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Suppression of Synchronization Errors in OFDM CR Networks Based Carrier Aggregation with Sensing Time and Power Optimization

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Abstract

Wireless systems are evolving to support the increasing traffic demands and it is achieved by higher rate of energy consumption. Aim of this paper is to maximize CR data rates, reduce the energy consumption and satisfy interference constraints at the primary user (PU) receiver(s) and also increase convergence and optimality. In this paper, we have considered jointly energy-optimal time allocation and pre coding in MIMO CR networks. The problem formulations turn out to be non-convex optimization problems. We tackle the non-convexity by applying an optimization decomposition technique. The average interference power from the SUs to the primary receivers measured by the interference-to-noise ratio (in dB), and in the "max-rate" scheme, the average interference-to-noise ratio is thus reduced. While considering optimal time & multiple streams", The optimal time allocation and transmit covariance matrices can be found in polynomial time. In the "max-rate" scheme, each SU uses the minimum time resource and the transmit covariance matrix. . In this paper, a proportional rate-adaptive resource allocation algorithm for TDMA is presented. Subcarrier and power allocation are carried out sequentially to reduce the complexity. Further this paper includes reduction of PAPR,BER,and STO using various algorithm to achieve performance gains.

Keywords: energy efficiency, interference, optimality, TDMA, MIMO, joint optimization.

1. Introduction

Cognitive Radio (CR) networks is one of the new long term developments taking place in communication technology. Cognitive radio networks is an innovative approach of wireless communications in which a special kind of radios are designed with un predictive level of intelligence, cognitive radios able to monitor, sense, detect the conditions of their operating environment, and dynamically reconfigure their own characteristics to best match those conditions. It enables radio devices to use spectrum in entirely new ways. This paper proposes the use of cognitive radio networks in an efficient way, especially we investigate energy efficient communications for TDMA (Time division multiple access) MIMO (Multi-Input Multi-Output) CR networks that is operated in underlay mode. The main aim of this paper is to increase CR data rates and satisfy interference constraints. Here we particularly consider the joint optimization of time resource and transmit pre coding matrices to minimize the energy consumption of the entire single cell secondary network with multiple secondary users, while ensuring their quality of service(QoS). Cognitive radio allows the secondary users to use the spectrum allocated to the primary users(PUs) in order to reduce the spectrum scarcity. The usage of MIMO techniques causes the SUs to coexist with PUs without any harmful interference. A closely related problem to energy minimization is rate maximization, hence this paper shows that rate maximization for a single secondary link under perfect CSI and no interference from the primary system to the secondary system is a convex optimization problem. Here, mathematical formulations turn out to be non-convex, and thus highly complex to solve. We tackle the non-convexity by applying a proper optimization decomposition technique that allows the overall problem to be solved efficiently. Particularly, we could prove that when the SUs only have statistical CSI, the optimal solution is found in polynomial time. however, according to the requirement of practical wireless system, if we consider the additional integer constraints on the time variable the overall problem becomes a mixed-integer non-convex optimization that is more complicated. By finding a special structure of this particular problem, we could prove that the optimal integer time solution can be achieved in polynomial time with a simple greedy algorithm. With the perfect CSI of SUs, the decomposition based algorithm is guaranteed to find the optimal solution when the secondary system is under-utilized. Simulation results show that the energy-optimal transmission scheme adapts to the traffic load of the secondary system to create a situation where the SUs are able to decrease the energy consumption and the PUs experience less interference from the secondary system. The effect is particularly pronounced when the secondary system is under-utilized

This paper also proposes, synchronization problem in non-continuous CA scenario and propose a block type pilot based synchronization algorithm that is used to suppress the STO (Sampling Timing Offset). The pilot pattern used is CAZAC (Constant Amplitude Zero Autocorrelation) sequence. As the proposed method is a parallel processing, different bands could experience different synchronization errors but the proposed method can significantly improve system performance and has smooth performance on variation of synchronization. Simulation results show that the developed algorithms closely approach the global optimal performance and achieve significant performance gain.

2. System Model

We consider a CR network with Sus K and PUs J. The primary links are active and needs to be protected always. The primary network composes J pairs of transmitters and receivers and the secondary system is a single cell network, where the SUs send uplink traffic to the same secondary BS via TDMA. To avoid interference the uplink transmissions are synchronised by secondary BS.

