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OPTIMIZED SYSTEM MODEL FOR ANTENNA SELECTION IN COGNITIVE RADIO

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ABSTRACT—Cognitive Radio is the most important and emerging technologies of today, as it solves Spectral scarcity in highly traffic channels. The main aim of CR is to reduce the interference as low as possible of the secondary user at primary user. Multiple Input-Output systems are implemented with CR to enhance diversity gain. However all the antenna used at the same time in the system is wastage of transmitter power and also increases the interference. The better way to deal with this problem is to select a few groups of antennas which optimize the system performance in a dynamically varying channel environment. Here, this issue is considered as an optimization issue where the main objective function is to maximize data transmission rate, and constraints are to minimize total transmission power and interference.

KEYWORDS—Antenna Selection; CR System; Multiple Input-Output system; Optimization

I. INTRODUCTION

A. Cognitive Radio Systems (CRS):

Having three key abilities, for example: cognitive capability, learning ability and reconfiguring capacity CRS have enough potential of being a detrimental force within the spectrum management. Utilizing SDR for actualization of reconfigurable radios, CRS gives extra adaptability and offers better efficiency for the use of overall spectrum. It might also utilize the white spaces or spectrum holes of licensed spectrum bands given that it doesn't create unsafe impedance for any of main subscribers to upgrade efficiency of the range of frequency usage. The principal issue confronting future remote frameworks is the place to discover appropriate range groups to satisfy the need for future services. While basically the part of radio range is distributed to different applications, and customers, observation gives proof, the use of range is low. So as to conquer this issue and to improve the spectrum use, CR ideas have been presented. The CR target is to utilize scarce and to restrict normal resources proficiently without effecting uncontrolled interference to any of main licensed subscribers. CR will recognize and understand its spectrum environment, associate its temporarily idle spectrum, gain from its conduct and transmit adaptively. [1].Currently used radio systems aren't sensible about their radio spectrum context as it was schemed in such a way that it could be operated in defined band by using frequency range access system. Some inquires for range of frequency utilization specifies that the spectrum is not effectively utilized most often. All in all spectrum utilization could be improved considerably after permitting secondary unlicensed users to vigorous approach towards spectrum holes as it is not temporarily occupied by the main subscriber in the geographical part of notice as shown in Fig 1.

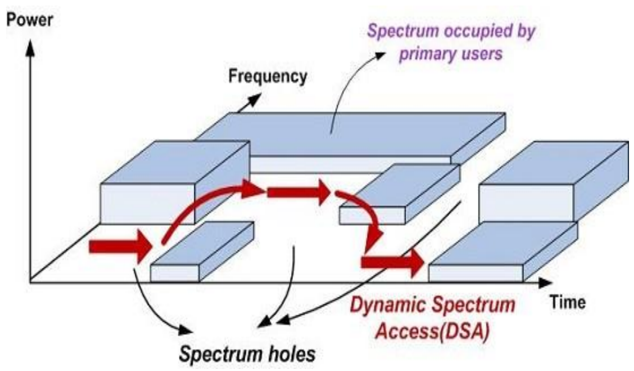

Fig. 1 Various approach Spectrum hole

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The spectrum space is the range of frequencies allocated to the main subscribers, at a specific time and different region, the band isn't used by that subscribers. The space idea may be summed up as transmission open doors in radio white hole which is a hypothetical space involved by signals that have location dimensions, time, angle of reach, energy, frequency and others [3].Radio developed is able to perceive and feel its near spectrum atmosphere, to recognize space in radio spectrum hole able to craft decision by their own about how it accesses spectrum. Such CR utilizing dynamic spectrum can possibly altogether upgrade the spectrum efficiency utilization bringing about simple and adaptable spectrum access for present or future purpose to provide wireless services.

CR is a present day concept that is first introduced by Joseph Mitola and Gerald Maguire [4] which introduced CR as conservatory of software-defined radio which was able to enhance the litheness of wireless help with radio domain based model interpretation by a unique language called RKRL.CR's structural design is an corporate agent for software-based radio of private technology at the crossing point of intersection and computational intelligence was additionally evolved in Mitola's doctoral thesis. [5].

