Multi User Detection in Multi Carrier- Direct Sequence Code Division Multiple Access (DS-CDMA) System

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Abstract- *Wireless transmissions are affected by non-ideal channel conditions, including multipath fading and multiple-access interference (MAI). To alleviate the effects of such conditions, several approaches that are designed to improve system capacity and transmission reliability have been proposed in recent years. This paper presents the reduced complexity and effective, multiuser detectors (MUDs) for the uplink of spatial–frequency–time-domain (SFT-domain) spread multicarrier (MC) direct-sequence code-division multiple-access (DS-CDMA) systems. Each MUD first converts a received signal into the corresponding format. It detects the transmitted symbols iteratively by using a one-domain minimum-mean-square-error (MMSE) detector and a two-domain MMSE detector alternately. Performance analyses of the bit-error-rate (BER) bound, the convergence, and the required computational complexity are conducted to assess the feasibility of the proposed MUDs. Finally, the results of computer simulations demonstrate that the performance of the proposed schemes is close to that of the joint SFT-domain MMSE MUD in most scenarios but with lower computational complexity.*

Keywords- Direct Sequence Code-division multiple access (DS-CDMA), Minimum Mean Square Error (MMSE), Multipath fading, multiple-Access Interference (MAI), Multiuser Detector (MUD).

I. INTRODUCTION

Multiple Accesses is a technique where many subscribers or local stations can share the use of the use of a communication channel at the same time or nearly so despite the fact originate from widely different locations. The channel can be defined as a portion of the limited radio resource, which is temporarily allocated for a specific user, such as someone’s phone call. A multiple access method is a definition of how the radio spectrum is divided into channels and how the channels are allocated to the many users of the system. There are three basic techniques of multiple accesses.

1. Frequency Division Multiple Access (FDMA)
2. Time Division Multiple Access (TDMA)
3. Code Division Multiple Access (CDMA)

In telecommunications and wireless networks, a channel access method or multiple access method allows several terminals connected to the same multi-point transmission to transmit over it and to share its capacity. The examples of shared physical media are wireless networks, bus networks, ring networks, hub networks and half-duplex point-to-point links. The channel-access method is based on a multiplexing method that allows communication channel or physical medium.

Multiplexing technique is in this context provided by the physical layer. The multiplexing technique also may be used in full-duplex point-to-point communication between nodes in a computer switched network, which should not be considered as multiple access methods. A channel-access scheme is also based on a multiple access protocol and control mechanism, also known as media access control (MAC). This protocol deals with issues such as addressing, allocating multiplex channels to different users, and avoiding collisions. The MAC-layer is a sub-layer in Layer 2 (Data Link Layer) of the OSI model and a component of the Link Layer of the TCP/IP model.

A number of promising approaches have been proposed to mitigate the effects of MAI in wireless communication. Multiuser detection is one of the most effective approaches. In contrast, the computational complexity of the optimum multiuser detector (MUD), which is a maximum-likelihood- based approach, is prohibitive as it exponentially increases with the number of users. Sub optimum schemes, such as successive interference cancellation, parallel interference cancellation, the de correlating detector, and minimum-mean-square-error.

(MMSE) MUD, do not incur such high computational complexity; therefore, they are more feasible in practice. Among the aforementioned schemes, MMSE MUDs have emerged as feasible solutions for suppressing MAI because they yield significant performance gains and have reasonable computational complexity.

In particular, multicarrier (MC) direct-sequence code-division multiple access (DS-CDMA), which is a hybrid of orthogonal frequency-division multiplexing (OFDM) and DS-CDMA, has attracted a great deal of attention. The hybrid scheme, namely, MC DS-CDMA, provides the advantages of OFDM and CDMA, such as high spectral efficiency and robustness to inter symbol interference (ISI). However, the demand for quality of service (QoS) in wireless communications continues to grow at a rapid pace. Therefore, to provide advanced QoS requirements for future communication systems, enhancing the performance of MC-DS- CDMAs is a matter of urgency.

II. RELATED WORKS

You and Hong proposed a frequency–time-domain (FT-domain) spread MC DS-CDMA scheme, in which the transmitted symbols are first spread by time-domain (T-domain) signature codes; then, they are copied to each subcarrier and multiplied by the corresponding entry of frequency-domain (F-domain) signature codes. Because of the two-domain (2D) spread mechanism, FT-domain spread MC DS-CDMA systems provide more system capacity than the previous MC DS-CDMAs. In addition to the benefit of high capacity, the systems offer other advantages, including high flexibility for variable rate services, as well as short and low-chip-rate signature codes to achieve low-rate signal processing.

