Journal of Network and Computer Applications 36 (2013) 1018–1026

Contents lists available at SciVerse ScienceDirect

Journal of Network and Computer Applications

journal homepage: www.elsevier.com/locate/jnca

Performance improvement of QO-STBC over time-selective channel for wireless network

Youxiang Wang [a], Jianquan Wang [a], Zhaobiao Lu [a], Xingang Liu [b,*]

[a] Network Technology Research Center, China Unicom Research Institute, Beijing, China
[b] School of Electronic Engineering, UESTC, Chengdu, China

ARTICLE INFO

Article history:
Received 15 July 2011
Received in revised form
1 January 2012
Accepted 12 January 2012
Available online 25 January 2012

Keywords:
QO-STBC
Time-selective channel
DFE
ZF
MMSE

ABSTRACT

Signal detection for vehicle-to-vehicle and wireless network application has motivated new design for conditions in which channel is time-selective fading. Since the physical layer (PHY) forms the foundation of the communication protocol stack, the performance of this layer affects all high layers of the system stack. Quasi-orthogonal space-time block code (QO-STBC) can provide full rate transmission and partial diversity under low decoding complexity. Previous papers on QO-STBC assume that the channels are slow fading or remain static over the length of the codeword. However, time-selective channels do exist, and in this case, the decoder proposed in Jafarkhani (2001) cannot be used to achieve a proper error performance. In order to mitigate the severe performance degradation, the zero forcing (ZF) and minimum mean square error (MMSE) decoders are employed in this paper. We also propose a zero forcing interference cancellation decision-feedback equalizer (ZF-IC-DFE) and a minimum mean-square error interference cancellation decision-feedback equalizer (MMSE-IC-DFE) via Cholesky factorization of the channel Gram matrix after performing interference cancellation. By feeding back past decisions on previously detected symbols, DFE schemes can achieve an additional performance gain compared to their corresponding linear decoders.

© 2012 Elsevier Ltd. All rights reserved.

1. Introduction

In future, signal detection for vehicle-to-vehicle and wireless network application has motivated new design for conditions in which channel is time-selective fading. Since the physical layer (PHY) forms the foundation of the communication protocol stack, the performance of this layer affects all high layers of the system stack. Some research has also begun to make new design to reduce the time-selective fading channel effect on transmission performance to high layers.

Alamouti (1998) first proposed an elegant space-time block coding scheme for transmission with two transmit antennas. This scheme achieves full diversity gain using a linear maximum-likelihood (ML) decoder over flat fading or quasi-flat fading channels. Tarokh et al. (1999) introduced the concept of orthogonal space-time block codes (OSTBCs) from orthogonal designs. These orthogonal code matrices lead to full diversity and low decoding complexity at the receiver. Unfortunately, they incur a loss of data rate under complex constellations. In fact, full rate complex transmission is achievable only in the case of two transmit antennas (Tarokh et al., 1999). To improve the data rate of space-time block code (STBC) with four transmit antennas, several quasi-orthogonal space-time block codes (QO-STBCs) have been proposed (see Sharma and Papadias, 2003; Tirkkonen et al., 2000 and the references therein). Although these QO-STBCs provide a lower diversity order, they do lead to full rate transmission.

Most existing results on QO-STBCs assume that channel remains static over the length of the codeword. This is reasonable when the channel changes gradually with respect to the symbol rate. While such an assumption is approximately valid in most cases, fast fading or time-selective channels do exist. For example, a third-generation European cellular standard is required to operate on trains with a speed up to 500 km/h, which can induce Doppler shifts up to 800 Hz for a carrier frequency of 2 GHz (Tran and Sesay, 2004). In such a communication scenario, the channel may vary significantly from symbol-to-symbol. In wireless communications, time selectivity is mainly caused by Doppler shifts and carrier frequency offsets, which are jointly independent. It has been proved that the first-order Gauss–Markov random process provides an accurate model for time-selective fading channels, and therefore, this channel model is adopted in this paper (Wang and Chang, 1996).

