Chapter 7
BER Fairness and PAPR Study of Interleaved OFDMA System

Sabbir Ahmed
Ritsumeikan University, Japan

Makoto Kawai
Ritsumeikan University, Japan

ABSTRACT
For an OFDMA system, the role of interleavers is analyzed to ensure fairness of BER performance among the active users and investigate their respective PAPR properties. In this paper, the authors consider a generic system and show that for a slowly changing multipath channel, individual user’s BER performance can vary, implying that the propagation channel effect is unfairly distributed on the users. Applying different types of frequency interleaving mechanisms, the authors demonstrate that random interleaving can ensure BER fairness on an individual user basis but the associated system overhead for de-interleaving is very high. In this context, the authors introduce the application of cyclically shifted random interleaver and demonstrate its effectiveness in achieving BER fairness (dispersion in individual users BER reduced by 94% compared to no interleaving at 20dB SNR) with little system overhead. The authors also explore the comparative performance of different interleavers for scenarios with varying number of total subcarriers and subcarriers per user. Based on the scenario specific results, the authors conclude that for a heavily loaded system, i.e., relatively low number of subcarriers per user, cyclically shifted random interleavers can effectively ensure uniform performance among active users with reduced system complexity and manageable PAPR.

1. INTRODUCTION
Future generation wireless communication systems demand multiple access schemes with capabilities of high data transmission even in very harsh propagation environment. In this context, Orthogonal Frequency Division Multiple Access or OFDMA, a multiple access scheme based on the well known Orthogonal Frequency Division Multiplexing (OFDM) technique, has drawn significant research interests. OFDM is known for its robust performance against inter-symbol interference (ISI) which is a common phenomenon in high speed data transmission, especially
under multipath propagation environment (Prasad, 2004). In addition, since OFDM employs overlapped carriers, its spectrum efficiency is also very good. Considering these, OFDMA appears to be a strong candidate as a future multiple access method. In fact, it has already been standardized for the PHY layer of IEEE 802.16 wireless metropolitan area networks (Marks, Stanwood, & Chang, 2004) and the downlink of 3GPP-LTE (http://www.3gpp.org).

In OFDMA, the task of subcarrier allocation amongst the active users is a crucial resource allocation issue. Based on the concept of OFDM, in OFDMA, the total available bandwidth is at first divided into narrowband orthogonal subchannels each having its own carrier known as subcarriers. Then users are assigned subcarriers (for that matter subchannels also) depending on different criteria. Literature survey reveals that the resource allocation problem is being investigated from different perspectives, e.g., joint power control, rate control and scheduling, data rate, type of data traffic, throughput and delay performances, fairness in throughput achievement, computational complexity, condition of the propagation channel and so forth (Kulkarni, Adlakha, & Srivastava, 2005; Cao, Tureli, & Liu, 2004; Toktas, Biyikoglu, & Yilmaz, 2009).

High peak to average power ratio (PAPR) is another important issue for any OFDM based system (Jiang & Wu, 2008). High PAPR in OFDMA signal means the possibility of BER due to non-linearity in power amplifier is also high. Due to its significant influence on the system performance, the problem of PAPR from the perspective of subcarrier allocation has also been addressed by some recent research works. In particular, Wang and Chen (2004) analyzed the relationship between asymptotic distribution of peak power of uplink OFDMA system and subcarrier allocation scheme and He, Xiao, and Li (2008) and Xiao, Peng, and Li (2007) proposed low complexity solutions for reducing high PAPR.

In this study, based on our previous works (Ahmed & Kawai, 2010, 2011) considering the downlink of a generic 64-IFFT OFDMA system, we investigate the impact of subcarrier allocation on the physical layer performance of the system on an individual user basis. We show that for a slowly changing multipath propagation environment, i.e., channel co-efficients remaining unchanged over many OFDM symbols, if subcarriers are allocated on a contiguous basis there may be significant amount of dispersion in the individual users BER performances. We refer to this disparity or non-uniformity as lack of fairness in BER. If BER performance is not fair, it implies that the SNR values required by individual users to attain a common acceptable BER varies over a very wide range, which in turn means the power control scheme needs to be strictly adjusted on an individual user basis. We replace this strict power control requirement by a central frequency interleaving mechanism and show that it can achieve BER fairness amongst the users. We show that interleaving the subcarriers in a randomized fashion achieves better fairness compared to fixed equidistant interleaving. But the associated overhead in the corresponding de-interleaving process is quite high and as such may seem infeasible to some extent. In this context, for achieving BER fairness with little system overhead, we introduce the application of cyclically shifted random interleaver and compare its performance with fixed and random interleavers. Cyclically shifted random interleaver is a modified version of a pure random interleaver that needs less memory space and low-side information transmission. We show that when BER fairness, reduction in SNR requirement for acceptable BER and system overhead all are taken into account, cyclically shifted random interleaver outperforms the others.

In order to look into the scalability issue, we then explore the comparative performance of these interleavers where different pertinent sys-