Yang and Wang have presented a joint MMSE and several separate MUDs, each of which uses a two-stage detection mechanism, such as a T-domain (an F-domain) linear detector cascaded by an F-domain (a T-domain) linear detector, to estimate the transmitted symbols. Therefore, the separate MUDs can be easily implemented with lower complexity than that of the joint MMSE approach. Yang and Wang also implemented the separate MUDs in modular structures for dynamic communications, such as cognitive radios. Although the aforementioned schemes are effective in suppressing the effects of MAI in FT-domain spread MC DS-CDMAs, the approaches in do not incorporate antenna arrays. It has been shown that receivers equipped with antenna arrays provide spatial diversity, which increases the signal space and thereby reduces the effects of MAI. Because the direction of arrival of each user's transmitted signal to receive antenna arrays is usually different, the corresponding antenna response is usually referred to as the spatial-domain (S-domain) signature code. This implies that an FT-domain spread MC DS-CDMA system with multiple antennas can be regarded as a spatial–frequency–time-domain (SFT-domain) spread MC DS-CDMA system. Therefore, developing feasible, yet low-complexity, MUDs for the three-domain (3D) spread MC DS-CDMAs is an important issue; however, there is a dearth of literature on such uplink systems.

Wireless mesh networks (WMNs) are being developed actively and deployed widely for a variety of applications, such as public safety, environment monitoring, and wireless Internet services. They have also been evolving in various forms (e.g., using multi-radio/channel systems to meet the increasing capacity demands by the above-mentioned and other emerging applications.

A relatively low-chip-rate and short spreading codes can be employed in TF-domain spread MC DS-CDMA schemes. Second, the broadband multiple-access systems are expected to support a wide range of services and bit rates, as well as a number of simultaneous users. It is widely used in CDMA-based communications, multiuser detection is capable of reducing the multiuser interference and of significantly increasing the system's user capacity.

When a single-carrier DS-CDMA or a MC-CDMA, which uses high spreading factors, is invoked for the sake of supporting a large number of users, the employment of advanced multiuser detection algorithms becomes impractical due to their high complexity. By contrast, in the proposed TF-domain spread MC DS-CDMA schemes, simultaneous users can be separated in both the T-domain and the F-domain directions with the aid of unique signature codes connectivity related issues.

In path failure, a node along the path fails, causing other nodes to fail or there are collisions along the path. In sink (i.e., base station) failure, the whole network appears to be failing when it is the sink that has failed. Failure at the sink may be due to bad sink placement, changes in the environment after deployment, and connectivity issues.

A. Linear multiuser detection

Linear multiuser detectors are an important class of sub optimal techniques that are additionally used in the front end of many of the feedback based non-linear multi user detectors .The goal of linear MUD is to attain as much of the capacity increase from optimum MUD as possible, with a feasible and low-complexity implementation based on well understood linear filters. The block diagram of Linear Multiuser Detector is shown in fig 1.

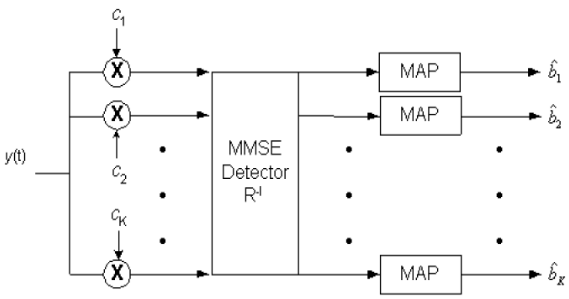

Figure 1: Linear Multiuser Detector Block Diagram

B. Joint SFT-Domain MMSE MUD

Four multiuser detectors (MUD) are considered and which are listed as follows:

1) Joint TF-domain de correlating MUD
2) Joint SF-domain MMSE MUD
3) Separate TS-domain correlating/MMSE MUD, where correlating is invoked for T-domain detection and MMSE is used for F-domain detection; and
4) Separate SFT-domain MMSE/de correlating MUD, where MMSE is used for T-domain detection, and de correlating is employed for F-domain detection. To find the joint SFT-domain MMSE MUD, incurs a large computational overhead because of the number of operations required to compute the inversion of a large matrix; hence, implementing the joint SFT-domain MMSE scheme is not feasible. To address this problem, we propose three low-complexity MMSE MUDs, which we discuss in the following sections.