We use S_k to denote the kth SU and M_{Sk} denotes number of transmit antennas of S_k similarly, N_{BS} denotes total number of receiver antennas at the secondary BS. Let $H_{BS,Sk} \in C^{N_{BS} * M_{Sk}}$ denotes the channel matrix between S_k and secondary BS. While jth primary transmitter-receiver pair is denoted by P_j as well, Let M_{Pj} and N_{Pj} denote the number of transmit antennas and receiver antennas respectively. Since the SUs coexist with the PUs signal interference may takes place. Let $H_{Pj,Sk} \in C^{N_{Pj} * M_{Sk}}$ and $H_{BS,Pj} \in C^{N_{BS} * N_{Pj}}$ denote the channel matrix between S_k and receiver P_j and the channel matrix between transmitter Pj to the secondary BS respectively. We could make 2 main assumptions to make the channel realizations uncorrelated in different frames, firstly frequency flat fading channel which makes the channel same for considered bandwidth and secondly, block fading channels that makes the channel matrices not to change during TDMA frame[1]. As the secondary system is centralized, the secondary BS estimates $H_{BS,Sk}$ and feedback it to each S_k with a separate control channel.

There are three main cognitive radio network paradigms: underlay, overlay, and interweave. The secondary users of underlay paradigm operates if the interference caused by them is below a given threshold or meets a given bound on primary user performance degradation. In overlay systems the secondary users over hear the transmissions of the primary users, and then use this information along with sophisticated signal processing and coding techniques to maintain or improve the performance of primary users, with some additional bandwidth for their own communication. In ideal conditions, sophisticated encoding and decoding strategies allow the secondary and primary users to remove either all or part of the interference caused by the users. In interweave systems the secondary users detect the absence of primary user signals in space, time, or frequency, and then establish communication. For all three paradigms, if there are multiple secondary users then these users must share bandwidth amongst themselves as well as with the primary users, subject to their given cognitive paradigm. This gives rise to the medium access control (MAC) problem among secondary users similar to that which arises among users in conventional wireless networks. Given this similarity, MAC protocols that have been proposed for secondary users within a particular paradigm are often derived from conventional MAC protocols. In addition, multiple secondary users may transmit to a single secondary receiver, as in the uplink of a cellular or satellite system, and one secondary user may transmit to multiple secondary receivers, as in the corresponding downlink.

3. TDMA Technology

It is proposed that primary users makes use of TDMA to access the channel while the secondary users use slotted TDMA to sense the time slots of TDMA and transmission takes place during idle time slots. Here, TDMA based protocol uses a single transceiver and in-band signaling. This protocol ensures coexistence among the CR users and the PUs by adapting the transmission power and rate of the CR network.

The cellular radio network considered has n arbitrary cells. It is assumed that channels are evenly spaced in the radio frequency spectrum. Using an appropriate mapping, channels are represented by consecutive positive integers.

With traditional TDMA scheme, the primary user transmits the packets after its respective time slots. Under the wireless fading channel environment, the number of packets sent in a time slot depends on the number of buffered packets and the channel condition. In some time slot, the number of sent packets is small because either the number of buffered packets is small or the channel condition is poor. In this condition, those time slots are not utilized efficiently and the wireless resource is wasted. Thus it can be utilized by the secondary users if we carefully design the TDMA scheduling scheme for the primary network. TDMA will evaluate the performance of the primary user with single frequency channel. The fundamental requirement for the sensing based spectrum usage is to protect the PU. So as to ensure, each PU has to specify a maximum interference time (t_{max}) that specifies the maximum time a reoccurring PU can tolerate from an SU before the interference limit. After this period the PU should make sure that no interference takes place from secondary units.

The TDMA signal is made up of a series of IFFTs, At each symbol period boundary, there is a signal discontinuity, these discontinuities causes high frequency spectral noise, to avoid this a window function may be applied to each symbol period. Thus the window function depreciate the time waveform at the starting point and the ending point of each period, which could reduce the discontinuities, and so high frequency noise is reduced. Moreover, this depreciation distorts the signal and some of the desired frequency content is lost.

We consider a coexistence scenario with a SU operating in close geographical proximity of a PU and show how imperfect channel state information (CSI) in null space based SU transmission in cognitive radio networks can affect the performance of PU. SU possess M transmit antennas and similarly PU possess NR receiver antennas. if x(t) is the signal transmitted from SU, then the received signal at PU receiver can be written as y(t).

