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POWER CHANNEL ALLOCATION AND PAPR REDUCTION IN UNDERLAY MIMO COGNITIVE RADIO NETWORKS

Madhubala.P.K,
Department of ECE,
Valliammai Engineering College,
Kattankulathur-603203,

Mohan.J,
Department of ECE
Valliammai Engineering College,
Kattankulathur-603203,

ABSTRACT-In this paper, we investigate the power and channel allocation with joint beam forming and Peak-to-Average Power Ratio (PAPR) reduction for Multiple-Input Multiple- Output (MIMO) Orthogonal Frequency Division Multiplexing (OFDM) based Cognitive Radio Networks (CRN) operating in an underlay mode. In this system, we are going to maximize the spectrum utilization by mitigate the interference by implementing beam forming techniques. Here the secondary user transmitter reuse the primary users' spectrum. We are going to maximize the sum rate and reducing the Inter-Carrier-Interference (ICI) by using joint Maximum Likelihood- Linear Minimum Mean Square Error (ML-LMMSE), Zero Forcing - Least Minimum Mean Square Error (ZF-LMMSE) and Zero Forcing – Simulated Annealing (ZF-SA) for sub-optimal channel allocation. We are also going to allocate the power using Modified water filling algorithm. Since OFDM is used as a transmission medium, PAPR has to be reduced using All-pass filters and Selected Mapping (SLM) for proper transmission. Simulation results show that the proposed system model performs better than the existing ZFBF model by exploiting interference tolerance capacities, and the proposed algorithms can achieve better performance in terms of sum- rate with lower computation complexity so they are suitable for practical applications and PAPR has been reduced effectively by using All-pass filters which is less complex than SLM.

INDEX TERMS-Beam forming, Cognitive Radio Networks, LMMSE, Simulated Annealing, modified water-filling algorithm, PAPR, SLM, All-pass filters.

I INTRODUCTION

Recent studies states that the existing static spectrum allocation is the key reason for highly inefficient spectrum utilization, which in turn leads to a problem of spectrum scarcity. To overcome this issue, in 1998, Joseph Mitola III proposed a novel concept called Cognitive Radio (CR) [1] was introduced, which allows unlicensed users or Secondary Users (Sus) to access the primary users' spectrum when they are in idle state.

For an underlay Cognitive Radio Network (CRN) existing with a multiple channel Primary User (PU) network, interference mitigation is a key issue since spectrum is reused among the multiple users which causes negative effects at both PUs and SUs. By exploiting multiple antennas [7], a novel technology called beam forming [10] has been introduced to CR for directional signal transmission, so as to effectively eliminate the mutual interference and Signal to Noise Ratio (SNR) has been improved. They afford other advantages such as antenna gain, diversity gain and spatial multiplexing. OFDM is a popular technique for high-rate data transmission over frequency-selective channels which is used as a transmission medium. PAPR has to be reduced for proper transmission. One of the major drawbacks with OFDM is the high peak-to-average power ratio (PAPR) of transmitted signals.

The high PAPR introduces inter- modular distortion and out-of-band radiation due to the nonlinearity of the high power amplifier. The distortion and radiation cause degradation of the bit error rate (BER) and high adjacent channel interference respectively. Therefore, we have to reduce the PAPR of an OFDM signal over the transmission.

In literature, most of the works were on the cellular architecture for secondary network. Namely, either SU transmitter or receiver is the secondary base station. However, a base station can only provide reduced coverage and serve certain amount of users adopting the limited number of antennas and resources. Joint beamforming and resources allocation have been widely studied for multiple- antenna CRNs. Xie et al. in [11] considered a sum-rate maximization problem with beamforming in a single PU channel CRN. The Zero-Forcing Beam Forming (ZFBF) [11] is a technique, which completely nullifies the interference among the co-channel users. However, application of ZFBF is confined to limited practical scenarios.

