Combined Coding and Spreading in CDMA Systems using Maximum Free Distance Convolutional Codes

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Abstract— In CDMA systems maximum theoretical performance can be obtained by spreading with low-rate error-control codes. Previously, orthogonal and superorthogonal codes have been proposed for this purpose. We present in this paper a family of rate-compatible low-rate convolutional codes with maximum free distance. The performance of these codes for spectrum spreading in a CDMA system is evaluated and shown to outperform that of orthogonal and superorthogonal codes as well as conventional coding/spreading schemes. We also show that our low-rate codes will give simple encoder and decoder implementation. With these codes any $1/n$ rate can be obtained regardless of the constraint length, resulting in a more flexible and powerful scheme than those proposed up to now.

Keywords— CDMA, low-rate convolutional codes, orthogonal codes, superorthogonal codes, rate-compatible, maximum free distance.

I. Introduction

SPREAD spectrum systems have been used for decades as a way of achieving robustness against interference and jamming by means of spectrum spreading [1]. The spread spectrum technique is now also becoming popular in commercial systems because of its inherent robustness in multipath fading channels, and as a promising multiple-access technique. As a multiple-access method, most interest has been given to direct-sequence code-division multiple-access (DS-CDMA), where spreading is achieved by multiplication of the signal by a pseudo-random spreading sequence. In order to achieve sufficiently low error rates with such a system, some kind of multiuser detection technique must normally be applied. Recent results though, indicate that, compared to the conventional detector, such multiuser detectors are rather sensitive to errors in the channel parameter estimates [2]. This fact indicates that complexity might be better spent on implementation of powerful channel coding schemes. Bandwidth spreading can also be obtained by the redundancy added by error correcting codes. In a conventional narrow-band communication system this bandwidth increase is generally an undesired feature. However, in spread spectrum systems, maximum theoretical performance is achievable by employing low-rate channel codes alone for bandwidth expansion [3,4]. We will refer to spreading by channel codes only as combined coding and spreading or code-spreading. A limiting factor though, has been the lack of good low-rate codes. The work of [3] proposes the use of orthogonal convolutional codes [5], and an investigation of the performance of a such a system with orthogonal convolutional codes is given in [6]. A comparison between orthogonal and biorthogonal codes for CDMA is given in [7]. Modifying the orthogonal codes, one can obtain an improved class of low-rate codes called superorthogonal convolutional codes [8]. In this paper we present low-rate convolutional codes with maximum free distance (MFD) for different constraint lengths and code rates between $R = 1/4$ and $R = 1/512$. We further show that the structure of these codes leads to simple encoder and decoder implementation. It will also be straightforward to change the spreading factor to achieve multiple rates and variable processing gains. Furthermore, the performance of this code-spread multiple-access system is superior to both that of conventional spread systems with higher rate coding, and that of low-rate orthogonal and superorthogonal convolutional code-spread systems.

II. Low-rate Codes for CDMA Systems

The low-rate codes, proposed for spectrum spreading in this paper, are obtained from feed-forward convolutional encoders giving minimum information error. We therefore start by a short description of these codes. We define an *optimum distance spectrum* (ODS) convolutional code as a code generated by a feed-forward encoder giving superior distance spectrum compared to all other feed-forward encoders with the same rate and constraint length, where the term *superior distance spectrum* is defined as:

Definition 1 (Superior Distance Spectrum)
A feed-forward encoder with error weights c_d, giving a code with free distance d_f has a distance spectrum superior to a feed-forward encoder with error weights $\tilde{c}_d$ giving a code with free distance $\tilde{d}_f$, if one of the following conditions is fulfilled: (1) $d_f > \tilde{d}_f$ or (2) $d_f = \tilde{d}_f$ and there exists an integer $l \geq 0$ such that $c_d = \tilde{c}_d$, for $d = d_f, d_f + 1, \ldots, d_f + l - 1$ and $c_d < \tilde{c}_d$, for $d = d_f + l$.

An exhaustive computer search, using the algorithm described in [9] for calculating the distance spectrum, has been performed to obtain feed-forward encoders giving optimum distance spectrum for the code rates $1/2$, $1/3$ and $1/4$ and different constraint lengths [10].

