Signal-to-Noise-Ratio (SNR), thus largely decreasing the feedback load, but then the achieved data rate is far from the maximum achievable one. In recent standardization activities of the 3GPP for the LTE technology (European Telecommunications Standards Institute, 2011), (Sesia et al., 2009), the option of Best-M scheme is recommended (Pedersen et al., 2007), where each user is asked to feedback the M subCs showing largest SNR values.

The heterogeneity of applications in the current and future telecommunication system necessitates characterization of the QoS, in terms of several metrics based on the required design (Jindal & Ramprashad, 2011). These metrics can be interpreted by minimum required rate and maximum tolerable SER for the reception quality, among others. This chapter tackles the aforementioned QoS for the Best-M scheme, where the serviced user has strict QoS demands in terms of its reception SER.

In order to optimize the Best-M feedback strategy and to characterize all the involved parameters, this chapter obtains the closed form expressions for its data rate and SER performance. Furthermore, with both the SER and data rate expressions, the system throughput is also obtained (Kim & Lee, 2012). Therefore, the Best-M scheme can be easily optimized by any commercial operator and/or manufacturer to account for each operating scenario conditions. In order to compare it to other feedback strategies, the resultant amount of feedback bits for the Best-M scheme is obtained. Thanks to the mathematical formulated expressions, interesting results are obtained about the impact of the number of available users, the average SNR and the allowed feedback load.

The remainder of this chapter is organized as follows: while section 2 deals with the Background, then system model in section 3, in section