When the channels are time-selective fading, the interference can not be completely eliminated by the linear combiner causing performance degradation (Jafarkhani, 2001; Liu et al., 2000). Under this condition, a linear quasi-ML decoder with an interference suppression scheme was proposed in order to mitigate the effect

* Corresponding author.
E-mail address: hanksliu.xg@gmail.com (X. Liu).

1084-8045/$ - see front matter © 2012 Elsevier Ltd. All rights reserved.
doi:10.1016/j.jnca.2012.01.005

from time-selective fading channels (Tran and Sesay, 2004). Zheng and Burr (2003, 2004) extended the linear quasi-ML decoder from two to four transmit antennas. This method diagonalizes the channel matrix at each receive antenna in order to cancel the interference, at the same time the conditional noise covariance is achieved which results in degraded performance.

Liu et al. (2002) propose a simple linear near-ML decoder where the decision statistics is computed in the same way as if the channel is quasi-static by assuming that the variation between adjacent channel gains is small (Tran and Sesay, 2004). The simulation results show that the linear near-ML decoder exhibits error floors at high signal-to-noise ratio (SNR) values since the interantenna inter-ference (IAI) occurs when the channel varies from symbol to symbol.

In this paper, we propose two decoders for the QO-STBC proposed in Jafarkhani (2001) for wireless communications over time-selective fading channels. We adopt the auto-regression (AR) model to model the time-selective fading channel and study the effect of it on the channel Gram matrix (Slock, 2007). And from the analysis we know that the channels' time-selectivity causes IAI on the off-diagonal elements (elements other than the diagonal elements and anti-diagonal (Horn and Johnson, 1985) elements of the Gram matrix) of the channel Gram matrix which degrades the system performance. In our proposed decoders, we develop a novel interference cancellation method to remove IAI between the four transmit antennas. The two decoders consist of three parts, in the first two parts (ZF-IC or MMSE-IC) of which interference due to off-diagonal elements of the channel Gram matrix is canceled, and in the last part (DFE) of which interference due to anti-diagonal elements of the channel Gram matrix is removed.

This paper investigates efficient detection method for quasi-orthogonal space-time block code (QO-STBC) in time-selective fading channel. In PHY, channel condition is the main point to affect signal recovering. For time-selective fading channel, the interference caused can not be eliminated by the traditional methods. In this case, we design two three-step decoding methods to mitigate the severe performance degradation. The proposed methods have better performance than their corresponding linear decoders and some existing decoders.

We begin by establishing the channel and system models in Section 2. Efficient interference cancellation techniques are shown in Section 3 that are based on different criteria. Section 4 presents a theoretical performance analysis of the proposed decoders. Section 5 considers the simulation results and complexity analysis, and some computer simulation results are presented to confirm our schemes. Conclusions are given in Section 6.

The following notation will be adopted in this paper. Column vectors and matrices are denoted by boldface letters; superscripts $(\cdot)^T$, $(\cdot)^*$, and $(\cdot)^H$ denote the transpose, complex conjugate, and complex conjugate transpose, respectively; $E[\cdot]$ stands for the expectation; I_N denotes the $N\times N$ identity matrix, and the subscript N is omitted when the dimension of the matrix I is obvious.

2. System model

2.1. Channel model

Consider a wireless system equipped with $M_T=4$ transmit antennas and M_R receive antennas as shown in Fig. 1, where symbols are transmitted using a quasi-orthogonal space-time block encoder.