Furthermore, since it does not consider the potential interference tolerance at SUs, which in turns results in a degradation on overall sum-rate of the secondary network. Various schemes are used to reduce the PAPR in the literature. It include clipping, clipping and filtering [5], block coding [8], precoding, tone reservation and injection [2], [4], nonlinear companding transform schemes [3], a partial transmit sequence (PTS) scheme [6], and selected mapping (SLM) schemes [12]. Of these schemes, the SLM scheme has been considered the most effective one due to its high PAPR reduction performance without experiences signal distortion. SLM scheme has a disadvantage of high computational complexity due to its requirement of multiple Inverse Fast Fourier Transform (IFFT) modules.

In this paper, we address power and channel allocation with joint beam forming, problem in an underlay CRN among multiple PU and SU pairs. Specifically, in our work, beam forming is performed by each SU-TX to promote the spatial diversity and mitigate the interference. Our aim is to maximize the sum-rate capacity of the secondary system while mitigate the interference. We are using Joint Maximum Likelihood- Linear Minimum Mean Square Error (ML-LMMSSE), Zero Forcing - Least Minimum Mean Square Error (ZF-LMMSE) and Zero Forcing – Simulated Annealing (ZF-SA) [9] for sub- optimal channel allocation and ICI elimination. We are going to allocate the power using Modified water filling algorithm. All-pass filters produces alternate OFDM sequences by rotating the symbol phase by using multiple all-pass filters, whereas the phase rotation of conventional Selected Mapping (SLM) is performed with multiple complex multiplication modules combining with Inverse Fast Fourier Transform (IFFT) modules. Observations shows that the proposed system model outperforms the existing ZFBF model by exploiting interference tolerance capacities, and the proposed algorithms can achieve better performance in terms of sum-rate with lower computation complexity so that they are more suitable for practical applications and PAPR has been reduced better using All- pass filters which is less complex than the SLM scheme.

II .SYSTEM MODEL

We consider a CR network with N-PU transceivers and K- SU transceivers which are randomly distributed over the coverage area of primary network. Each PU transceiver engages one separated licensed channel so that there are N PU channels in total. Each SU-TX is provided with J- antennas and its receiver is provided with a single antenna, while each PU transceiver has a single antenna. Each SU- TX is allowed to communicate with its corresponding receiver in the underlay mode while satisfying a pre-defined interference constraint at the corresponding PU- RX. There is a central entity whose function is to all SUs.

A.SUB-CHANNEL AND POWER ALLOCATION AND ICI ELIMINATION

We are using Joint Maximum Likelihood- Linear Minimum Mean Square Error (ML-LMMSE), Zero Forcing - Least Minimum Mean Square Error (ZF- LMMSE) and Zero Forcing – Simulated Annealing (ZF- SA) [9] for sub-optimal channel allocation and ICI elimination. We are going to allocate the power using Modified water filling algorithm. Zero Forcing - Least Minimum Mean Square Error (ZF-LMMSE) for sub-channel allocation

Step 1: Assume initial set of receiver weights $w1.....wk$. Two good candidates for this are to use the dominant left singular vectors of the corresponding channel matrices H and compute full co-ordinated ZF solution as wj.

Step 2: For $w1.....wk$ calculate $\bar{H}$ and find beamforming vectors B using semi-definite relaxation.

Step 3: By using B, recalculate the receiver beamformers $w1.....wk$ depending on LMMSE receiver design.

Step 4: If the sum rate achieved by B and wj has altered from the last iteration, go to step 2; otherwise; stop.

Zero Forcing – Simulated Annealing (ZF-SA) for sub-channel allocation

Step 1: Set initial channel allocation $X0$, computation time n, number of SU pairs K, number of PU channel N and initial temperature and set iteration i=1 and calculate the sum rate.

Step 2: Generate new channel allocation Xi+1.

Step 3: Accept or reject Xi+1using metropolis criteria and update i=i+1.