III. PROPOSED SYSTEM

S–FT-Domain MMSE MUD*:* Based on the structure of the received signal matrix defined in (5), we use the S-domain MMSE detector and the FT-domain MMSE detector to construct the S–FT-domain MMSE MUD for a user. The objective is to minimize the error between the transmitted bit and the output of the S–FT-domain MMSE MUD. The problem can be formulated as follows [8] where, and is the complex conjugate operation. It has been shown that computing a minimization like that in (3) to jointly determine and does not have a closed form solution [4], [5], [6]. Hence, we utilize the alternating method proposed in [7] and [1] to determine the detectors and iteratively as follows. For ease of presentation, we assume that the S- and FT-domain MMSE detectors of the previous iterations of the proposed S–FT-domain MMSE MUD were determined by the alternating method.

A. BER Performance

Here, we derive the BER of the joint SFT-domain MMSE MUD as the benchmark to compare the performances of the three proposed low-complexity MMSE MUDs. First, for ease of derivation, the joint SFT-domain received signal is re expressed as sink node which eventually reduces the quality and efficiency of the network operation.

The idea of this distributed method is based on maintaining the route information at each node to the sink and then utilizing such information for the relocation of the sensors. Route recovery scheme is to solve the link failure problem caused by the movement of node, packet collision or poor channel condition. Since it considers backup node mobility during transmission/ reception and carry out route recovery perfectly, it can support fast route recovery and then provide reliable and stable route for routing protocol.

Routes need not be included in packet headers Nodes maintain routing tables containing entries only for routes that are in active use At most one next-hop per destination maintained at each node DSR may maintain several routes for a single destination sequence numbers are used where the diagrams are the effective SFT-domain signature and the transmission power matrices, respectively; and is the transmitted symbol vector. The estimated symbol for the joint SFT-domain MMSE MUD of user, i.e., in (9) is sgn; sgn is the signum function [1], and is the real part of. Then, the BER of user can be derived as follows [1], [6]:

B. Low-Complexity MMSE MUDs

$$\mathrm{BER}_j = \frac{1}{2^{K-1}} \sum_{b_k \in \{-1,1\}} P_r\left(\mathcal{R}e\left\{\mathbf{w}_j^{SFT^H}\mathbf{r}^{SFT}\right\} < 0 | \; b_j = 1, b_k \quad \forall k \neq j\right)$$
$$= \frac{1}{2^{K-1}} Q\left(\sqrt{\frac{2\mathcal{R}e\left\{\mathbf{w}_j^{SFT^H}\mathbf{C}^{SFT}\mathbf{P}^{\frac{1}{2}}\mathbf{b}\right\}^2}{\sigma^2\mathbf{w}_j^{SFT^H}\mathbf{w}_j^{SFT}}}\right) \quad ($$

where $j = 1, \ldots, K$, and $Q(x) = (1/\sqrt{2\pi})\int_x^\infty e^{(-\beta^2/2)} d\beta$

We evaluate the computational complexity of the proposed MMSE MUDs based on the number of complex multiplications/divisions (CMD) that is MXM and complex additions/subtractions (CAS) required. The computational complexity occurring in joint SFT-domain MMSE MUD does not depend on the number of users because the inversions of the matrices of the joint SFT-domain MMSE detector for the K users are all the same. However, we observe that the 1D and 2D MMSE detectors for the users are all different; thus, the detectors need to be computed individually. Thus, the computational complexity of the proposed schemes depends on K.

The proposed schemes still converge at about the third or the fourth iteration. Note that the proposed schemes with the corresponding 1D signature codes as initials generally converge at the third iteration and usually yield slightly better BER results than the schemes that choose initials in a random manner.

Based on the aforementioned results and because of the assumption of the 1D signature codes are fully known at the receiver. The effect of the narrowband interference is also investigated. In the simulations, we can see that the performance of the SCRAKE system degrades rapidly as interference-to-signal ratio increases. On the contrary, the performance degradation by the narrowband interference is not severe for the hybrid MC system. The proposed schemes that choose initials at random converge at about the third or the fourth iteration, whereas the proposed schemes that use the corresponding signature codes as the initials converge at about the third iteration.