We consider the communication scenario where the relative motion between the transmitter and receiver is significant. Therefore, the channel coherence time is comparable to the symbol duration. The channel is modeled as uncorrelated frequency-flat, time-selective Rayleigh fading. We adopt the first-order AR model for the time-varying channel gains (Wang and Chang, 1996). The channel gain $h_{j,i}(n)$, which indicates the channel coefficient from transmit antenna i to the receive antenna j, is modeled as independently identically distributed (i.i.d.) circularly complex Gaussian random variables with zero-mean and variance $\sigma_h^2=1$. The channel gains are assumed to be invariant during one signaling interval but vary from one signaling interval to another according to

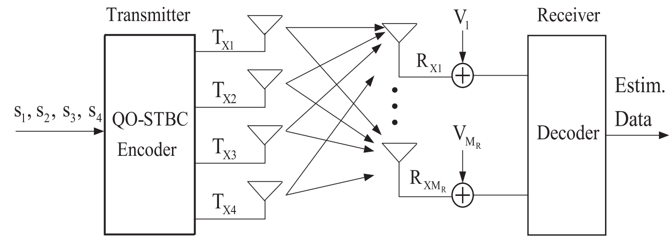

Fig. 1. Model of a MIMO system with M_T–T_x and M_R–R_x.

$$h_{j,i}(n)=\alpha h_{j,i}(n-1)+\omega_{j,i}(n)$$
$$i=1\ldots M_T,\, j=1\ldots M_R, \tag{1}$$

where the complex variable $\omega_{j,i}(n)$ is a zero-mean with variance σ_ω^2 and is statistically independent of $h_{j,i}(n-1)$, and the coefficient α can be estimated as detailed in Wang and Chang (1996). As $h_{j,i}(n)$ is a zero-mean, unit-variance complex Gaussian variable, it follows that:

$$|\alpha|^2+\sigma_\omega^2=\sigma_h^2=1 \text{ and } \alpha=E[h_{j,i}(n)h_{j,i}^*(n-1)] \tag{2}$$

According to Jake's model (Liu et al., 2002), a time-varying fading channel $h_{j,i}(n)$ is a zero-mean complex Gaussian process, and it has time-autocorrelation properties governed by the Doppler rate f_dT_s given as

$$E[h_{j,i}(n)h_{j,i}^*(n-1)]=J_0(2\pi f_d T_s), \tag{3}$$

where $J_0(\cdot)$ is the zeroth-order Bessel function of the first kind, f_d denotes the maximum Doppler shift, and T_s is the symbol duration.

2.2. Quasi-orthogonal STBC transmission scheme

The Alamouti code (1998) has two complex modulation symbols s_1 and s_2, which are transmitted from two antennas during two signaling intervals, using the code matrix:

$$\mathbf{S}_{12}=\begin{bmatrix} s_1 & s_2 \\ -s_2^* & s_1^* \end{bmatrix}. \tag{4}$$

As a complex orthogonal design that provides full rate and full diversity for a space-time block code is not possible for more than two transmit antennas, some new quasi-orthogonal space-time block codes have been proposed to provide full rate.

Jafarkhani (2001) first proposed a space-time block code from quasi-orthogonal design. For four transmit antennas, a code with transmission rate one was extended from the concept of the Alamouti scheme as follows:

$$\mathbf{S}=\begin{bmatrix} \mathbf{S}_{12} & \mathbf{S}_{34} \\ -\mathbf{S}_{34}^* & \mathbf{S}_{12}^* \end{bmatrix}=\begin{bmatrix} s_1 & s_2 & s_3 & s_4 \\ -s_2^* & s_1^* & -s_4^* & s_3^* \\ -s_3^* & -s_4^* & s_1^* & s_2^* \\ s_4 & -s_3 & -s_2 & s_1 \end{bmatrix}. \tag{5}$$

In observing matrix $\mathbf{S}$, we can think of the vertical dimension as representing "time" and of the horizontal dimension as representing "space".

Assuming a fading propagation environment and one receive antenna (we define the index of h_i as the number of transmit antennas i to replace (j,i)), the received signal $[r(4n-3) \quad r(4n-2)$

Download English Version:

https://daneshyari.com/en/article/457318

Download Persian Version:

https://daneshyari.com/article/457318

Daneshyari.com