Step 4: If I is greater than or equal to n then go to next iteration and reduce the temperature. If not go to step 2

Step 5: If the convergence criteria satisfied then stop the process. If not go to step 2.

The zero-forcing beamforming (ZFBF) [11] is a technique, which completely nullifies the interference among the co-channel users. However, application of ZFBF is confined to limited practical scenarios. Furthermore, since it does not consider the potential interference tolerance at SUs, which in turns results in a degradation on overall sum-rate of the secondary network. So we go for joint ML-LMMSE algorithm.

Joint ML-LMMSE Algorithm for sub-channel allocation

ML with LMMSE algorithm gives better Spectral efficiency and less ICI (inter channel interference) and less error probability than Zero Forcing Algorithm. In this procedure, we use a two-step procedure. Initially, we use an LMMSE filter to generate an LMMSE estimation of the original transmitted symbols S. Subsequently, we use the ML principle in a neighbourhood of LMMSE estimate. The neighbourhood consists of the set of transmitted symbols whose binary representation is within a Hamming distance, P from LMMSE.

Step 1: Set the initial channel allocation $X0$ and assume initial set of receiver weights $w1.....wk$.

Step 2: Compute the virtual channel matrix $\bar{H}$and find beamforming vectors B using semi-definite relaxation.

Step 3: By using B, recalculate the receiver beamformers $w1.....wk$ depending on joint ML and linear
MMSE receiver design.

Step 4: Update the receiver beamformers wj.

Step 5: Repeat step 2-5 until it converges.

Modified water-filling algorithm for power allocation

We consider a water-filling problem with N channels and a total power constraints $Ptota$. The water level is w. we allocate each sub-channel to an individual PU. There are N sub-channels corresponding to N PUs in the networks. Each sub-channel consists of different subcarriers which have different channel gains. We have to make sure the transmit power Pt is under a certain threshold. This is represented as

$Pt \leq Gj$ (1)

Gj is the interference constraint for sub-channel j

Step 1: Initialize transmit power $Pt>0$.

Step 2: Consider a set $A = \{ j \mid j = 1, 2,..., N\}$.

Step 3: Running the Water-Filling for set A with P, get the water level w.

Step 4: Move the sub-channels to set B if $Fj>Gj$, update set A.

Step 5:Perform power decrement on set B and

Perform Power increment on set A. update the common water level w, Fj.
Step 6: If $Fj > Gj$ *go to step 4.Otherwise stop.*

B. PAPR REDUCTION SCHEMES

Let X(k) for k=0,1,….N-1 denote the frequency domain OFDM sequence, where N is the number of subcarriers required for multicarrier modulation. The time domain OFDM signal is represented as
$(n)=1\sqrt{N}\Sigma X(k)ej2\pi knN/N-1k=0$ (2)
The PAPR of an OFDM signal can be defined as the ratio of the maximum power to its average power and it is given by
PAPR= $\max 0\leq n\leq N|(n)|2E[x(n)]2$ (3)
E[x(n)]-Expected value

Selected Mapping

The Phase rotation of Selected Mapping (SLM) [12] is performed with multiple Complex multiplication modules is combined with Inverse Fast Fourier Transform (IFFT) modules. The system representation of SLM is shown in Fig.1.

