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PERFORMANCE ENHANCEMENT BY USING OPTIMUM BEAMFORMING ALGORITHM IN COGNITIVE NETWORK

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Abstract

Cognitive Networks are an emerging new type of networking technology that can utilize both Radio Spectrum and Wireless Station. Based on the Knowledge of the availability of such resources gathered from past experience the resources can be utilized efficiently. Signaling is the major issue in Cognitive Network. Multiple Input Multiple Output (MIMO) technique is used for the transmission of signals in Cognitive Network. In this paper, the performance of MIMO in a Rayleigh fading environment is analyzed and water filling algorithm is used to maximize the capacity of MIMO channels we also propose an optimum beamforming algorithm to design beamforming vectors such that, interference caused by the primary transmitter to the Cognitive receiver and the interference caused by the Cognitive transmitter to the primary receiver is completely nullified while maximizing the rate of both primary and secondary links. The Proposed technique does not require any changes in the existing environment between the Primary and Secondary user. The secondary user will be allowed to transmit concurrently to the Primary user. Since the primary user is a licensed one it need not to have any Knowledge about the resources utilized and performance of the secondary user and it transmits independently. Further it is also proved that the rate of Cognitive Multiple Input Multiple Output (MIMO) link implemented by the proposed beamforming algorithms is equal to interference free Multiple Input Single Output (MISO) link.

Keywords- **Beamforming, Cognitive Network, MIMO, MISO.**

I. INTRODUCTION

Due to the increase in Wireless devices there is a great demand for the Spectrum. Reusing the available Spectrum will be the optimum solution for this problem. This can be done by using Cognitive Network. A Cognitive network has a cognitive a process that can perceive current network conditions, and then plan, decide and act on those conditions [7]. The network can learn about these adaptations and the ultimate aim is to provide end- to-end communication .There will be two types of of users in Cognitive Network, Primary or licensed users and Secondary or unlicensed users. The Primary users have the rights to exclusively use the Spectrum and Wireless resources. Secondary users are allowed to use the Spectrum which is not used by the Primary users. The Secondary users have to utilize the white spaces in the Spectrum [2]. 4G wireless communications uses Software Defined Radio (SDR), which is a single platform that provides a variety of services.SDR is mainly used in military applications.SDR supports a variety of modulation schemes.

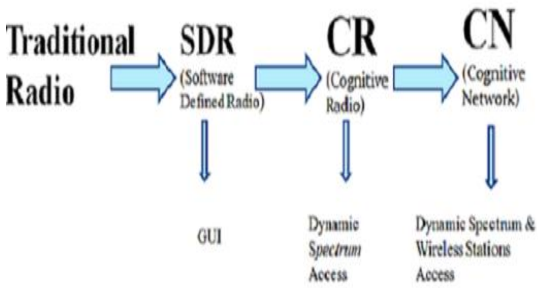

Fig. 1. Evolution path of Cognitive Network

Cognitive Radio (CR) is a transceiver which automatically detects available channels in Wireless spectrum and accordingly changes its transmission or reception parameters so more Wireless communication may run concurrently in a given spectrum band at a place. This spectrum allocation process is known as Dynamic Spectrum Management [9]. Cognitive Radio deals with point to point communication but Cognitive Network provides end to end communication. Cognitive Network can be considered as networks that efficiently utilize Cognitive Radio.

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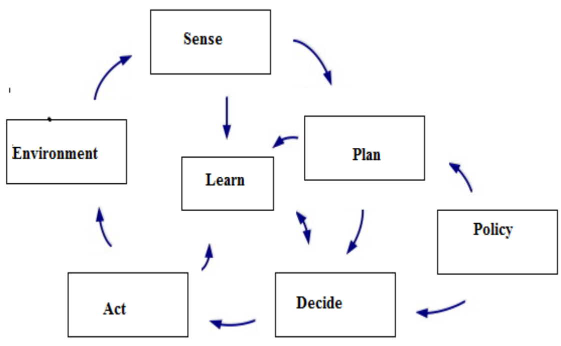

