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Coded cooperation diversity for uncoded oversampled OFDM systems

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ABSTRACT

Recently, user-cooperation diversity has been introduced as an effective scheme that can bring about antenna diversity in wireless networks. In this paper, we introduce a coded cooperation diversity technique for single antenna uncoded orthogonal frequency division multiplexing (OFDM) systems, in which implementation of coded cooperation is provided by the oversampling potential in OFDM, instead of using extra channel coding. In fact, zero-padding followed by IFFT in OFDM is similar to oversampling and could be an alternative to applying correction codes. Furthermore, we use this oversampling to implement an iterative receiver at the partner terminal. This receiver works based on the nonuniform sampling theorem for reconstructing of lost symbols. The lost symbols appear at the partner terminal of cooperative network because of dividing each OFDM block into two segments through the puncturing at the user terminal of the cooperative network. We provide simulation results for our proposed scenario, and observe significant gains over the non-cooperative oversampled OFDM systems without any need whatever for using extra channel coding.

1. Introduction

Signal quality in mobile radio channels is severely affected by undesirable channel quality due to the effects of multi-path fading, in which mobile users experience strong variations in signal attenuation during a given call. Recently, user-cooperation diversity has been emerged as a new form of spatial diversity, whereby diversity gains are attained via cooperation of sparse terminals in wireless networks. This diversity technique enables terminals, where it is not easy to be equipped by multiple antennas due to size and cost limitations, to obtain higher data rates which are less prone to channel variations [1–3]. Coded cooperation scheme using channel coding for cooperative systems has been proposed in [4–6], for its efficient usage of the available bandwidth. This cooperative transmission protocol should be implemented in state-of-the-art transmission technologies, such as orthogonal frequency division multiplexing (OFDM), that has recently received substantial attention in the areas of wireless communication systems for its simple implementation with FFT/IFFT pairs, efficient use of the available bandwidth, and robustness to frequency selective fading [7,8].

For the first time in this paper, we will use the oversampling potential for implementing the coded cooperative diversity in OFDM systems as an alternative for using formal channel coding. In fact, the oversampling can act as an error-correction code without the need for the complex Viterbi decoding algorithm used in decoding convolutional codes in the conventional coded cooperative systems. Oversampling is performed by padding the QAM modulating sequence with some zeros before IFFT at the transmitter of OFDM systems to provide oversampled OFDM systems, a special case of the precoded OFDM systems, known as the zero-padded OFDM (ZP-OFDM) systems by the papers of the past [9,10]. However,

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oversampling can be considered for providing other properties as well, such as decreasing edge effects of OFDM signal in frequency domain, channel estimation, and PAPR reduction, as explored in [11–14]. The oversampling in our proposed cooperative system is used for two reasons. First, this oversampling provides a special DFT code (or a Reed Solomon code in real field) without any need for using extra channel coding which is mandatory for putting the coded cooperative diversity schemes into practice. We use the oversampling potential secondly to reconstruct the lost QAM modulated symbols of each OFDM symbol at the partner terminal. In fact, our cooperative scheme partitions each user's OFDM symbol into the two segments through puncturing. So, the partner terminal should reconstruct user's OFDM symbol from a received version which has lost some of its QAM modulated symbols. However, if the average symbol rate of the remaining QAM modulated symbols stays above the Nyquist rate, as the nonuniform sampling theorem states, complete recovery of each OFDM symbol would be possible [15]. This perfect reconstruction can be guaranteed at the partner terminal if the high enough oversampling factor is chosen at the user terminal. Therefore, using the iterative receiver working base on the nonuniform sampling theory at the partner terminal can be a proper choice for its simple implementation.

The rest of this paper is organized as follows. In Section 2, the oversampled OFDM system and the iterative receiver included in our coded cooperative scheme are reviewed. In Section 3, we describe the proposed coded cooperation model in the oversampled OFDM system. Simulation results illustrating the performance of the oversampled OFDM for the coded cooperation scenario are presented in Section 4. Section 5 is dedicated to concluding remarks and future works.

