POWER AND CHANNEL ALLOCATION PROCESS IN MIMO COGNITIVE OFDM SYSTEM

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Abstract - In this paper, we implement methods to increase joint beam forming, power and channel allocation in a multi-user multi-channel system with multi-input multi-output (MIMO) cognitive radio network (CRN). Here, secondary user transmitters (SUTX) can reuse the spectrum used by primary users' (PU) in-order to increase spectrum utilization while minimizing the intra user interference with beam forming at the SUTX. After developing the process on cognitive radio network, we implement beam forming on specific user based distance analysis on singular value decomposition (SVD) using receiver analysis. Primarily, they implemented searching algorithms for MISO systems to find parameters required for channel estimation. In our modification, we implement Genetic Algorithm and Simulated Annealing Algorithm, explicit searching algorithms along with SVD for MIMO systems for channel allocation parameters in comparison to MISO searching algorithms.

Keywords: *Cognitive radio, SVD, MIMO*

I. INTRODUCTION

Cognitive Radio (CR) is a software defined radio designed for spectrum sensing which improves the utilization of spectrum allocation. CR can be programmed and configured dynamically. CR enables secondary users (unlicensed users or cognitive users) to utilize channel spectrum over licensed users (primary users) by identifying the spectrum holes. In spectrum sensing there are 3 categories of signal processing techniques: Energy detection, Matched filter detection and feature detection. Energy detection technique cannot differentiate signal types, but is for implementation. Matched filter is an optimal detector in stationary Gaussian noise, but requires primary signal information. Feature detection can differentiate modulated signal from noise and interference but requires higher computational complexities. In present OFDM systems, only a single user can transmit on all subcarriers at any time, time division or frequency division multiple access is used to support multiple users. OFDM divides the high-rate data stream into parallel lower rate data and hence increases the symbol duration, thus eliminating Inter Symbol Interference (ISI). This technique cannot fully utilize the spectrum. OFDMA allows multiple users to transmit simultaneously on various sub carriers per OFDM symbol. Probability that users experience interference on sub carrier is very low. It can be confirmed that, sub carriers are assigned to users who have maximum channel gain on them. Fixed Relay is low power transmit element that receive and transmit data from base station to users and vice-versa. Fixed Relays, when placed in cell edge or in regions of significant shadowing can increase coverage area in cellular networks. Fixed Relays are low cost solution to meet high data rate communication at the cell edge. Unfortunately, only a few relays can be placed in a cell. So, each relay should support multiple users. This helps in developing point to multi-point relays, where the relays forward data to and from the users. Challenge in Point to Multi-point relays is to provide high capacity link between base station and relays, while providing multiple data links to multiple users. Solution to this problem is to utilize the advantages of MIMO communication. MIMO communication uses multiple antennas to increase system capacity and improve flexibility against fading. Initial work on MIMO deals only with point to point MIMO relay channel but point to multi-point MIMO has gained no importance. In this paper, we assume that base station and fixed relay have multiple antennas and the mobile user have a single receiver antenna. In this way high-throughput MIMO link can be established between the base station and relay, then the MIMO broadcast channel (MAC channel) is used to deliver data from and to multiple users.

II. SYSTEM MODEL

In this section, we discuss about the system model of multiuser fixed relay system. We elaborate the system block diagram and assumption of system and then deal with downlink signal model.

Single Input Single Output System (SISO):

SISO is a standard radio channel, in which both transmitter and receiver operates with a single antenna. There is neither diversity required nor additional processing.

Single Input Multi Output System (SIMO):

In this system, the transmitter has a single antenna and the receiver has multiple antennas. This is called as receiver diversity. It is often used in a system where the receiver receives signals from independent sources to tackle the effects of fading. SIMO is relatively easy to implement but requires processing in the receiver. Applications of SIMO may be limited due to the size, cost and battery drain in mobile receiver.

Multi Input Single Output System (MISO):

In MISO systems, transmitter has multiple antennas where receiver has a single antenna. This is also called transmit diversity. The receiver has the ability to receive optimal signal from the multiple transmitted signals and can extract the required data.

Multi Input Multi Output System (MIMO):

MIMO system has multiple antennas at both the transmitter and the receiver. MIMO system has improved channel robustness and channel throughput. In order to fully attain benefit from a MIMO system it is necessary to code channels to separate data from different paths. This requires complex processing but provides high throughput and channel robustness.

MIMO Relay Path Process:

Fading may affect a channel and will impact signal to noise ratio and in turn increase the bit error rate (assuming digital data is transmitted). The principle of diversity is to provide the receiver with multiple versions the transmitted signal. Diversity helps in stabilizing a link, improving performance and reducing bit error rate. Signal transmitted has the lower chances of getting affected by noise through all the signal paths. MIMO is a radio antenna technology as it enables multiple signal paths to transmit data. The core idea behind the MIMO wireless systems space- time signal processing, in which time is complemented with space dimensions uses the multiple spatially distributed antennas i.e. use of multiple antennas located at multiple points.

