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Joint Beamforming, Power and Channel Allocation in Multi-User and Multi-Channel Underlay MIMO Cognitive Radio Networks

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ABSTRACT

In this paper, a joint beamforming, power and channel allocation in a multi-user and multi-channel underlay MIMO cognitive radio networks is considered. The primary users (PU's) spectrum is reused by the secondary user transmitters (SUTXs) to maximize the spectrum utilization while the intra-user interference is minimized by implementing the beamforming at each secondary user transmitter. After formulating the joint optimization problem as a non-convex, mixed integer non-linear programming problem, a solution is proposed into a two stages. First stage is deriving the beamforming vectors and power allocation under a given channel by converting the original problem into a convex form with an introduced optimal auxiliary variable and semi definite relaxation approach. In the second stage, an explicit searching algorithm i.e., genetic algorithm is proposed to determine suboptimal channel allocation. Simulated result shows that the proposed allocation scheme has a better achievable rate than the existing zero forcing beamforming method.

Keywords : Cognitive radio networks, genetic algorithm, primary user, secondary user, MIMO, semi-definite approach, singular value decomposition.

I. INTRODUCTION

The information and communication technology industry is today faced with global challenge develop new services with improved quality of services (QoS) and at the same time reduce its environment impact, clearly there is a deep need of global efficiency not only in energy domain but also in spectrum domain. A huge amount of spectrum is required for broadband use in the future as suggested in National Broad Plan (NBP) in USA and the digital agenda in Europe.

In order to address the spectrum usage efficiently, the cognitive radio concept was proposed. Cognitive radio system is a radio system which aware of its operational and geographical environment established policies and its internal state. The principle of cognitive radio is a temporal, spatial and geographic "reuse" of licensed spectrum where an "unlicensed" secondary user (SU) can be permitted to use licensed spectrum provided that it does not interfere with any primary spectrum utilization have shown that spectrum is underutilized, in the sense that the typical duty cycle of spectrum usage at a fixed frequency and at a random geographical location is low. This means that there are many holes in radio spectrum that could be exploited. Opportunistic radio system should be able to exploit this spectrum holes by detecting them and using them in an opportunistic manner. Because of the outstanding propagation channel in the television bands with strong wall and floor penetration capability, long range and flexible bandwidth, it could be used to allow brand new class of services and increases the limited capacity of existing system.

II. METHODS AND MATERIAL

A. Beamforming

The directionality of reception or transmission of a signal on a transducer array can be controlled by a signal processing technique called beamforming. The majority of the signal energy can be transmitted from a group of transducer in a chosen angular direction and the receiver receives the signal energy in predominantly angular direction. The beamforming can be achieved by setting the multiple transducers next to each other sends the same signal energy i.e., it going to produce some kind of interference pattern. The spacing and delay in the transducer signal is changed, the interference pattern also changed.

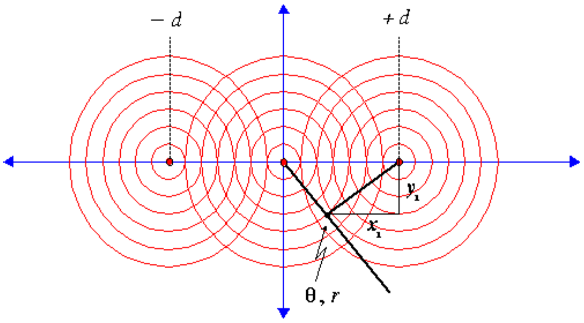

Figure 1: Interference pattern of beamforming

The polar coordinates system is considered because the interference pattern affects things angularly. For example, consider five sources set at 10 unit apart on x axis – one source in the middle and two on each sides. The sources do not all ping at the same time. The maximum 5 unit delay is considered in the sources. This result in a warping of the interference pattern i.e., the beam is steering in a particular direction.

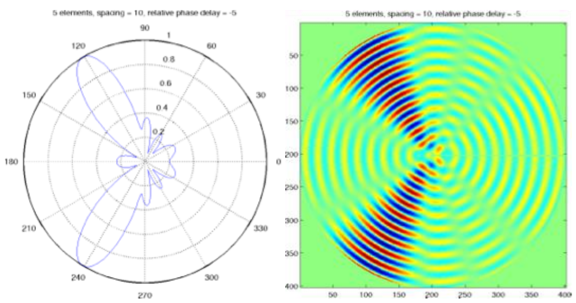

Figure 2 : Beamforming pattern for five elements, spacing at 10 and its polar response.