III. RESULTS AND DISCUSSION

We evaluated the proposed schemes via simulations. For ease of presentation, we assume that, the channels are frequency-selective slow Rayleigh fading for all users, and transformed to be flat in each subcarrier [8]. It is also assumed that the ISI effect is small and can be ignored. All users are assigned a unique T-domain signature code and a unique F-domain signature code, which are pseudo noise codes [1]. In addition, the channel information and all the signature codes utilized are available at the base station.

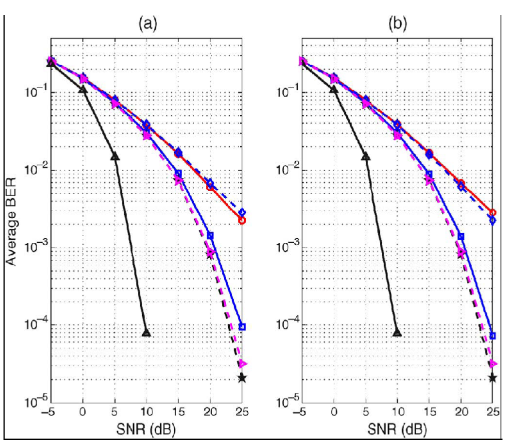

Fig.2. Convergence of BER versus SNR for the S–FT-domain MMSEMUD at K=40 M=8 and N=12

Random vectors with unit norm and their coefficients uniformly distributed in (-1, 1). (b) S-domain signature codes.

The base station is deployed with receive antennas, and all users simultaneously transmit BPSK modulated symbols to it. First, we calculate the convergence of the proposed T–SF-domain scheme.

The number of users is k=40, and the settings of the F- and T-domain signature codes are and N=9 and M=8, respectively. Two kinds of initials are individually used to provide more insight into the convergence node undergoes for each LMU [10]. The corresponding states are for proposed T–SF domain scheme. The first one randomly chooses the coefficients of the T-domain detectors of the T–SF-domain technique in the range of {-1, 1} and then normalizes the values of detectors for each user.

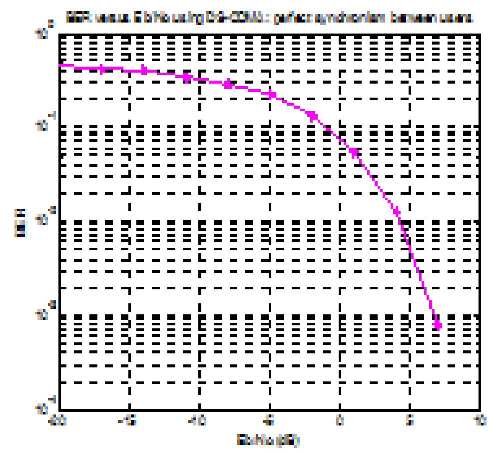

Fig.3. Convergence of BER versus SNR for the S–FT-domain MMSEMUD of the Rayleigh fading channel

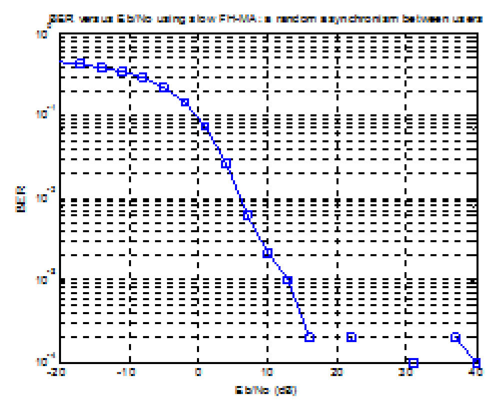

Fig. 4. BER versus SNR for slow FH-MA

IV. CONCLUSION

We observe that the proposed T–SF-domain scheme, which randomly chooses initials, converges at about the fourth iteration; however, the T–SF-domain technique with T-domain signature codes as the initials converges at about the third iteration. At this point, the BER performances of the two kinds of initials are almost the same. Furthermore, using the same system parameters defined earlier, we carry out the F–ST- and S–FT-domain MMSE MUDs.

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