Performance of a Multiple-Access DCSK-CC System over Nakagami-m Fading Channels

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***Abstract*—In this paper[1], we propose a novel cooperative scheme to enhance the performance of multiple-access (MA) differential-chaos-shift-keying (DCSK) systems. We provide the bit-error-rate (BER) performance and throughput analyses for the new system with a decode-and-forward (DF) protocol over Nakagami-m fading channels. Our simulated results not only show that this system significantly improves the BER performance as compared to the existing DCSK non-cooperative (DCSK-NC) system and the multiple-input multiple-output DCSK (MIMO-DCSK) system, but also verify the theoretical analyses. Furthermore, we show that the throughput of this system approximately equals that of the DCSK-NC system, both of which have prominent improvements over the MIMO-DCSK system. We thus believe that the proposed system can be a good framework for chaos-modulation-based wireless communications.**

I. Introduction

In wireless communication applications, such as wireless personal area networks (WPAN) and sensor networks (WSN), multipath fading is a major factor that deteriorates the quality of information transmission. As a spread-spectrum modulation, differential chaos shift keying (DCSK) offers a promising solution to mitigate the effect of fading in such systems [1].

The DCSK communication system can be easily implemented in hardware since it can work without synchronization nor channel estimation but requiring only frame and symbol rate samplings, which makes it very promising in WPAN and WSN applications [2]. In recent years, some variants of the DCSK modulation technique have been proposed [3], [4]. Aiming to further overcome the signal fading arising from multipath propagation, cooperative diversity has been applied to the conventional DCSK system to construct a two-user cooperative DCSK system [5], [6].

Another desirable application of DCSK is to be combined with multiple-access (MA) techniques. Recently, a large amount of research work have been devoted to MA-DCSK systems [7], [8]. In particular, the Walsh code has been used to ensure the orthogonality of DCSK channels [8], so that the interference among different users can be avoided. In [9], the multiply-antenna relay was adopted in the MA-DCSK system (i.e., MIMO-DCSK system) to increase the robustness against signal fading. However, to the best of our knowledge, in all existing MA-DCSK systems, cooperative communication (CC) technique has never been applied, for which the cooperative method developed in [5], [6] is not applicable.

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In this paper, we propose a novel cooperative scheme for the MA-DCSK systems, forming a MA-DCSK-CC system, to improve the performance of communications. We analyze the bit-error-rate (BER) performance and the throughput of the new system under a decode-and-forward (DF) relaying protocol over Nakagami-m fading channels. Both theoretical analyses and computer simulations demonstrate that the proposed system has significant performance improvement in comparison with the DCSK non-cooperative (DCSK-NC) system and the MIMO-DCSK system. Moreover, we show that the throughput of the proposed system is almost the same as that of the DCSK-NC system, superior to that of the MIMO-DCSK system.

II. System Model

A. *Overview of MA-DCSK System*

For an N-user MA-DCSK system, the orthogonal Walsh code sequences are adopted to eliminate interference among users (i.e., there is no interference among users if Walsh code is used) [8]. In such a system, the 2^n-order Walsh code is defined to accommodate N users, where

$$W_{2^n} = \begin{pmatrix} W_{2^{n-1}} & W_{2^{n-1}} \\ W_{2^{n-1}} & -W_{2^{n-1}} \end{pmatrix}, \quad n = 1, 2, ... \tag{1}$$

in which $2^n = 2N$ and $W_{2^0} = W_1 = 1$.

Each DCSK modulated signal includes $2N$ sub-segments. Let β denote the length of each carrier segment (i.e., sub-spreading factor). Then, the global spreading factor is kept at $2N\beta$. The lth transmitted signal of the Kth user is given by

$$s_{K,b_l} = \sum_{j=0}^{2N-1} w_{2K-b_l,j}\, c\left(t - j\frac{T}{2N}\right), \quad 0 < t < T \tag{2}$$

where $b_l = \{0, 1\}$ represents the lth transmitted symbol, $w_{i,j}$ represents the (i, j)th element of the $2N$-order Walsh code, and $c(t)$ represents the chaotic carrier.

At the receiver, we assume perfect timing synchronization and utilize the generalized maximum likelihood (GML) detector [10] to demodulate the received signals.

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