Where,

$y(t) = H_{NR}{*}M\, x(t) + n(t)$,

$H_{NR}{*}M$ is the interference channel matrix between SU and PU and n(t) denotes channel noise. SU maps its signals onto the null space of H. SU and PU are operating at the same frequency band, therefore we assume reciprocity of wireless channel H. Primary system can periodically inform the SU about its status, through a cognitive pilot channel (CPC). Despite, in the non-cooperative scenario, SU has to estimate the interference channel in order to shape its waveform in a way that does not interfere with PU. An adaptive null space based coexistence of PU with multiple SUs for a MIMO OFDMA uplink CRN is proposed. SUs transmit signals through the null-space of the channels seen between SUs and the PU base station.

TDMA demodulation must be synchronized with the start and end of the transmitted symbol period. If not, then ISI and ICI will occur and so orthogonality will be lost.

In order to avoid ISI and ICI, the guard period must be formed by a cyclic extension of the symbol period, which is done by taking symbol period samples from the end of the period and adding them to the front of the period. The concept of being able to do this, and its meaning, comes from the nature of the IFFT/FFT process. When the IFFT is taken for a symbol period that is during OFDM modulation, the resulting time sample sequence is periodic. This is because the IFFT/FFT is an extension of the Fourier Transform which is an extension of the Fourier Series for periodic waveforms. For the IFFT/FFT, the period is the number of samples used. Thus with the cyclic extension, the symbol period is longer, but exactly represents the frequency spectrum. Since the complete period could be integrated, orthogonality is maintained efficiently. Therefore, both ISI and ICI are removed.

4. Simulation and Results

The performance of the proposed algorithm is evaluated in terms of energy consumption, interference to primary system, convergence, and optimality. A sample random CR network with 2 primary links with 10m distance and 35 secondary users uniformly distributed in 200x200m square area shown in Fig 1. Each node in the network possess 4 antenna and for each network 1000 independent simulation runs are executed.

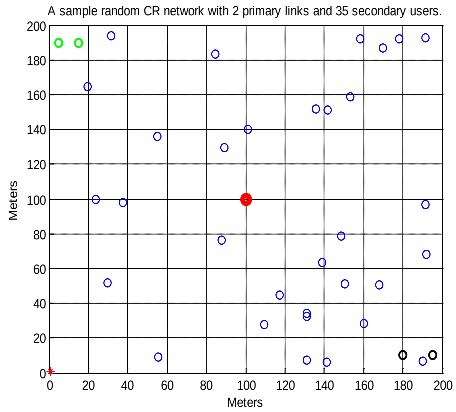

Fig 1 A Sample random CR network

A. Energy consumption

Average energy consumption per bit of the secondary system in the statistical scenario is shown in Fig 2, Here, maximum rate of transmission is shown. The simulation results shows that if the secondary system is under-utilized or experiences some interference from primary system, each SU performs transmit pre-coding of single data stream. Similarly if the secondary system possess SUs less than 8 then, “optimal time & single stream” and “optimal time & multi stream” perform same results.

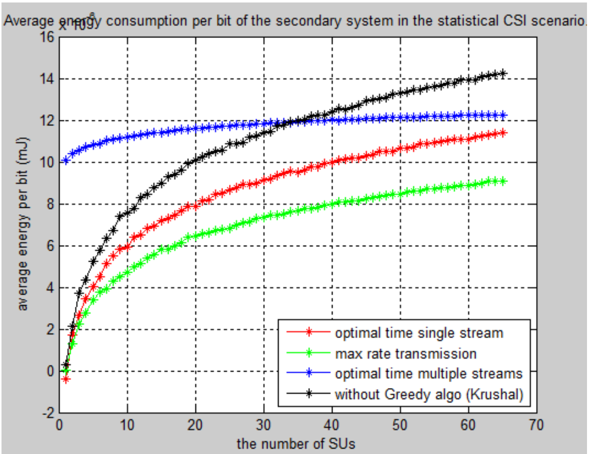

Fig 2: Average energy consumption per bit of the secondary system

B. Interference

The average interference power at primary receiver vs. the number of SUs in the statistical CSI

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scenario is shown in the fig 3, it is measured by interference to noise ratio (in db). The simulation result of interference shows that the interference power increases slowly in the "optimal time & multiple streams" compared to the "optimal time and single stream"

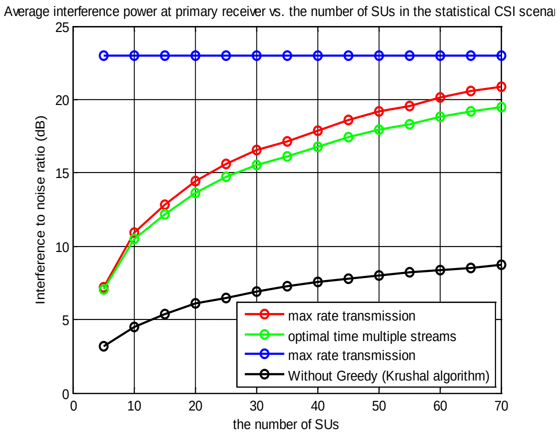

Fig 3 The average interference power at primary receiver vs. the number of SUs

C. Channel Utility

MIMO channel links utility is shown in the Fig 4 , This is performed using modified greedy algorithm. The simulation results shows the performance of the factors such as AWGN, Reileigh, and Rician with respect to average utility of the link (Mb/s) that is measured in distance to the transmitter.