B. Beamforming Techniques

The directionality of an array can be controlled by the phase and relative amplitude of a signal at each transmitter which creates a pattern of constructive and destructive interference. The two beamforming techniques are

- Conventional beamformer
- Adaptive beamformer

The conventional beamformer uses a fixed set of weights and time delays to combine the signal from the sensors in the arrays whereas adaptive beamformer technique adapts its response to a different situation. Sonar phased array are at low data rate which can be processed in software but radar phased array are at high data rate which requires dedicated hardware processing technique and can be programmed in software also.

C. Sonar Beamforming Requirements

The sonar has many applications such as wide area searching and ranging, under water imaging sonars such as side scan sonars and acoustic cameras. Many sonar systems such as on torpedoes, are made up of arrays of up to 100 elements that must accomplish beam steering over a 100 degree field of view and work in both active and passive arrays.

Sonar arrays are used both actively and passively in 1-, 2- and 3-dimensional array. The beamforming technique is deployed in sonar to compensate the significant problem of slower propagation speed of sound as compared to that of electromagnetic radiation. The focusing algorithm is intended to improve reception, many sides scan sonar also employ beam steering i.e., forward and backward movement of sonar arrays to catch the incoming pulses.

D. Beamforming Scheme

A conventional beamformer is a simple beamformer also known as delay-and-sum beamformer in this all the weights of the antenna element have equal magnitudes. By selecting appropriate phase for each antenna, the beamformer is steered in a specified direction. The cellular phone standard uses beamforming techniques to achieve higher density cells with higher throughput.

Beamforming for speech audio is used to extract the sound sources in a room. The location of a speaker to be known in advance for this type of beamforming. The specialized filter banks are used to separate frequency bands prior to beamforming. Standard filters such as FFT bands are sub-optimal for this purpose because they are not designed to isolate bands. The recombination property is also required to reconstruct the transmitted signals. These basis are typically non-orthogonal unlike effective basis.

E. Cooperative Communication Systems

An adhoc network is an infrastructureless network whose operation is relay on intermediate mobiles. The information from the source to destination is transmitted via other mobiles. Multi-hop ideas are also utilized in cellular and wireless LAN system to provide higher quality of service power savings and extended coverage. The relay channel was introduced by Van der Meulen and investigated extensively by Cover and El Gamal. The capacity of general relay channel is unknown. The multi-hop technique is not to overcome path loss but also it provides diversity.

Cooperative communication involves two ideas: i) using relays to provide spatial diversity in a fading environment, ii) envision of collaborative scheme where the relay has its own information sends to both terminals.

F. Performance of Mimo

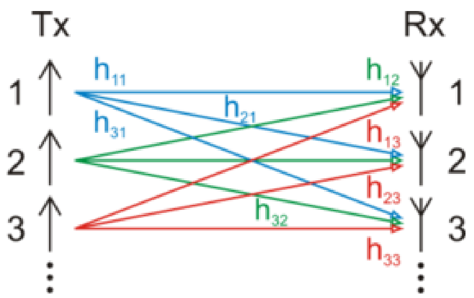

Figure 3: MIMO channel model

In the MIMO systems, a transmitter sends multiple streams by multiple transmit antennas. These streams go through a matrix channel which consists of all path between the N_t transmit antennas and N_r receiver antennas. Then, the receiver gets the received signal vectors by the multiple receive antennas and decodes the received signal vectors into the original information. A narrow band flat fading MIMO system is modelled as

$$Y=Hx+n \quad (1)$$

Where y and x are the receive and transmit vectors respectively and H and n are the channel matrix and the noise vector respectively.

G. Proposed System

Joint beamforming based achievable rate improvement on genetic algorithm using multiple relay paths for power and channel allocation on cognitive radio network. In modified genetic algorithm, to determine suboptimal channel allocations using 3:2:6 MIMO systems using achievable rate improvement on 6 destinations with the help of 36 paths.

