Physical Communication 4 (2011) 13–25

Contents lists available at ScienceDirect

Physical Communication

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

Full length article

An iterative interference cancellation method for co-channel multicarrier and narrowband systems

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ARTICLE INFO

Article history:
Available online 27 July 2010

Keywords:
CDMA
Co-channel interference
Femtocell
NBI
OFDMA
Successive interference cancellation

ABSTRACT

Coexistence of narrowband (NB) and multicarrier technologies will be a major concern in next generation wireless communication systems due to the co-channel interference (CCI) problem. In this paper, an efficient CCI cancellation method is proposed that may be utilized for improved coexistence of NB and multicarrier technologies. The method treats both co-channel signals as desired signals and enhances them in an iterative manner. In every iteration, the signals are demodulated, regenerated, and subtracted from the received signal successively in order to obtain a better estimate of the other co-channel signal. Computational complexity of the proposed method is compared in detail with the joint demodulation technique. Through computer simulations, it is shown that the proposed method has lower complexity compared to joint demodulation, and it yields significant gains in the symbol error rate (SER) performance of both the NB and multicarrier systems.

1. Introduction

Transition from third generation (3G) to the fourth generation (4G) wireless systems is a major challenge that will be faced in the near future. Two different physical (PHY) layer technologies that have a high chance of being employed by next generation systems are Long Term Evolution (LTE) and WiMAX, both of which are multicarrier (MC) systems and can have a bandwidth up to 20 MHz. Relative to these technologies, 3G systems such as EDGE, DECT, CDMA-2000, and even W-CDMA with its 5 MHz bandwidth need to be considered as narrowband (NB) systems. During the transition phase from 3G to 4G, various multicarrier and NB systems might have to share the same spectrum, which will result in a severe performance degradation in both systems due to the co-channel interference (CCI).

Suppression of narrowband interference (NBI) in OFDM systems has already been considered in several works in the prior art [1–9]. In [1], linear minimum mean-square error (LMMSE) estimates of the interference are utilized. The proposed algorithm requires a priori information about the power spectral density of the NB signal. In [2], a normalized least mean squares (N-LMS) adaptive noise cancellation algorithm is introduced for suppressing NBI in pilot symbol assisted OFDM systems. NBI rejection via interferometry spreading codes is proposed in [3], whereas in [4,5], a prediction error filter (PEF) is introduced in order to mitigate the effect of narrowband interference in the time domain. The NBI in an OFDM system has been addressed through successive interference cancellation methods in [6,7]. In [6], assuming that the first subcarrier in consideration is interference-free, an error term is detected and used to mitigate the interference in subsequent subcarriers. This may result in error propagation in subsequent subcarriers in case of any error in the interference estimate. A generalization of the idea in [6] is discussed in [7] using soft decisions of the OFDM symbols. Two different NBI detection and cancellation algorithms

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doi:10.1016/j.phycom.2010.07.003

using compressive sensing techniques have been proposed in [8], which show important gains in the OFDM bit-error-rate performance with respect to no cancellation. In [9], the NB signal is estimated over the unused OFDM subcarriers to cancel the NBI over the used OFDM subcarriers. The feasibility of this method is limited in practice due to the very few number of unused subcarriers in a well-designed OFDM based system.

In this paper, we treat both co-channel signals as desired signals and propose a method that combats CCI through enhancing both signals in an iterative manner. In the literature, iterative co-channel interference cancellation techniques have been considered in [10–16], which typically assume narrowband systems and consider that the interferer and victim both use the same technology. In [10], it is emphasized that by exploiting the differences in signal features such as their delays, initial signal separation can be obtained, which considerably increases the efficiency of iterative interference cancellation. In the current paper, we exploit the inherent initial signal separation that exists due to the multicarrier vs. single carrier natures of interfering signals as well as the fact that the information is in frequency domain for MC signal and in time domain for NB signal. The proposed method assumes availability of signal reception and transmission capabilities for both systems. At each iteration, each signal is demodulated and then regenerated based on the symbol decisions and the channel impulse response. This way, a better estimate of the signal is obtained. The regenerated signal is subtracted from the aggregate signal to obtain an estimation of the other co-channel signal. Through extensive simulations, it is proved that this method can provide a fundamental improvement in the performances of both systems in as few as three iterations. The relatively high computational burden (associated with multiple transitions between time and frequency domains) as well as the extra cost caused by the addition of a second system's transceiver functionalities are compensated by the fundamental performance gain obtained. Our other contributions include a detailed comparison of the computational complexity of the proposed method with the joint demodulation technique and evaluation of the Gaussian approximation (GA) method for characterizing the interference from the other system.