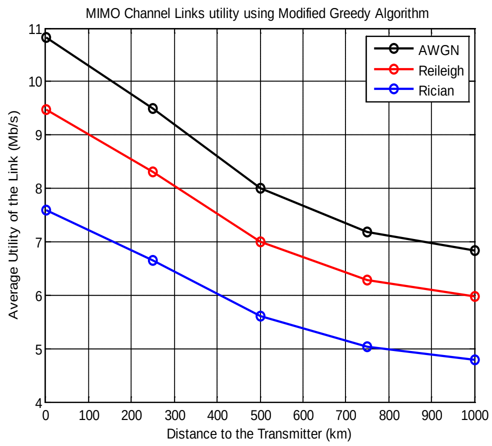

Fig 4. MIMO Channel links utility using modified Greedy algorithm.

Similarly various output factors with respect to its are showed in the simulation

Fig 5 shows the energy consumption with energy ratio algorithm. Thus the amount of energy consumed is reduced using this algorithm.

The fig 6 shows the simulation result of career frequency of various components with respect to MSE that is measured in SNR (db) per sample.

Fig 7 gives the channel utilities achieved by primary and secondary units.

Fig 8 shows the simulation result of PAPR (peak to average power ratio) reduction performance which is satisfied using all pass filter algorithm for PAPR reduction.

Fig 9 shows the result of reducing BER (bit error rate) , ICI and ISI cancellation is done with BER reduction in this simulation

Fig 10 and 11 shows the performance and minimisation of CFO using CAZAC algorithm and STO performance and minimization using OML (optimal maximum likelihood) algorithm respectively.

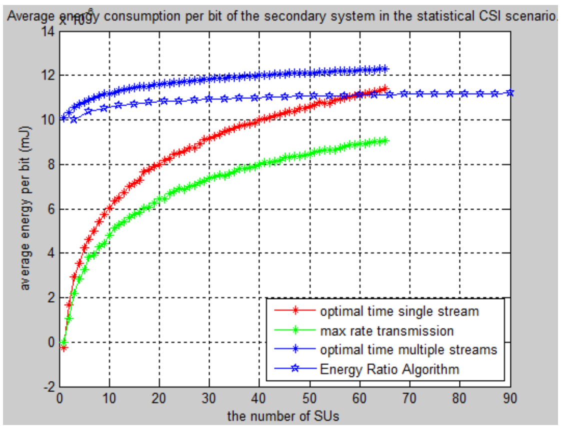

Fig 5 Average energy consumption per bit of the secondary system

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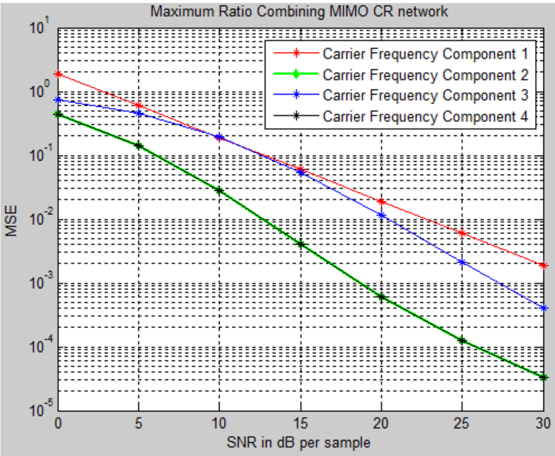

Fig 6 Maximum ratio combining MIMO CR network

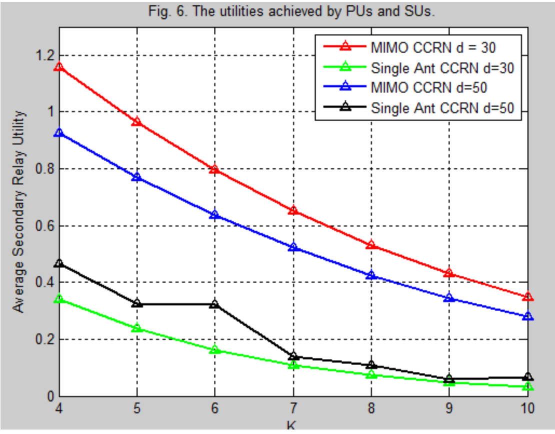

Fig 7 Utilities achieved by PUs and SUs.