H. Performance Analysis:

In wireless channels, transmission of signals can be done by multi-carrier modulation technique called OFDM. It separates the high rate-data stream into parallel lower level rate data; by the way it avoids ISI.

MISO:

It consists of multiple antennas at transmitter side and single antenna at receiver side say " y " with different fading channel coefficient i.e., h1 and h2. The capacity of the channel is not be so efficient and it is given by

$$C = M_t B \log_2 (1+S/N) \quad (2)$$

Where,
C – Capacity
Mt –no.of antenna at transmitter side
B – Bandwidth
S/N – signal to noise ratio

MIMO :

It consists of multiple antenna at transmitter and receiver side say $S=[S1\ S2\ S3\ldots S_M]t$ and $y=[y1\ y2\ y3\ldots y_M]t$ as the vectors respectively and $n=[n1\ \ n2\ \ n3\ldots n_M]t$ is the AWGN. To achieve good SNR, we use BPSK modulation scheme in each block modulation of signal transmission. The MIMO channel is given by

$$H = \begin{bmatrix} h11 & h12 & \cdots & h1MT \\ h21 & h22 & \ddots & h2MT \\ hMR,1 & hMR,2 & \cdots & hMR,MT \end{bmatrix} \quad (3)$$

The capacity of MIMO is given by

$$C = M_t M_r B \log_2 (1+ S/N) \quad (4)$$

where,
C – capacity
M_t – no.of antennas at transmitter
M_r – no.of antennas at receiver side
B – Bandwidth
S/N – signal to noise ratio

Consider a network with source(s), relay(R) and destination (D). The link between S and R is direct and it uses half duplex mode, so that R can't transmit or receive signals at same time. Hence there exists 2 phases. In the 1st phase (source phase) S transmits information to D and in the 2nd phase (Relay), R decodes the received information and then forwards the decoded information to D. In source phase, x_s (transmitted information system) is multiplied with w_s(unit norm vector) and complex baseband received symbol at D in the source phase is given by

$$Y_{D,S} = h^T_{D,S} \cdot w_s x_s + n_{D,S} \qquad (5)$$

where,

$h^T_{D,S}$ - channel gain vector from S to D

$n_{D,S}$ – Scalar AGN with unit variance

The received SNR at D during source phase is given by

$$\gamma_{D,S} = |h^T_{D,S} . w_s|^2 P_s. \qquad (6)$$

The complex baseband signal vector received at N antennas of node R is given by

$$y_{R,S} = H_{R,S} \cdot w_s x_s + n_{D,R} \qquad (7)$$

where $= H_{R,S}$ - channel gain matrix from S to R. Applying SVD, we can rewrite

$H_{R,S}$ as $H_{R,S} = U \wedge V^H \qquad (8)$

Then the effective received SNR at R is given by $\gamma_{R,S} = \|H_{R,S} \cdot w_s\|^2 P_s \qquad (9)$

The achievable information rate from S to R is $C_R = \log_2(1+\gamma_{R,S}). \qquad (10)$

Hence the complex symbol received at D in the relay phase is given by

$$y_{D,R} = h^T_{D,R} w_r x_r + n_{D,R} \qquad (11)$$

where $h^T_{D,R}$ is the channel gain vector from R to D. The received SNR at D during relay phase is given by

$$\gamma_{D,R} = |h^T_{D,R} w_r|^2 P_r \qquad (12)$$

Thus the achievable information transmits rate at D in the relay phase is

$$C_D = \log_2(1+\gamma_{D,S}+\gamma_{D,R}) \qquad (13)$$

Thus achievable rate is given by

$$C_{DF} = ½ \min\{C_R, C_D\} = ½ \min\{\log_2(1+\gamma_{R,S}), \log_2(1+\gamma_{D,S}, \gamma_{D,R})\} \qquad (14)$$

Where, ½ is the time division feature of the half duplex relay system.