Fig. 2. Cognitive loop

Cognitive loop consists of self-explanatory components, which guides to choose an appropriate action based on the input from the environment [9]. Cognitive Network absorbs the network environment by using location sensors like Global Positioning System (GPS) or Galileo Sensors. Spectrum (White Space) detection is done by using RF stimuli. Then it will orient with respect to past experience and plan according to the available alternatives and decide what the actions to be taken are. Signaling is the major issue in Cognitive Network. MIMO is a communication technique,in which the multipath properties of the channel ate utilized to support greater throughput.Intersymbol Interference(ISI)and fading in multipath propagation are major threats in wireless communication.MIMO improve the performance of communication networks by overcoming these challenges.MIMO enabled Cognitive Network performs well when compared to normal Cognitive Network[3].To achieve maximum capacity of Cognitive Network an adaptive power algorithm is proposed in this paper. After achieving this the second constraint is while sharing Spectrum between the Primary and Secondary users there should not be any interference. For this, we propose an efficient beamforming technique to avoid the interference between the primary and secondary user [4].

II. MIMO In Rayleigh Environment

MIMO is based on spatial multiplexing technique, in which the independent and separately encoded data signals are transmitted from each of the multiple transmit antennas. Water filling algorithm is used as an adaptive equalizer in a communication channel.

The water filling algorithm is based on the effective noise on the fading channels[9]. When the transmitter has perfect knowledge about the channel, the water filling algorithm divides the total power in such a way that more power is allocated to sub channels with high gain and vice versa[6]. The main objective of this algorithm is to allocate power to the channel so as to maximize the total capacity.If the total available power,P_T and the gains in the parallel sub channels are known,the power allocated to i_{th} sub channel is given by

$$P_i = (\mu - \frac{1}{\lambda_i^2}) \quad (1)$$

Where P_i is the Power allocated to i_{th} sub channel and μ is the water filling parameter or threshold, λ_i is the eigenvalue of channel matrix H.Water filling parameter μ should satisfy the following condition

$$P_T = \sum_{i=1}^{n} \left[\mu - \frac{1}{\lambda^2} \right] \quad (2)$$

Capacity of MIMO channel can be expressed as

$$C_T = \sum_{i}^{n} \log\left[1 + \frac{\rho_i}{\sigma^2} * \rho_i^2 \right] \text{bps/Hz} \quad (3)$$

2.1. Steps in water filling algorithm

The step-by-step procedure for water filling algorithm is given below

1. Determine the water filling parameter or threshold μ.
2. Compare the inverse of Eigen values of matrix H with threshold.
3. If $\frac{1}{\lambda_i^2} \geq \mu$, then such eigen channel will not be considered for communication.
4. Let us assume number of transmitters is equal to the number of receivers and $\lambda_1 \geq \lambda_2 \geq \ldots \lambda_n$.
5. The optimum power allocated to i_{th} sub channel is given by

$$\mu_i = \left[\mu - \frac{1}{\lambda_i^2} \right] \quad (4)$$

After maximizing the capacity of the MIMO enabled Cognitive Network our goal is to cancel the interference which is discussed in the next section.

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III. Cognitive Network Model

Consider a Cognitive network with single primary and single secondary user. Let, N^P_t and N^P_r be the number of antennas at the primary transmitter and receiver respectively. Similarly, N^S_t and , N^S_r be the of antennas at the secondary transmitter and receiver. The MIMO channel between the primary transmitter and receiver is denoted by h_{11} and the channel between the secondary transmitter and secondary receiver is denoted by h_{22}.

$$\{popt, qopt, topt, vopt,\} = \underset{p,t,u,v}{\operatorname{argmax}} \{\log 2\,(1+SINRP) + \log 2\,(1+SINRS)\} \quad (5)$$

$$\text{Subject to } \{t \in \text{Null}\,(q^*h21) \in \text{Null}\,(h12p)$$

the interference channel between the primary transmitter and secondary receiver is denoted by h_{11} and the channel between the secondary transmitter and secondary receiver is denoted by h_{22}.