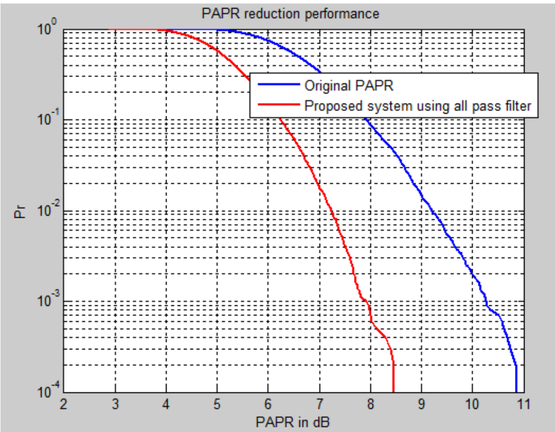

Fig 8 PAPR reduction

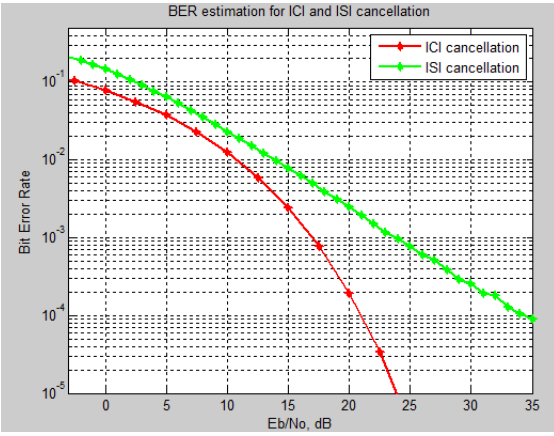

Fig 9 Estimation of BER

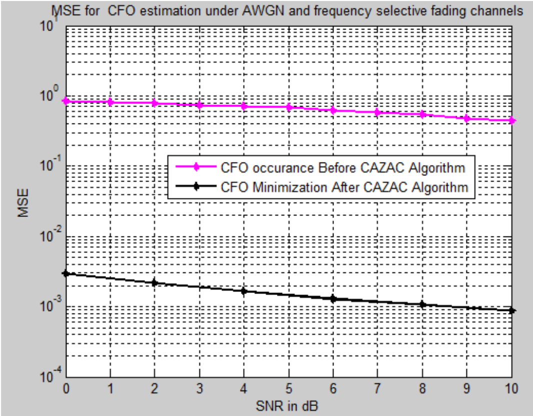

Fig 10 Occurance and minimization of CFO

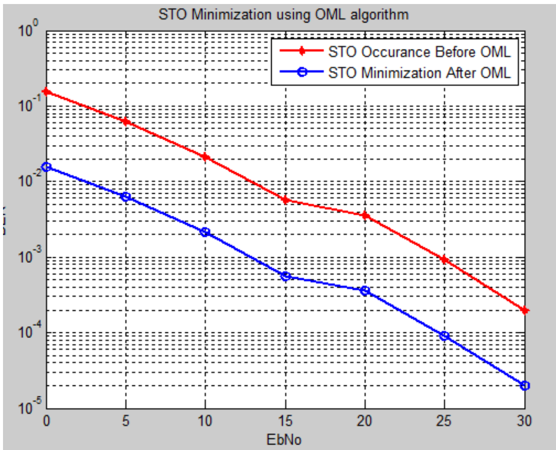

Fig 11 Occurance and minimization of STO

5. Conclusion

The main objective of this paper is to maximize the CR data rates and satisfy the interference constraints at the primary receivers which is achieved effectively. The non -convexity arised due to mathematical formulation is also solved by decomposition technique. Energy efficient transmission is done successfully with reduction of BER, synchronization errors, and with reduced noise in the system. Various algorithms are proposed to reduce PAPR,and to perform ICI and ISI cancellation. CFO occurance and minimization is done using CAZAC algorithm Similarly,STO minimization is achieved using OML algoritm. The optimal time allocation, the optimal transmit covariance matrix is obtained by greedy algorithm

Finding the optimal transmit covariance matrices for SUs is much more challenging , with the help of trade-off between diversity gain and spatial multiplexing gain we could achieve it and that would be the future improvisation of this paper.

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