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Near-Capacity-Achieving Design of BICM-ID Based IDMA

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Mobile wireless communication, in the last few decades, was an expensive communication medium, and therefore, only a few selected individuals of people and/or organizations could take benefits from it. Now, it has grown so rapidly and become ubiquitous communication tool that are commonly used by people all around the world. It started with analogue mobile radio systems in 1980s, known as the first generation or 1G, followed by 2G, the first digital mobile systems, then 3G, the first broadband multi-media mobile communication systems, and presently 4G evolution scenario-making is one of the hottest topics of discussion in the world. The basic concepts of our next mobile communication systems are to realize high data rate transmission, low latency, and low energy consumption. Many researchers have been devoted to developing such technology that can satisfy exponentially increasing high demands for a variety of services.

Shannon was the person who first derived the theoretical limits, known as Shannon limit, of data transmission in 1948. He showed that information can only be transmitted without any errors or arbitrarily low Bit Error Rate (BER) if the rate of channel coding is smaller than the so-called channel capacity. In other words, for the reliable transmission, the channel capacity must be larger than the data transmission rate. Therefore, approaching channel capacity or Shannon limit based on powerful channel coding schemes are required to enable high data rate transmission with efficient energy use. Because high order modulation can transmit several bits per symbol with a given signal point, it has been widely used to improve the bandwidth and power efficiency. However, since the complexity grows when the order of modulation increases, there is still a limit of using the very high order modulation, e.g. 256-QAM, 512-QAM.

It has been recognized that the joint design of coding and modulation can optimize the performance of the wired and wireless transmission systems. One of the well-known schemes based on this idea is Bit-Interleaved Coded Modulation with Iterative Detection/Decoding (BICM-ID). It is comprised of a serial concatenation of channel encoder, interleaver, and mapper at the transmitter. Iterative detection and decoding, following the turbo principle, is performed at the receiver side. It is found that the iterative demapping-and-decoding plays very important role in improving the performance of the system, where demapper and decoder exchange their *extrinsic* Log Likelihood Ratio (LLR) via interleaver and deinterleaver, respectively. According to the area property of the serially concatenated system, BICM-ID performance analysis can rely on the matching of the Extrinsic Information Transfer (EXIT) curves of the demapper and decoder. Several researches have been devoted to finding the design of the suitable coding scheme as well as the optimal symbol mapping, e.g. Quadratic Assignment Problem (QAP), Reactive Tabu Search (RTS), Binary Switching Algorithm (BSA), which can be seen simply as determining the mapping rule from binary vectors to complex constellation points.

Recently, Kisho Fukawa, a graduate from JAIST in March 2011, proposed an EXIT-constrained BICM-ID system, which uses simple single parity check and irregular repetition codes, combined with partial accumulator and unbalanced Extended Mapping (EM). He proposed an EXIT-constraint Binary Switching Algorithm (EBSA), which is simply seen as combining Linear Programming (LP) technique together with BSA, to design the optimal labeling mapping rule and the node degree distribution for the system. With this approach, it is guaranteed that very narrow convergence tunnel in the EXIT chart opens until the demapper and decoder curves reach closely (1.0, 1.0) point of the Mutual Information (MI), yielding a close Shannon limit threshold signal-noise-ratio (SNR), and no error floor. The BER performance shows that the threshold SNR of only roughly 0.54 dB away from the Shannon limit can be achieved. However, due to the DC-Offset problem, the BICM-ID with unbalanced mapping may not be practical for the real systems. The main reason that he used unbalanced EM instead of balanced EM is because of good matching between the demapper and decoder curves without crossing each other in the early point of MI. While this can not be avoided when the balanced EM is used; the crossing point of the two curves happen at the (0.0, 0.0) point of MI, and therefore, the LLR exchange does not start, yielding the system unworkable.

This thesis, first of all, introduce a Modulation Doping (MD) technique to solve the unbalanced mapping problem based on the same system model as that used in the unbalanced mapping case. It is found that, with this technique, even with balanced labeling mapping patterns the performance is as good as the one obtained by using unbalanced mapping scheme. This thesis further investigates the performance of the BICM-ID with higher order modulation. The results show that, to achieve a spectrum efficiency of 1.33 bits per 16-QAM symbol, the SNR threshold at only roughly 0.4 dB and 0.2 dB away from the Shannon and 16-QAM coding limit can be achieved, respectively, with the proposed technique. Finally, based on the key findings that the very good performances can be achieve with the proposed simple BICM-ID, this thesis applies the designed BICM-ID to Interleave Division Multiple Access (IDMA), which is considered a bandwidth efficient multiple access scheme for forth generation wireless communication systems. It is shown through simulation that the proposed BICM-ID based IDMA with Multiple User Detection (MUD) technique outperforms conventional IDMA systems, while the computational complexity is still very low.