MIMO wireless systems are an extension to smart antennas that have been used to improve wireless technology. The small moment of antennas can cause new signal paths for transmission and receiving of data. The number of paths occurring between the transmitter and receiver depends on the number of objects between them. These multi paths caused interference in the previous methods but in MIMO systems it acts as an advantage. These paths can provide additional robustness to the data link by increasing the signal to noise ratio or the link capacity.

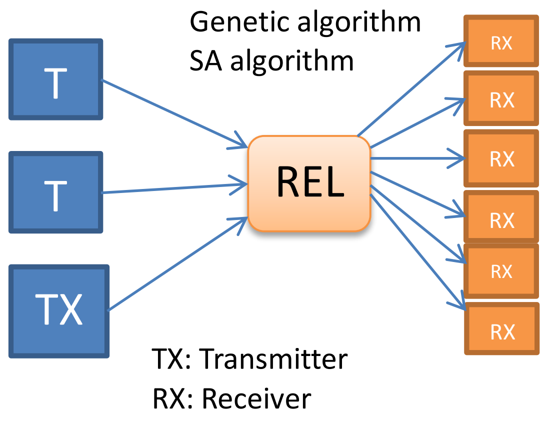

Fig 1: MIMO Block diagram using relay

Beam Forming Analysis:

In this paper, we consider joint source-relay beam forming three-node MIMO relay network with a source destination direct link. We assume that both source and relay are equipped with multiple antennas where-as, destination is equipped with a single antenna. This scenario is similar to the relay enhanced cellular network where base station and relay nodes can have multiple antennas but mobile has a single antenna due to size constraints. In downlink transmission to mobile nodes the overall performance of cellular system is reduced. So, our systems aims to fully utilize the advantage of MIMO relay channel to increase the channel through-put. We identify several unique properties of optimal beam forming vectors for source and relay nodes for various systems. This process of deriving expressions for beam forming antenna is not so simple because of the MIMO cannel between the source and the relay and the MISO channel between the relay and the destination has to be equally balanced.

III. PROCESS OF EQUAL POWER AND CHANNEL ALLOCATION

In addition to Beam forming technique used for achieving maximum transmission rate, we also implement two searching algorithms namely Genetic Algorithm and Simulated Annealing Algorithm in order to increase the SNR value at the secondary user transmitter.

A. Genetic Algorithm:

Genetic Algorithm is an evolutionary algorithm which is similar to biological process and is used to solve complex computational problem providing an optimal solution. The performance of GA depends on two operators namely, crossover and mutation. Crossover is an operation intended to pull the population towards a local maximum or a minimum value whereas, mutation is a divergence operation intended to separate one or more members of the local minimum/maximum space providing a better space. GA is primarily used to optimize the bit error rate in a cognitive network. GA is used for two operations namely (i)To detect the presence of a PU over a spectrum, (ii)To reduce the probability of false alarm. Maximum SNR value is achieved when GA is used. The main idea of GA is to select known values for the variables and later design new solutions based on previous values. In this paper we design a KxN matrix as a chromosome, where elements of matrix describe whether nth channel is allocated to kth SU or not. Here we consider 3 Base stations as transmitters, 1 relay node and 6 receivers.

Genetic Algorithm Steps:

Step 1: Initialize the parameters i.e. 3 base stations, 1 relay path, 6 destinations.

Step 2: Select a random variable signal in order to process channel path. [rand (3,64)]

Step 3: Analyze each channel path on one by one loop on the set of chromosomes.

[3x1] matrix size for base station to relay

Base station 1 to relay: [1 0 0]

Base station 2 to relay: [0 1 0]

Base station 3 to relay: [0 0 1]

Step 4: Depending on the corresponding rate of transmission we need to decide the best and worst paths.

1. $[R^{(g)}_{sorted}, G^{(g)}_{sorted}] \leftarrow$ sort $(R^{(g)}, G^{(g)}$, 'Descending')
2. $[R^{(g)}_{best}, G^{(g)}_{best}] \leftarrow$ select $(R^{(g)}_{sorted}, G^{(g)}_{sorted}$, 'Best')
3. $[R^{(g)}_{worst}, G^{(g)}_{worst}] \leftarrow$ select $(R^{(g)}_{sorted}, G^{(g)}_{sorted}$, 'Worst')
4. $[R^{(g)}_{luckies}] \leftarrow (R^{(g)}_{best} - R^{(g)}_{worst})$
5. $[G^{(g)}_{luckies}] \leftarrow (G^{(g)}_{best} - G^{(g)}_{worst})$

Step 5: Generate paths based on best and luckies and perform crossover on both and then mutation on the crossover paths.