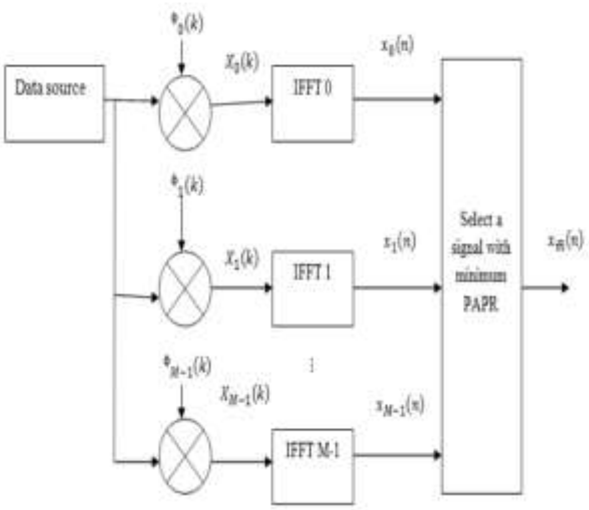

Fig. 1. System representation of SLM

All-pass Filters

SLM has high computational complexity due to its requirement of multiple inverse fast Fourier transform (IFFT) modules. Computational complexity becomes critical when a large number of subcarriers on the order of thousand are used for multimedia transmission. To overcome this issue All-pass filters is used. All-pass filters produces OFDM signals by rotating the symbol phase using multiple all-pass filters.It reduces computational complexity. The alternative OFDM sequences are performed are generated using multiple all-pass filters. An all-pass filter passes all frequency components with constant gain but with a desired phase shift. The system representation of All-pass Filters is shown in Fig. 2.

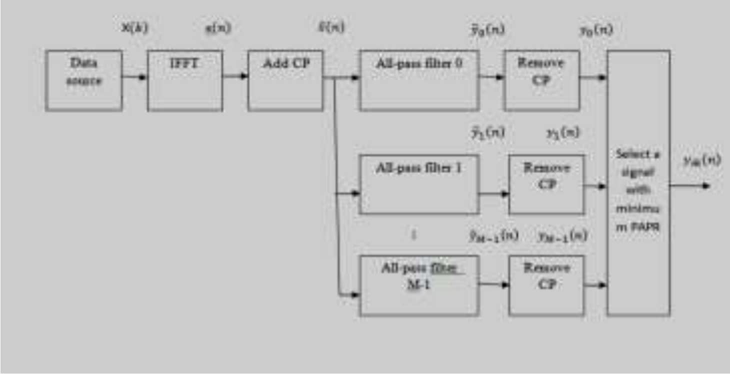

Fig. 2. System representation of All-pass Filters

III SIMULATION RESULTS

The following figures shows the simulation analysis results. Sum rate has been analysed with joint ML- LMMSE, ZF LMMSE and ZF Simulated annealing. Fig. 3. shows the convergence plot. ZF-SA finds a suboptimal channel allocation with a sum-rate value of 41.0557 bps/Hz. ZF LMMSE finds the sum-rate of 60.09 bps/Hz since it has equalization process and is less complex than ZF-SA. ZFBF does not consider the potential interference tolerance at SUs, which in turns results in a degradation on overall sum-rate of the secondary network. Joint ML- LMMSE considers the potential interference, so it maximizes the sum-rate upto 70.08 bps/Hz and it has better Spectral efficiency and less ICI (inter channel interference) and less error probability than Zero Forcing Algorithm.

Fig. 4. Shows the Optimal sum rate with an increased number of SU pairs. ZF-SA finds a suboptimal channel allocation with a sum-rate value of 90.01 bps/Hz. ZF LMMSE finds the sum-rate of 110.02 bps/Hz .Joint ML-LMMSE maximizes the sum-rate upto 140 bps/Hz

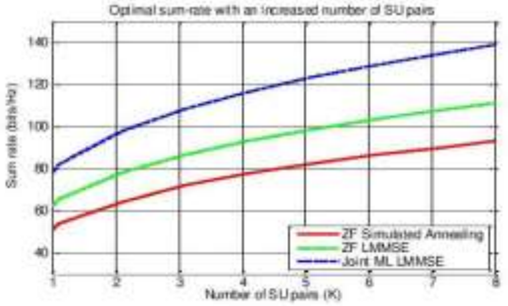

Fig. 4. Optimal sum rate with an increased number of S pairs

Fig. 5. Shows the power allocation using modified water filling algorithm. It illustrates the performance of sum-rates by varying power budget, Pmax. As we increase the power, the sum-rate also increases. The sum-rate performance gap between those algorithms is small and keeps approximately unchanged as we increase Pmax. It is mainly because the convergence properties of those algorithms do not change with the power. With the increased power, the SUs are preferred to have more individual power allocation. Hence, they are rewarded with more power as long as the interference constrains are satisfied, which in return increases the sum-rate.