The concept behind CR has emerged with the need to use the radio spectrum productively, and to have the option to keep up the most proficient type of correspondence for certain conditions like overarching and using the level of dealing out that are available currently, it is conceivable to build up a radio that's capable to see the spectrum, distinguish the frequency and it can be easily identified, and afterward execute the supreme type of communication for the needed conditions. So, in this way CR innovation can choose the frequency band, power levels generally fit the necessities, the type of modulation, and prevailing conditions, and geographic dogmatic requirements. CR may be defined as an intellectual system that knows about general condition, gains by the atmosphere and adjusts inside states to measurable quantity in the further frequency stimuli by making changes accordingly in assured parameter in practical-time, with two main ideas: reliable communications when and where ever important as well as proficient deployment of radio spectrum [2].

In general, the CR might be relied upon to take a gander at parameters, for example: free channels, inhabitancy, the kind of transmitted data, and the modulation types that are used. It should likewise take a gander at the intended requirements. For certain conditions, it may be requisite to use a software-defined radio, and might be reconfigured itself to meet and accomplish the optimal transmission technology for a specified arrangement of parameters. Respectively, CR technology and software-defined radio are regularly firmly linked. In request to accomplish these targets, CR is obligatory to rapid change the properties and to get the spectrum without creating worthless interference to the main subscribers. Steps followed by the cognitive cycle are: frequency range sensing, frequency range decision, sharing, and mobility [6].

Spectrum observing: It is dynamic range understanding process where CR screens geographical surroundings and radio atmosphere as well as distinguishes between utilization measurements of certain users (primary as well as secondary) and decides to calculate spectrum holes. Spectrum observing can be possible by many CR terminals or by unknown observing networks exchange data in a way that will improve on the whole accuracy.

Spectrum decision: By seeing above data, CR chooses when to start its event, operates the frequency, and its parameters used. CR's main target is to send useful data and to fulfil the quality of service. At the same time, CR may utilize information from the regulatory and policy database in order to better its outage operation.

Spectrum sharing: As large number of unlicensed subscribers taking interest in the use of present spectrum space, CR have to get a balance between its aim of sending data in an efficient manner and considerate aims to share the present sources with other subscribers either cognitive or non-cognitive subscribers . But this can be done with rules deciding that CR conducts in specific conditions.

Spectrum mobility: Let the main subscriber start to work, then CR have to halt the activity or renounce right now the utilized spectrum and changed frequency.So, In order to evade intrusion for the main subscribers, it function has to be implemented in practical-scenario, therefore CR has to regularly explore all the feasible substitute spectrum holes.

Radio Environment: Purpose behind Radio Environment Maps (REMs) designs is to make a decision to store the information in a sorted manner and the way it is able to access the different-different radios (CR or otherwise). It could cover the multi-domain ecological data like spectral regulations, geographical importance or location of various entity to notice (reflectors, obstacles, radios) plus radio-equipment capability profiles, pertinent policies, and many more. Its information is often modernised with respect to the interpretations from CR nodes and promulgate all through CR networks.

B. Multiple Input -Output Systems:

These wireless systems are the systems whose both ends have multiple antenna elements i.e. transmitter and receiver [7]. Computer simulations was the first one to present this system in the 1980s [8], and then, papers

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reconnoitre analysed [9], [10]. From then to till now, interest in the above System has been fulminate that are used for WCDMA as well as discussed for best-performance mode of the booming IEEE 802.11 paradigm for LAN. Topics which are related to Multiple Input-Output Systems occupy main component of communications. In above system, many antennas are used in two ways. First is the foundation of efficient antenna diversity system; whereas second one is for the transmission of different parallel data streams using the multiple antennas to enhance the capacity of the system.

Digital communications using MIMO Systems has come out together of the important research field in communications and also figures on the chart of technologies that can have a chance to sort out the bottlenecks of traffic in the coming high-speed rate broadband Internet access system.