The paper is organized as follows: Section 2 provides application examples and the system models for the MC and NB systems in consideration. Also, it shortly discusses the GA based symbol error rate (SER). Section 3 reviews the joint demodulation technique for the NB and MC signals, while Section 4 is a detailed description of the proposed CCI cancellation method. A complexity comparison of the joint demodulation and iterative interference cancellation approaches is made in Section 5, simulation results are presented in Section 6, and the last section concludes the paper.

2. Application examples and system model

2.1. Application examples

Earlier examples of coexistence studies in the prior art include [17,18], which investigate the coexistence of code division multiple access (CDMA) and GSM systems. A contemporary example scenario, where coexistence of NB and multicarrier systems might be unavoidable, is the co-channel deployment of wideband CDMA (W-CDMA) based femtocells with LTE based macrocells, which has not been studied in the literature to the best of our knowledge. Femtocells [19,20] are miniature cellular networks that have a communication range in the order of 10 m. They can coexist with a macrocell network through either a split-spectrum approach, which leads to an inefficient spectrum utilization, or a shared-spectrum approach [21–23], where CCI is a potential concern. The initial deployments of femtocells will be mostly based on CDMA based technologies, such as the W-CDMA. In the future, while macro-cellular networks migrate to wider-band multicarrier based technologies such as LTE, it might be expected that it takes a longer time for the consumers to replace their existing 3G femtocells with their next generation versions. Hence, an LTE based macrocell may need to coexist with a large number of 3G femtocells within its coverage area. In a shared-spectrum deployment, this would result in an interference from the macrocell at a femtocell, as illustrated in Fig. 1, which needs to be cancelled at the femtocell for an improved performance. Similarly, a W-CDMA femtocell may be interfering to an LTE based mobile station (MS) nearby, which again needs to be mitigated at the MS.

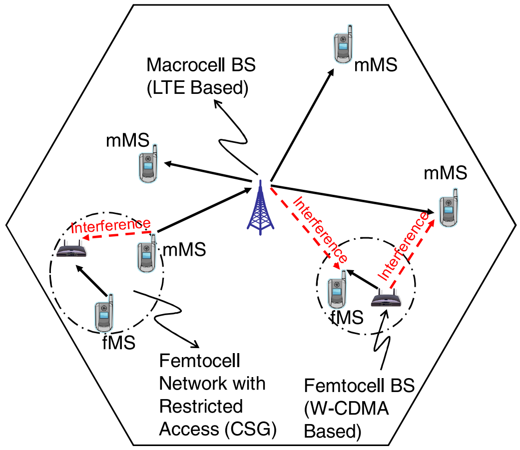

Fig. 1. An example coexistence scenario for an LTE based macrocell with a W-CDMA based femtocell during migration from 3G to 4G.

A particularly important scenario where interference cancellation may yield good gains for femtocell networks is for the restricted operation mode[1] of femtocells, where, the macrocell mobile stations (mMSs) are not allowed to make hand-off to the femtocell network even when the signal quality is superior at the femtocell [24,25]. As illustrated in Fig. 1, this may result in significant uplink interference from the mMS to the femtocell BSs (fBSs), and significant downlink interference from the fBS to the mMSs. As discussed before, for the interference cancellation to become effective, the interference should be sufficiently strong; therefore, femtocells with restricted

[1] Also referred as the closed subscriber group (CSG) operation.