EFFICIENT AND SECURE SYSTEM DESIGN
IN WIRELESS COMMUNICATIONS

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ABSTRACT

Efficient and secure system design in wireless communications

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Efficient and secure information transmission lies in the core part of wireless system design and networking. Comparing with its wired counterpart, in wireless communications, the total available spectrum has to be shared by different services. Moreover, wireless transmission is more vulnerable to unauthorized detection, eavesdropping and hostile jamming due to the lack of a protective physical boundary.

Today, the two most representative highly efficient communication systems are CDMA (used in 3G) and OFDM (used in 4G), and OFDM is regarded as the most efficient system. This dissertation will focus on two topics: (1) Explore more spectrally efficient system design based on the 4G OFDM scheme; (2) Investigate robust wireless system design and conduct capacity analysis under different jamming scenarios. The main results are outlined as follows.

First, we develop two spectrally efficient OFDM-based multi-carrier transmission schemes: one with message-driven idle subcarriers (MC-MDIS), and the other with message-driven strengthened subcarriers (MC-MDSS). The basic idea in MC-MDIS is to carry part of the information, named carrier bits, through idle subcarrier selection while transmitting the ordinary bits regularly on all the other subcarriers. When the number of subcarriers is much larger than the adopted constellation size, higher spectral and power efficiency can be achieved comparing with OFDM. In MC-MDSS, the idle subcarriers are replaced by strengthened ones, which, unlike idle ones, can carry both carrier bits and ordinary bits. Therefore, MC-MDSS achieves even higher spectral efficiency than MC-MDIS.

Second, we consider jamming-resistant OFDM system design under full-band dis-
guised jamming, where the jamming symbols are taken from the same constellation as the information symbols over each subcarrier. It is shown that due to the symmetricity between the authorized signal and jamming, the BER of the traditional OFDM system is lower bounded by a modulation specific constant. We develop an optimal precoding scheme, which minimizes the BER of OFDM systems under full-band disguised jamming. It is shown that the most efficient way to combat full-band disguised jamming is to concentrate the total available power and distribute it uniformly over a particular number of subcarriers instead of the entire spectrum. The precoding scheme is further randomized to reinforce the system jamming resistance.

Third, we consider jamming mitigation for CDMA systems under disguised jamming, where the jammer generates a fake signal using the same spreading code, constellation and pulse shaping filter as that of the authorized signal. Again, due to the symmetricity between the authorized signal and jamming, the receiver cannot really distinguish the authorized signal from jamming, leading to complete communication failure. In this research, instead of using conventional scrambling codes, we apply advanced encryption standard (AES) to generate the security-enhanced scrambling codes. Theoretical analysis shows that: the capacity of conventional CDMA systems without secure scrambling under disguised jamming is actually zero, while the capacity can be significantly increased by secure scrambling.

Finally, we consider a game between a power-limited authorized user and a power-limited jammer, who operate independently over the same spectrum consisting of multiple bands. The strategic decision-making is modeled as a two-party zero-sum game, where the payoff function is the capacity that can be achieved by the authorized user in presence of the jammer. We first investigate the game under AWGN channels. It is found that: either for the authorized user to maximize its capacity, or for the jammer to minimize the capacity of the authorized user, the best strategy is to distribute the power uniformly over all the available spectrum. Then, we consider fading channels. We characterize the dynamic relationship between the optimal signal power allocation and the optimal jamming power allocation, and propose an efficient two-step water pouring algorithm to calculate them.
PUBLICATIONS

Peer-Reviewed Journals


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