The random system given a link to the transmitting end as the receiving end is provided with many antenna elements, as given in Fig. 3. The idea of this system is that the signals on the TX antennas at one end and RX antennas on the former end are "mutual" in approach that the eminence (Bit Error Rate) or the data rate (Bit/Sec) of the communication will be better. Space-time processing method needed by the above system in which the time dimension is finished with the spatial dimension bring by the different antennas. These network are observed as an addition of the alleged "smart antennas”, a method, first invented in the 70s, for enhancing wireless transmission.[11].

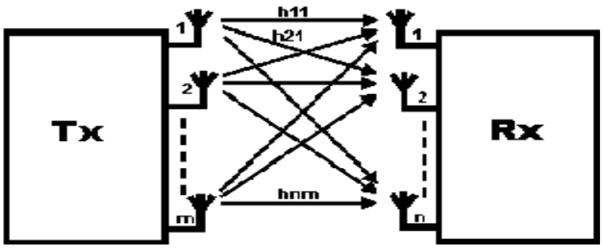

Fig. 2 General MIMO system

A channel could also be suffering from dwindling and this may affect the SNR that affects the error rate, by making assumptions of the transmission of digital data. The idea of diversity is to give many versions of an equivalent signal on the receiver. And this is impact in many ways from signal path, the chances that they're going to exaggerated at an equivalent total time is decreased. In similar way, diversity used to stabilize a link and increase performance, error rate. Different diversity modes provide a large number of benefits:

- *Time diversity:* In this, data signals transmitted at different times, e.g. via dissimilar time slots and channel coding.
- *Frequency diversity:* This uses different frequencies; it involves transmission of same information signals of different carriers such as spread spectrum.
- *Space diversity:* Multiple antennas are located at spatial positions or locations which results in different received signals.
- MIMO network is a radio method as multiple antennas are used at the TX and RX to permit a different signal paths to hold data, by selecting distinct paths for every antenna to let and use multiple signal paths.
- Common idea behind MIMO Systems wireless systems space signal processing in which time go together with the dimension integrated within the use of many spatially scattered antennas. Accordingly, MIMO wireless systems are considered as main idea for the smart antennas that are in used for many years to increase communication system performance.

It is obtained among TX and RX; the signal can acquire many paths .And also, by moving the antennas a distance, paths may change the variability of paths given which happens as result of large number of elements appearing to side between the TX and RX at the same time the multiple paths used are just to introduce interference. By using Multiple Input-Output System, these additional paths usually don't have any advantage, they grant supplementary strength to the link from recuperating SNR. Two specific formats for Multiple Input-Output System are mentioned below:

- *Spatial diversity*: It is used in the narrower way often present for TX and RX diversity which are used to offer improvement swith in SNR and identified from ameliorating the dependability of the network wrt the fading.
- *Spatial multiplexing*: MIMO network generally used to supply auxiliary information capacity by availing the many paths to hold added traffic, which directly increases the info throughput potential.

ISSN- 2394-5125 VOL 7, ISSUE 15, 2020

This results in the utilization of many antennas, and this method enhanced the range of the particular channel while following Shannon's law. So, to enhance the value of RX and TX antennas, there is a chance to enhance the throughput with every pair of antennas given to the network. It makes Multiple Input-Output System technology, the most important wireless technique used in the current period .For radio communications systems, spectral bandwidth is going to become the most estimable commodity and these method are needed to use the present bandwidth more and MIMO network method is one of these techniques.

A learning article [12] given an association among SISO and MIMO wireless. They need to compare Shannon ergodic ability of the SISO link and its diverse realization with the MIMO network channel. It is shown, wireless information rate augments linearly with enhancement of many antennas both at TX and RX. MIMO network wireless connect capacities once TX and RX each have high information of channel matrix. The sole TX has the matrix awareness and when the sole RX has the awareness is given. MIMO System channel decomposition using eigen amount and singular values decomposition technique is proposed. The generic issue can be specified as the joint selection of TX-RX antennas in a MIMO CR network. The idea is to enhance the attainable rate as much as possible of the CR during satisfying any intrusion constraint due to the PU RX (either capable with an antenna or many antennas) functioning in locality. We take the describe task by performing an Exhaustive Search all over combinations of antenna parts and optimize over the TX CM of the CR subscribers. After having simulation results other optimization methods also applied on it.