Low-rate convolutional codes for combined coding and spreading are found by searching additional polynomials to the encoder of a rate $R = 1/4$ ODS code (nested encoder search). The additional generator polynomial giving the best rate $R = 1/5$ encoder is found by an exhaustive

Coding Spreading Tradeoff In Cdma Systems

Zuqiang Tang

Coding Spreading Tradeoff In Cdma Systems:

    Coding-Spreading Tradeoff in CDMA Systems Eduardo J. Bolas,2002-09-01 In this thesis we investigate the usage of low rate codes primarily to provide the total bandwidth expansion required for a CDMA system Comparing different combinations of coding and spreading with a traditional DS CDMA as defined in the IS 95 standard allows the criteria to be defined for the best coding spreading tradeoff in CDMA systems The analysis of the coding spreading tradeoff is divided into two parts The first part is dedicated to the study of the deterministic components of the problem This includes the different factors with non random behavior that the system s designer can determine The processing gain the code characteristics and the number of users are well defined variables that can determine the overall performance and can consequently affect the tradeoff The second part of the study is dedicated to analyzing different combinations of coding and spreading with no ideal channel estimation and interference reduction techniques Small scale fading channel conditions are emulated through Nakagami m distribution Large scale path loss was incorporated through the extended Hata model while Lognormal shadowing considered the fluctuations on the received power at points with the same distance to the transmitter We assessed the performance of different combinations of coding and spreading considering in two cases a worst case scenario in which the mobile user was located at the corner of a hexagon cell in a seven cell cluster and a more realistic scenario in which the user could be physically located anywhere in the cell following a uniform probability distribution function Furthermore we investigated the improvement in performance generated by interference reduction techniques such as sectoring and power control **THE CODING-SPREADING TRADEOFF PROBLEM IN FINITE-SIZED SYNCHRONOUS DS-CDMA SYSTEMS.** Zuqiang Tang,2005 This dissertation provides a comprehensive analysis of the coding spreading tradeoff problem in finite sized synchronous DS CDMA systems In contrast to the large system which has a large number of users the finite sized system refers to a system with a small number of users Much work has been performed in the past on the analysis of the spectral efficiency of synchronous DS CDMA systems and the associated coding spreading tradeoff problem However most of the analysis is based on the large system assumptions In this dissertation we focused on finite sized systems with the help of numerical methods and Monte Carlo simulations Binary input achievable information rates for finite sized synchronous DS CDMA systems with different detection decoding schemes on AWGN channel are numerically calculated for various coding spreading apportionments We use these results to determine the existence and value of an optimal code rate for a number of different multiuser receivers where optimality is in the sense of minimizing the SNR required for reliable multiuser communication Our results are consistent with the well known fact that all coding no spreading is optimal for the maximum a posteriori receiver Simulations of the LDPC coded synchronous DS CDMA systems with iterative multiuser detection decoding and MMSE multiuser detection single user decoding are also presented to show that the binary input capacities can be closely approached with practical schemes The coding spreading tradeoff is examined