1. P1←select $(G^{(g)}_{best}$, 1,'Random')
2. P2←select $(G^{(g)}_{luckies}$, 1,'Random')
3. [Temp CH1, Temp CH2] ← Crossover(P1,P2)
4. [CH1, CH2] ← Mutation(TempCH1,TempCH2)

Step 6: Update the random channel with the child obtained after mutation.

Step 7: Perform decode forward relay process on relay to destination for optimal channel allocation.

B. Simulated Annealing Algorithm:

In order to reduce the computational complexity present in GA, we use SA algorithm. Unlike GA, SA uses neighbor- hood searching to determine sub-optimal solution. Initially the algorithm starts with a control parameter and an initial channel allocation which helps in determining the neighbor channel. If the neighbor channel gives any performance development then it is selected. SA also helps in improving the SNR value at the SU transmitter.

SA Algorithm Steps:

1. Initialize the control parameter(K), channel allocation(N), maximum iterations(S_{max}) and cooling rate.

2. Set the iteration index value l = 0.

3. Compute the value R (X_o) which is th sum rate for the initialized channel.

4. Perform the iterations till l<S_{max}.

5. Generate new channel $\hat{X}_l$ and calculate the sum rate R ($\hat{X}_l$).

6. $\Delta R = R(\hat{X}_l) - R(X_o)$

7. if l = 0 then compute T_o and end

8. if $\Delta R \geq 0$ then compute $X_o \leftarrow \hat{X}_l$ and $R(X_o) \leftarrow R(\hat{X}_l)$

9. else if $\exp(\frac{\Delta R}{T_l}) >$ random [0,1] then compute $X_o \leftarrow \hat{X}_l$ and $R(X_o) \leftarrow R(\hat{X}_l)$

10. Update T_{l+1} = cooling – rate * T_l till l<S_{max}.

IV. RESULTS AND EXPLANATION

The simulation results are given in this chapter. Simulation is being performed using Matrix laboratory (MATLAB) tool. The SNR values from -10 to 20db are used in simulation process.

By using GA we get the output related to optimum joint beam forming, and by using the SA based algorithm we can get the output related to optimal channel allocation of the consent channel.

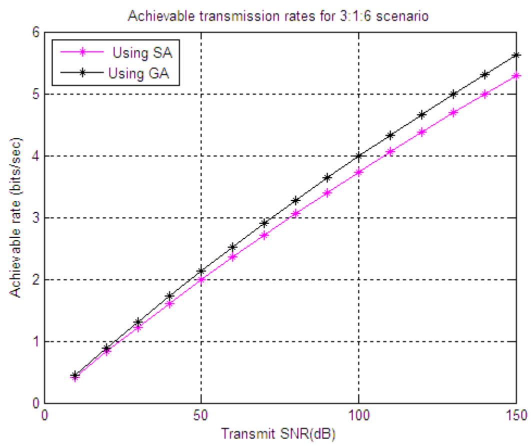

Fig 2: Comparison of SA &GA

The second simulation result is to show the comparison between all the possible ways of transmission i.e. without relay, with relay, using joint beam forming, using SA and using GA.

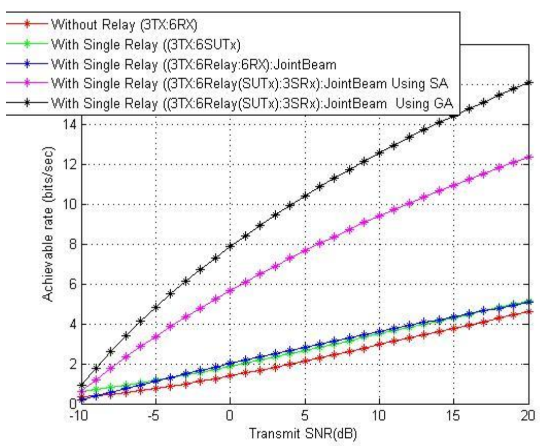

Fig 3: Comparison of all possible ways

V. CONCLUSION

In this paper, we dealt with the problem of power and channel allocation in a MIMO OFDM system is considered. Allocation of channel to the secondary users with a minimal interference to the primary user is achieved by a cognitive radio. The problem is formulated as a MINLP which comes under NP-hard. In order to reduce the computational complexity we divided the problem in to two steps which are beam forming for power allocation and GA and SA algorithms for channel allocation. The obtained simulation results shows that GA can give optimal solution to the problem whereas SA is less computational than GA and can give near to optimal solution.

VI. REFERENCES

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