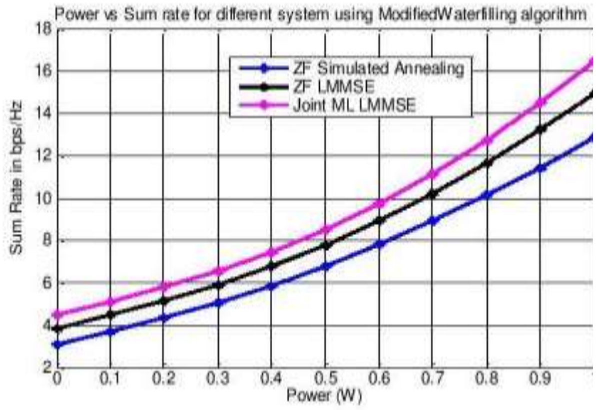

Fig. 5. Power allocation

Fig. 6. Shows the Inter-Carrier-Interference elimination. ZF-SA produces the probability of error of 10−1.5. ZF-LMMSE produces the probability of error of 10−1. Joint ML-LMMSE produces the probability of error of 10−2.8.

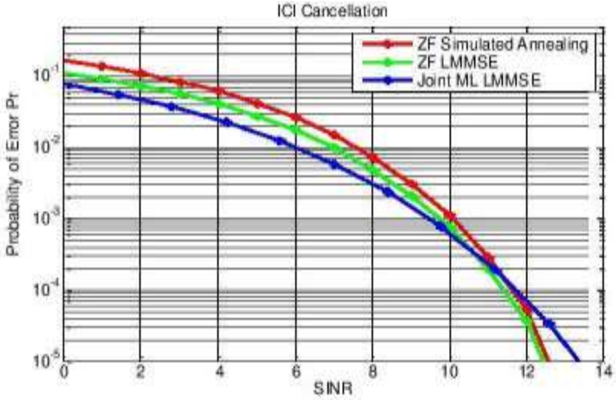

Fig. 6. ICI cancellation

Fig. 7. Shows the PAPR reduction over SLM and All-pass filters. All-pass filters reduces the computational complexity and also the peak power over SLM. PAPR has been reduced upto 8.2 Db by All-pass filter and SLM reduces the PAPR upto 10.8 dB.

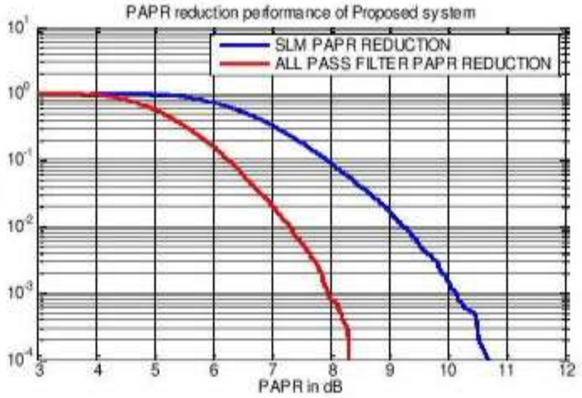

Fig. 7. PAPR reduction

IV CONCLUSION

In this paper, a problem of power and channel allocation with joint beam forming is considered for underlay cognitive radio networks. Joint ML-LMMSE outperforms the existing ZFBF model by exploiting interference tolerance capacities, and the proposed algorithms can achieve better performance in terms of sum-rate with lower computation complexity so that they are more suitable for practical applications and PAPR has been reduced effectively using All-pass filters which is less complex than SLM. In future, we can use discrete stochastic approximation (DSA)-based channel allocation method to find out the suboptimal channel allocation. Errors in the estimates of the CSI is inevitable due to some sensing limitations.

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