C. Organization of paper:

The present paper is organized as: Section II tells the network model, Section III tells framework and Section IV gives performance details analysis. Section VI concludes the given network

II. SYSTEM MODEL

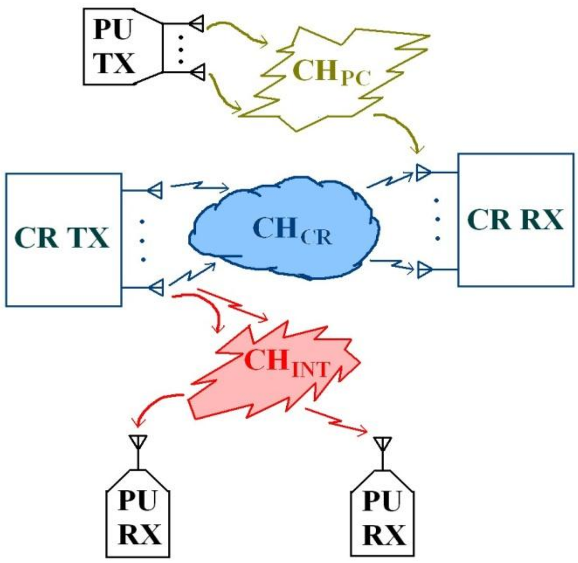

Fig. 3 System Model

The model shown in Fig. 3 CR transmitter and receiver equipped with many antennas. Channel matrix CH_{CR} formed in between the CR transmitter and CR recover. Here, assumed channel is Rayleigh channel with quasi-stationary type, which remains stationary for particular time. In the Cognitive system, interference of secondary users at primary users plays a major role. Interference channel matrix CH_{INT} is formed between CR transmitter and PU receiver. Here the linear relationship of interference with the number of PU receivers, if the amount of PU receivers increases then interference also increases. So our main constraint of the algorithm is to minimize the interference between CR users and PU. Another interference of PU transmitters at CR receivers can be formed. Channel matrix CH_{PC} shown in figure gives idea about interference of primary user transmitters at CR receivers. Same linear relationship of interference has also been applied here.

At the initial stage, we have considered that only one PU transmitter and one PU receiver is present in the MIMO cognitive system. The problem can be generalized by taking many numbers of primary users. As more as our system model is concerned, there are three channel matrices CH_{CR}, CH_{INT} and CH_{PC}, where each of them formulated by group of antennas used at TX and RX. CH_{CR} matrix has T_{CR} and R_{CR} number of columns, CH_{INT} matrix has T_{CR} number of rows and R_{PU}, and CH_{PC} matrix has T_{PU} rows and R_{CR} columns.

III. ANALYTICAL FRAMEWORK

The network mode which is being proposed here as shown in Fig 3. Let us assume that transmitter and receiver have with their corresponding T_{CR} and R_{CR} antennas. PU consists of two antennas i.e. T_{PU} TX antennas and R_{PU} RX antennas. It is assumed that more than one single receiving antenna when PUs operation in CR environs. These situations are considered as single and multiuser (SU, MU) respectively. The signal on CR receiver is as given:

$$f_{CR}(n) = CH_{CR}a(n) + b(n) + g(n) \quad (1)$$

where,

I. $\mathbf{CH_{CR}} \in \mathbb{C}^{RCR \times TCR}$ is the channel gain matrix whereas g(n) is Gaussian noise. **a**(n) and $\mathbf{f_{CR}}$(n) are the send and the RX signal vectors correspondingly, **b**(n) is the interference. In addition to this , the transmit covariance matrix of the CR subscribers is expressed $\mathbf{V_{CR}} = [\mathbf{a}(n)\mathbf{a}(n)^\dagger]$. Let consider the total average CR TX power is limited to P_{CR} that is$Tr(\mathbf{V_{CR}}) \leq \mathbf{P_{CR}}$. The CM of the interference and noise is distinct from $\mathbf{D} = [\mathbf{b}(n)\mathbf{b}(n)^\dagger + \mathbf{g}(n)\mathbf{g}(n)^\dagger] = \mathbf{I_{RCR}} + \mathbf{CH_{PC}CH_{PC}}^\dagger$. In Multi User it is presumed that the power decay exponentially as well as CR interference transversely the PU receivers [13]. Various simulation results might be applied to construct the chain of interfering links which is based on a series of random locations, and other values etc. Consequently, to simplify our design it is useful to apply the decay model. CR Transmitter and receiver for antenna selection keeps channel state information ($\mathbf{CH_{CR}}$, $\mathbf{CH_{INT}}$ and $\mathbf{CH_{PC}}$ .It is important that CR interference present at PU - RX must be below the defined threshold value. For a test case, The interference constraint for a subscriber may be written as,

$$\sum_{i=1}^{R_{PU}} CH_{INT}(i,:)V_{CR}CH_{INT}^\dagger(i,:) \leq \Theta \quad (2)$$

$$\Rightarrow T_r\left(CH_{INT}V_{CR}CH_{CR}^\dagger\right) \leq \Theta$$

Where $\mathbf{CH}_{INT}$ (i, :) $\in \mathbb{C}^{1\times TCR}$represents channel from the CR transmitter to the i^{th} receive antenna of the PU receiver and Θ is the adequate total power at the PU receiver.

In addition to, idea of doing constrained joint TX-RX antenna selection at the CR, here it usually begin with the familiar idea that the achievable rates of the CR network using total present antennas are [14]

$$R(CH_{CR}, V_{CR}) = det(I_{RCR} + CH_{CR}V_{CR}CH_{CR}^\dagger D^{-1}) \quad (3)$$

Similar to the approach of [15], it shows the diagonal selected matrices **E1**, **E2** of dimension $R_{CR} \times R_{CR}$ and $T_{CR}\times T_{CR}$ with binary diagonal entries respectively. Mathematically, elements define as

$(\mathbf{E_i})_{\mathbf{kk}} = \mathbf{1}$ if the k^{th} antenna is choosed

0 otherwise, (4)

Where I is equal to 1, 2.Diagonal elements of**E1**, **E2** are the elements of the antennas at the CR receiver and CR transmitter. Then the expression (3) reduces to

$$R(\underline{CH}_{CR}, \underline{V}_{CR}) = det(\underline{I}_{RCR} + \underline{CH}_{CR}\underline{V}_{CR}\underline{CH}_{CR}^\dagger) \quad (5)$$

where $\underline{CH}_{CR} = \underline{D}^{(-1/2)}E_1CH_{CR}E_2$ By selecting RX antennas we get a noise CM$\mathbf{D}_{re}$(dimension $m_{cr} \times m_{crd}$) and a new interference and the matrix is increased to Form$\underline{D}$, an $R_{CR} \times R_{CR}$ matrix, by placing columns and rows of zeros to the non-certain RX antennas. Similarly, with the obtained TX antennas, compact V_{red} matrix ($t_{cr}\times t_{cr}$) is inflated to $\underline{V}$, ($T_{CR} \times T_{CR}$) by placing columns and rows of zeros with respect to the non-selected TX antennas. So, the problem of combining TX-RX antenna selection with CR power allowance may mathematically cast in the SU case as the constrained optimization issue**P1** as

P1: maximization

E1, E2, VCR

$$det(I_{RCR} + \underline{D}^{(-1/2)}E_1CH_{CR}E_2V_{CR}E_2^\dagger CH_{CR}^\dagger E_1^\dagger \underline{D}^{(-1/2)})$$

Subject to

$$\{1,0\}, j = 1, \ldots, R_{CR} \; if \; i = 1 \; and \; j = 1, \ldots, T_{CR} \; if \; i = 2$$