2. Iterative receiver for oversampled OFDM systems

2.1. Oversampled OFDM transmitter

Fig. 1 gives the simplified model of oversampled OFDM transmitter. Let $\mathbf{c}$ stand for the information symbols after the QAM modulation and segmentation into blocks with size K,

$$\mathbf{c} = [c_1, c_2, \ldots, c_K]^{\mathrm{T}} \tag{1}$$

Then $(L-1)K$ trailing zeros are padded after each $\mathbf{c}$ to form a $N \times 1$ column vector of $\mathbf{c}' = [c_1, c_2, \ldots, c_K, 0, \ldots, 0]^{\mathrm{T}}$. L can be considered as an oversampling factor and in the case of the conventional OFDM system, $L = 1$, corresponding to the Nyquist symbol rate. Let N be the number of subcarriers in the OFDM system. Hence, N symbols of $\mathbf{c}'$ are transmitted at the same time in one OFDM symbol $\mathbf{s}$, which is a N-point IFFT transformed version of $\mathbf{c}$. It has been shown that $\mathbf{s}$ is a special DFT coded version of $\mathbf{c}$ that can be expressed as [15–17]

$$\mathbf{s} = \mathbf{Gc} \tag{2}$$

where $\mathbf{G}$ is the generator matrix. In the next section, we will see that in the proposed coded cooperation scheme, the oversampled OFDM transmitter partitions $\mathbf{s}$ into the two segments through $N \times N$ puncturing matrix of $\mathbf{P}$ and sends only one of these segments. The channel is assumed to be quasi-static frequency selective Rayleigh fading corrupted by $N \times 1$ additive white Gaussian noise (AWGN) vector of $\mathbf{v} = [\nu_1, \nu_2, \ldots, \nu_N]^{\mathrm{T}}$ at the receiver.

2.2. Iterative receiver

One can estimate $\mathbf{s}$ from its punctured version, $\mathbf{t}$, perfectly by the iterative receiver shown in Fig. 2 if a high oversampling factor, L, is chosen at the transmission side. This iterative receiver works based on the nonuniform sampling theorem [15]. Hence, as long as the average symbol rate of $\mathbf{t}$ stays above the Nyquist rate, perfect reconstruction of $\mathbf{s}$ would be possible. This iterative receiver consists of two main blocks, namely filtering and iterative reconstruction.

2.3. Linear filtering

The filtering stage begins by removing the interference among different symbols that can be carried out by time domain ZF equalization:

$$\widehat{\mathbf{t}} = \mathbf{t} + \mathbf{H}^{-1}\mathbf{v}' \tag{3}$$

where $\mathbf{t}$ is the punctured vector at the transmitter after N-point IFFT modulator (time domain transmitted signal), $\mathbf{H} = diag(H_1, H_2, \ldots, H_N)$, a diagonal matrix with diagonal elements $(H_1, H_2, \ldots, H_N)$, is the channel in the time domain and $\mathbf{v}'$ is $N \times 1$ AWGN noise. Note that multipath effects of quasi-static Rayleigh fading channel can be

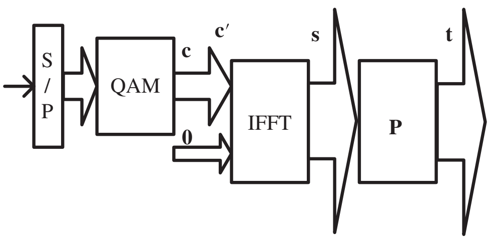

Fig. 1. Transmitter of the oversampled OFDM system.

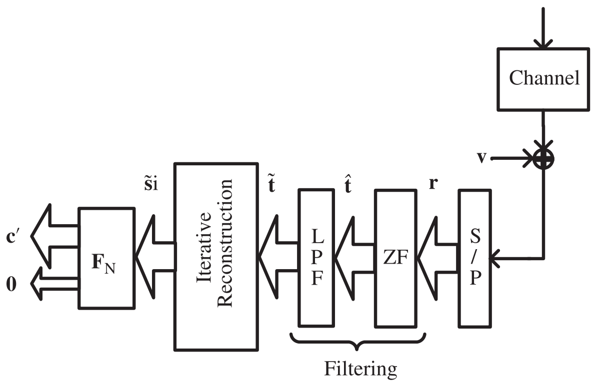

Fig. 2. The Iterative receiver for oversampled OFDM system.