using these LDPC code simulation results where agreement with the information theoretic results is demonstrated We extend our work to the DS CDMA systems on two idealized Rayleigh flat fading channels the chip level flat fading CLFF and the code symbol level flat fading SLFF These models represent ideal fast fading and slow fading channels respectively Both information theoretic results and LDPC code simulation results are presented to show the effects of channel fading on system performance and the coding spreading tradeoff It is shown that fast fading can be beneficial to system performance under the condition of perfect channel state information at receiver but slow fading is very harmful Slow fading also increases the importance of coding greatly compared to the AWGN and fast fading Finally we present some comparisons with large system results on AWGN and CLFF channels which show both consistencies and discrepancies *Information Theory and Coding for Spread Spectrum Communication Systems* Mehul Motani,2000 **Signal Processing for Wireless Communication Systems** H. Vincent Poor,Lang Tong,2006-01-19 Signal Processing for Wireless Communication Systems brings together in one place important contributions and up to date research results in this fast moving area The Contributors to this work were selected from leading researchers and practitioners in this field The book s 18 chapters are divided into three areas systems Networks and Implementation Issues Channel Estimation and Equalization and Multiuser Detection The Work originally published as Volume 30 Numbers 1 3 of the Journal of VLSI Signal Processing Systems for Signal Image and Video Technology will be valuable to anyone working or researching in the field of wireless communication systems It serves as an excellent reference providing insight into some of the most challenging issues being examined today **Bandwidth Allocation and Tradeoffs of Source Coding, Channel Coding and Spreading in CDMA Systems** Qinghua Zhao,2004 **1997 IEEE 6th International Conference on Universal Personal Communications Record** ,1997 Coded Modulation Systems John B. Anderson,Arne Svensson,2006-04-11 Coded Modulation Systems is an introduction to the subject of coded modulation in digital communication It is designed for classroom use and for anyone wanting to learn the ideas behind this modern kind of coding Coded modulation is signal encoding that takes into account the nature of the channel over which it is used Traditional error correcting codes work with bits and add redundant bits in order to correct transmission errors In coded modulation continuous time signals and their phases and amplitudes play the major role The coding can be seen as a patterning of these quantities The object is still to correct errors but more fundamentally it is to conserve signal energy and bandwidth at a given error performance The book divides coded modulation into three major parts Trellis coded modulation TCM schemes encode the points of QAM constellations lattice coding and set partition techniques play major roles here Continuous phase modulation CPM codes encode the signal phase and create constant envelope RF signals The partial response signaling PRS field includes intersymbol interference problems signals generated by real convolution and signals created by lowpass filtering In addition to these topics the book covers coding techniques of several kinds for fading channels spread spectrum and repeat request systems The history of the subject is fully traced back

to the formative work of Shannon in 1949 Full explanation of the basics and complete homework problems make the book ideal for self study or classroom use   **Advances in Informatics** Panayiotis Bozanis,2005-10-26 This book constitutes the refereed proceedings of the 10th Panhellenic Conference on Informatics PCI 2005 held in Volas Greece in November 2005 The 83 revised full papers presented were carefully reviewed and selected from 252 submissions The papers are organized in topical sections on data bases and data mining algorithms and theoretical foundations cultural and museum information systems internet scale software information systems wearable and mobile computing computer graphics virtual reality and visualization AI machine learning and knowledge bases languages text and speech processing bioinformatics software engineering educational technologies e business computer and sensor hardware and architecture computer security image and video processing signal processing and telecommunications computer and sensor networks   *IEEE International Conference on Personal Wireless Communications* ,2000   *Proceedings of the ... Conference on Information Sciences and Systems* ,1996   **Adaptive Signal Processing in Wireless Communications** Mohamed Ibnkahla,2017-12-19 Adaptive techniques play a key role in modern wireless communication systems The concept of adaptation is emphasized in the Adaptation in Wireless Communications Series through a unified framework across all layers of the wireless protocol stack ranging from the physical layer to the application layer and from cellular systems to next generation wireless networks This specific volume Adaptive Signal Processing in Wireless Communications is devoted to adaptation in the physical layer It gives an in depth survey of adaptive signal processing techniques used in current and future generations of wireless communication systems Featuring the work of leading international experts it covers adaptive channel modeling identification and equalization adaptive modulation and coding adaptive multiple input multiple output MIMO systems and cooperative diversity It also addresses other important aspects of adaptation in wireless communications such as hardware implementation reconfigurable processing and cognitive radio A second volume in the series Adaptation and Cross layer Design in Wireless Networks cat no 46039 is devoted to adaptation in the data link network and application layers   **Proceedings & Exhibition--future Access** ,2005   **The 11th IEEE International Symposium on Personal, Indoor and Mobile Radio Communications** ,2000   **IEEE International Conference on Communications, 1994** IEEE Communications Society,1994   1996 Fifth IEEE International Conference on Universal Personal Communications Record ,1996   **International Conference on Universal Personal Communications** ,1997   *Proceedings* ,2004   *Wireless Applications of Spread Spectrum Systems* Sawasd Tantaratana,Kazi M. Ahmed,1998 These selected readings bring together introductory and advanced papers on various wireless applications of spread spectrum technology The papers are grouped into sections according to the application areas spread spectrum technology cellular mobile systems satellite communications wireless local area networks and the global positioning system GPS   Conference Record ,1994   *Dissertation Abstracts International* ,2006

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