Chapter 13
Optimized-Fuzzy-Logic-Based Bit Loading Algorithms

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ABSTRACT

Next generation wireless communication systems promise the subscribers with Giga-bit-data-rate experience at low Bit Error Rate (BER) under adverse channel conditions. In order to maximize the overall system throughput of Orthogonal Frequency Division Multiplexing (OFDM), adaptive modulation is one of the key solutions. In adaptive modulated OFDM, the subcarriers are allocated with data bits and energy in accordance with the Signal to Interference Ratio (SIR) of the multipath channel, which is referred to as adaptive bit loading and adaptive power allocation respectively. The number of iterations required allocating the target bits and energy to a sub channel is optimized. The key choice of the paper is to allocate the bits with minimum number of iterations after clustering the sub channels using fuzzy logic. The proposed method exhibits a faster convergence in obtaining the optimal solution.

INTRODUCTION

OFDM is considered as the most widely adopted multicarrier communication technique for very high speed data transmission in wireless local area networks (WLAN) and digital subscriber link (DSL) systems. OFDM exhibits various advantages over the conventional single carrier communication systems. The OFDM systems are robust against frequency selective channels as the multipath channels effect as flat fading channels to individual subcarriers and hence one-tap equalization is made possible. The subcarriers in OFDM are orthogonal sine pulses so that the conventional frequency division multiplexing systems, the subcarriers can be closely spaced without interference, thereby improving spectral efficiency and reducing the total bandwidth requirements. Even though the time varying channels introduce inter carrier interference (ICI), several CFO estimation and correction techniques can be used to avoid this undesirable effect.

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In spite of these advantages of OFDM, a decrease in the performance occurs under multipath channels due to the fluctuations in the frequency response of the channels. This is severe in the case of highly frequency selective channels. The set of data to be transmitted are modulated onto orthogonal subcarriers which are summed up and transmitted through the channel. The multipath channel which is frequency selective in nature attenuates the data symbols modulated at different subcarriers differently. Certain subcarriers may be attenuated heavily so that the data symbols modulated on to those subcarriers are completely lost during transmission. Channel gain for certain other subcarriers will be very high. Hence, the system performance and throughput will be very much less than the optimum value if a fixed transmission scheme is used for OFDM transmission under a highly frequency selective channel. The data symbols modulated on to subcarriers which are attenuated heavily has very low SIR and hence high bit error rate which results in a poor performance. Hence, adaptive modulation aims at leaving out the subcarriers that are attenuated heavily and allocate bits to the subcarriers according to the channel gain. The adaptation of the modulation level according to the SIR results in better BER performance and high system throughput.

Several adaptive bit and power allocation loading schemes have been studied. The most powerful method to allocate bits with less energy is using Hughes-Hartogs Greedy Algorithm by (Hughes-Hartogs, 1988) but it takes a large number of iterations to converge to the optimal solution. Chow's Algorithm proposed by (Chow, Cioffi, & Bingham, 1995) uses channel capacity approximation and converges to the solution for given target bits and performance margin. Campello's Algorithm proposed by (Campello, 1999, 1998) is different in the way that it takes differential energy to achieve the target bits. But both these algorithms take a lot of iterations again. Simple bit loading algorithm proposed by (Nader-Esfahani & Afrasiabi, 2007) has low complexity and takes less iteration than Hughes Hartogs Greedy, Chow and Campello. It is based on grouping of sub channels based on gain. A clustering based bit loading algorithm which uses neural network for clustering the subcarriers is elaborated in (Birla, 2014). A computationally efficient bit loading algorithm for OFDM systems is proposed in (Vo, Amis, Chonavel, Siohan, & Member, 2015) which adaptively switches between Greedy algorithm and bit removing algorithm. The adaptive modulated multicarrier systems are also applied in the context of visible light communication (Hong, Member, Wu, Chen, & Member, 2016), power line communication (Gianaroli, Pancaldi, & Vitetta, 2015) and filter bank multicarrier based optical communication (Jung, Jung, & Han, 2015).

The proposed algorithm has very low computation complexity and is convergent to the optimal solution; moreover, it has low algorithmic complexity for implementation purposes. Grouping concept proposed by (Wang, Cao, & Statement, 2013; Nader-Esfahani & Afrasiabi, 2007) is used in proposed fuzzy based bit loading algorithm with very low complexity and less iteration with comparable energy as compared to existing algorithms. It is observed that maximum of 15 bits can be allocated to a sub-channel but for energy optimization with less iteration maximum of 11 bits can be allocated. Fuzzy is related to ambiguity. Fuzzy based Systems are based on Soft Threshold Concept where transitions are based on ambiguity i.e. various intervals can be decided based on discretion of user. So bit loading algorithms are optimized using fuzzy logic by (Sastry, 2010). The conventional bit loading algorithms require more number of iterations to find the optimum solutions and hence become difficult to be applied for real time applications. Hence in the present study, a fuzzy theory based solution is proposed for the adaptive bit loading problem formulated as a constrained optimization problem. In this chapter, an adaptive loading and modulation scheme is proposed in which all the parameters are adapted using a fuzzy logic base system. Rest of the chapter is organized as follows. Bit loading and Fuzzy introduction is given in the