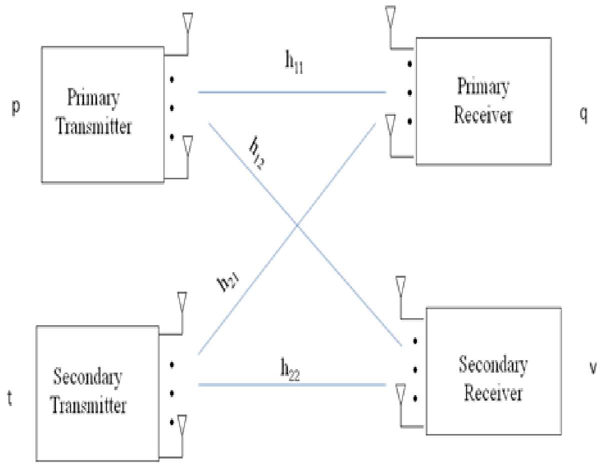

Fig. 3. Proposed Network Model

The interference channel between the primary transmitter and secondary receiver is denoted by h_{12} and the interference channel between the secondary transmitter and primary receiver is denoted by h_{21}.The primary and secondary transmitter employs Beamforming vector p, t for the transmission of their respective data's. Let q, v be the receive vector for the primary and secondary receiver. We also impose a unit energy constraint on all beamforming vectors.

IV. Proposed Work

4.1. Vector Design

The signal–to- interference- plus noise ratio (SINR) is calculated by

$$SINR = \frac{S_P}{I_P + N_P} \quad (6)$$

Where S_P=Signal power

We cannot increase the signal power or reduce the noise power because the increase in signal power may cause unwanted radiations and the occurrence of noise is a random process. We can only change the interference power.

The SINR of primary and secondary user is given by

$$SINR_P = \frac{(Ppq * h11 * pp * h11q)}{(Ppt * h21tt * h21 * q + q\sigma_P^2)} \quad (7)$$

$$SINR_S = \frac{(Psv * h22 * tt * h22v)}{(Psv * h12tt * h12 * v + v\sigma_S^2)} \quad (8)$$

It is obvious from (7) and (8) that in order to achieve zero interference, the beamforming vectors p, q, t, and v have to be designed such that $q^* h_{21} t = 0$ and $v^* h_{12} p = 0$.

The ergodic equation is given by

$$R = \log_2 (1+SINR_P) + \log_2 (1+SINR_S) \quad (9)$$

The design problem can be mathematically given as (5). The vectors designed from the above equation can be used to beamform in such a way that there will not be any interference between the primary and secondary user. The sum rate optimal solution requires the global Channel State Information. The secondary receiver can obtain Channel State Information (CSI) information by monitoring the primary link [5]. In the next section, we use gradient algorithm to provide a solution for the above optimization.

4.2. Gradient Algorithm

Gradient algorithm (steepest ascent) method is used to find the optimum beamforming vectors. Any vector in the null space of $q_{opt}{*}h_{21}$ and $h_{12}p_{opt}$ satisfies the zero interference condition.

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The direction of maximum ascent is calculated using the gradient vector[10]. The optimal beamformers are in the form

$$t=\frac{\hat{h}_{21}\, a}{\sqrt{a * a}} \text{ and } v=\frac{\hat{h}_{12}\, b}{\sqrt{b * b}} \qquad (10)$$

Where a ∈ $(N^s_t -1) \times 1$ and b ∈ $(N^s_r -1) \times 1$.

$$\begin{bmatrix} a[i+1] \\ b[i+1] \end{bmatrix} = \begin{bmatrix} a[i] \\ b[i] \end{bmatrix} + \mu \begin{bmatrix} \frac{\partial f(a[i],b[i])}{\partial a[i]*} \\ \frac{\partial f(a[i],b[i])}{\partial b[i]*} \end{bmatrix} \qquad (11)$$

Where i is the discrete iteration index and μ is the adaptive step size.The optimum value of a and b can be obtained in repeated iterations.

V. SIMULATION RESULTS

The performance of MIMO in a Rayleigh fading environment is considered. Water filling algorithm is used to distribute the available power to all communication channels and to maximize the overall capacity. From the simulation results we conclude that the capacity and Signal to Noise Ratio (SNR) of the channel increases with increase in transmit and receive antennas. The result obtained shows that there is an improvement in the capacity of MIMO channel when the water filling algorithm is used to allocate power. The power allocated with individual matrix element lands for different antenna selection is also plotted.