$T_r\left(CH_{INT}E_2V_{CR}E_2^{\dagger}CH_{INT}^{\dagger}\right) \leq \Theta, V_{CR} \geq 0$

$\mathrm{Tr}(\mathbf{V}\boldsymbol{CR}) \leq \mathbf{P}\boldsymbol{CR}$, $\mathrm{Tr}(\mathbf{E1})=\mathbf{rcr}$,$\mathrm{Tr}(\mathbf{E2})=\mathbf{tcr}$ (6)

Assume that

Here P1 is an objective function for maximizing data rates between selected antennas E_1 and E_2 at receiver and transmitter respectively. Constraints: covariance matrix V_{CR} must be positive and interference is less or equal to threshold Θ. It is assumed that power is less or equal to addition of diagonal parts of CM V_{CR} and sum of diagonal elements of E equals to the number of antennas selected at each side.

IV. SIMULATION RESULTS

In this system BPSK data is considered for data communication in Cognitive Network. Here, MIMO channel matrix $\mathbf{CH_{CR}}$ is 2 × 2 configured, and also one primary user transmitter $\mathbf{T_{PU}}$& one primary user receiver $\mathbf{R_{PU}}$ present in the CR environment. By performing number of iterations for calculating interference it can be summarized that CR interference observe at PU RX value should not be more than the threshold value Θ=3.9373 which is already defined. It is obvious that transmitting and receiving power is minimized in a selected pair of antennas compared to using all antennas simultaneously. So assuming that minimum power requirement, data rates for two pairs of $\mathbf{T_{CR}}$-$\mathbf{R_{CR}}$ have been calculated with interference threshold as a main constraint.

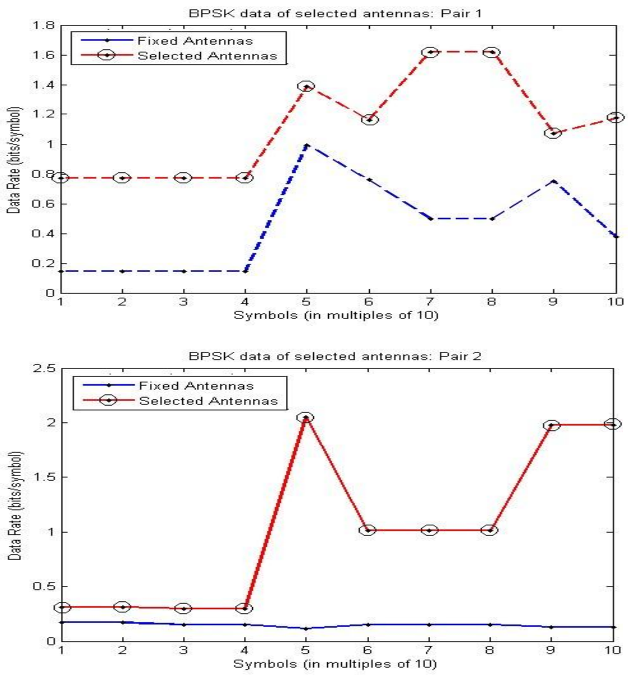

Fig. 4 Simulation results for BPSK

It can be observed from above fig. 4 that the throughputs (data rates) of antennas chosen by our algorithm are quite higher than using the fixed configured antennas. The BPSK scheme has two values for symbols are -1 and 1, which can be generated randomly for communication in our system model.

V. CONCLUDING REMARKS AND FUTURE WORK

It has been observed that antenna selection schemes outperform conventional fixed antenna schemes with interference and saving energy as constraints at same time. Here it is considered that the channel is Rayleigh fading distribution during simulation. So our antenna selection system gives higher and better data rates as compared to fixed arbitrary antenna selection configuration. In this scheme simulation is performed only for

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both antennas which are at both transmitter and receiver end, where they are combined with a single antenna. Here only BPSK technique is used for data communication, at later stage the scope of system is elaborated for defining algorithm and could be applicable for one or more number of antennas at both secondary and primary side, and better optimization method is selected to reduce complexity at transmitter and receiver side with individual modulation schemes.

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