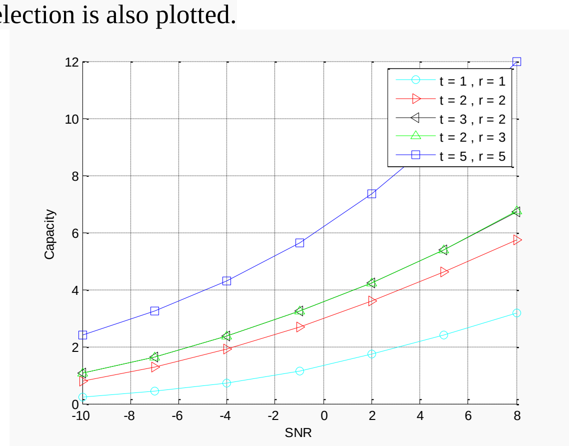

Fig. 4.Channel capacity of MIMO with Water Filling algoritnm

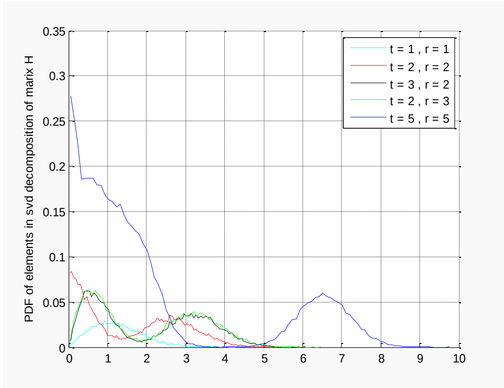

Fig 5: PDF of elements in SVD decompostion

Assume, $N^P_t = N^P_r = 1$. For the initialization of the Gradient algorithm,

$$a[1]=\frac{NSt-1}{\sqrt{NSt-1}} \text{ and } b[1]=\frac{NSr-1}{\sqrt{NSr-1}} \qquad (12)$$

From the simulation results, it is concluded that the optimum values of a and b is converged at i =400.

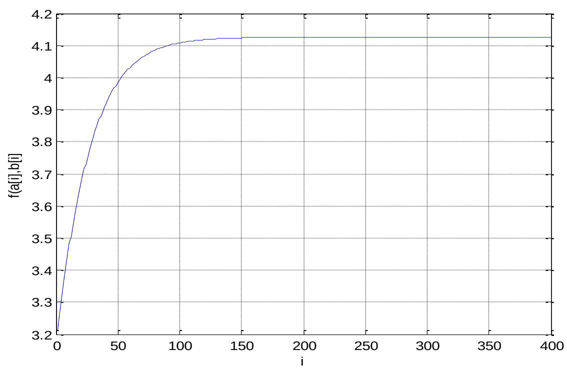

Fig. 6. f(a[i],b[i])vs iteration index i

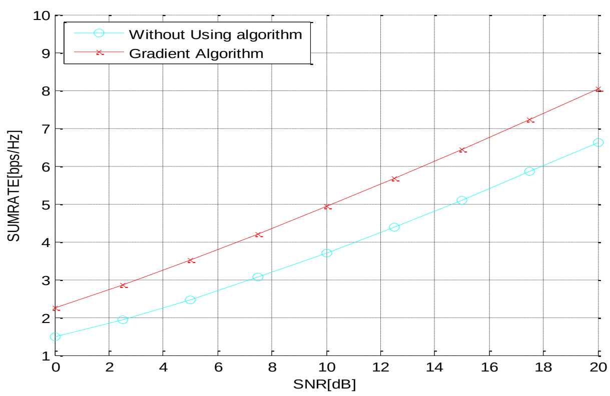

Fig. 7. SUMRATE [bps/Hz] VS SNR [dB]

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Furthermore, μ=0.04 is used as adaption size. From the simulation, we observe that by using optimum beamforming vectors, the interference can be nullified and sum rate can be increased.

VI. CONCLUSION & FUTURE WORK

In this paper, we have maximized the capacity of the MIMO enabled Cognitive network by using water filling power adaptive algorithm. Further, the interference between the primary and secondary user is eliminated. This is different from the existing technology, which requires the coordination between the primary and secondary user. Since a primary user is a licensed one there is no interference is created in primary receiver, traditional approaches can be used to design beamforming vectors or preceding matrix of the primary user. Gradient algorithm was proposed for the design of beamforming vector of the Cognitive link. However we propose uncoordinated beamforming and sum rate maximization in a Cognitive network, these results can also be applied to practical systems like Cognitive radio, small cell deployment in macro network etc.. In future, we can extend in such a way that secondary user can also transmit without monitoring the primary link.

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