PROBLEM FORMULATION:

To minimize the achievable rate (C_{DF}) for MIMO DF relay, we optimize beamforming vectors and it is given by

$$\max_{W_s, W_r} ½ \log_2(1+\min(\gamma_{R,S}, \gamma_{D,S}+\gamma_{D,R})) \text{ where } \|W_s\|^2=1 ; \|W_r\|^2=1 \qquad (15)$$

The function $f(x) = 1/2 \log_2(1+x)$ is monotonically increases as $f(x)>0$ and (1) is given by

$$\max_{W_s, W_r} \min\{\gamma_{R,S}, \gamma_{D,S}+\gamma_{D,R}\} \qquad (16)$$

where $\|W_s\|^2=1 ; \|W_r\|^2=1$

SNR at D during source phase

$$\gamma_{D,S} = |h^T_{D,S} . w_s|^2 P_s \qquad (17)$$

SNR at relay

$$\gamma_{R,S} = \|H_{R,S} \cdot w_s\|^2 P_s \qquad (18)$$

SNR at D in during relay phase

$$\gamma_{D,R} = |h^T_{D,R} w_r|^2 P_r \qquad (19)$$

From (17), (18) and (19), (19) alone is affected by beamforming vector w_r by adopting maxi-ratio transmission (MRT). Thus optimal beamforming vector from R to D in relay phase is given by

$$W_r^* = h_{D,R} / \|h_{D,R}\| \qquad (20)$$

Substitute (20) in (19), then

$$\gamma^*_{D,R} = \|h_{D,R}\|^2 P_r \qquad (21)$$

The optimization problem in (16) can be transformed into

$$\max_{W_s} \min\{\gamma_{R,S}, \gamma_{D,S}+\gamma^*_{D,R}\} \qquad (22)$$

Then introducing SDR method in (22),

$\min_{w_s} -t$

s.t $\|H_{R,S} \cdot w_s\|^2 P_s \geq t$

$| h^T_{D,S} .w_s|^2 P_s + \gamma *_{D,R} \geq t$

$||w_s||^2 = 1,$

$w \geq 0$ (23)

then by defining

$G = H_{R,S} H^H_{R,S}$ and $F = h_{D,S} h^H_{D,S}$ (24)

and a new matrix variable

$W = w_S w_s^H$ with $w \geq 0$ then problem in transformed into

min w –t

s.t $t_r(WG) \geq t$

$t_r(WG) + \gamma *_{D,R} \geq t$

$t_r(w) = 1$

rank (w) =1

$w \geq 0$ (25)

The SDR is more complexity then CVX method. Therefore we adopt an alternative approach based on the properties of optimal solution with lower complexity without any relaxtion. V= (V1 V2 V3….V_{NS}) in the equation

$H_{R,S} = U\wedge V^H(11)$ (26)

is a unitary matrix of full rank, for an arbitrary beamforming vector $||w_S||^2 = 1$ then

$w = (w1, w2, w3 \ldots W_{NS})^T$; $w_s = v_W = v_1 w_1 + v_2 w_2 + \ldots + v_{NS} w_{NS}$ (27)

$w = v^H w_s$ is a unit norm complex vector. Substitute (27) in (17) and (18)

$\gamma_{D,S} = || h^T_{D,S} .w_S||^2 P_S$

$= || h^T_{D,S} .v_W||^2$

$= ||h^T_{D,S} v_1 w_1 + h^T_{D,S} v_2 w_2 + \ldots .. + h^T_{D,S} v_{NS} w_{NS}||^2 Ps$

$= (\sum_{i=1}^{Ns} |h^T_{D,S} v_i w_i|)^2 P_S$ (28)

$\gamma_{R,S} = || H_{R,S} .w_S||^2 P_S$

$= ||U\wedge V^H V_W||^2 P_S$

$= ||U\wedge w||^2 P_S$

$= (U\wedge w)^H (U\wedge w) P_S$

$= w^H \wedge^H U^H U \wedge w P_S$

$= ||\wedge w|| P_S$

$= \sum_{i=1}^{Ns} lamda_i^2 |w_i| P_S$ (29)

$lamda_i = 0$; $i = N+1, \ldots, N_S$ where N = min $\{Ns, N_r\}$. To find w_S*is equivalent to w* then

$\max_W \min \{ \gamma_{R,S}, \gamma_{D,S} + \gamma *_{D,R} \}$ (30)

from (28) and (29), phase angle of each element w only affect $\gamma_{D,S}$ and $\gamma_{R,S}$ is found busst the amplitude of elements of vector w. optimal phase angle

$<w^* = (<w_1^*, <w_2^*, \ldots, <w_{NS}^*)$ (31)

then we use lemma value i.e., phase should be same value $2k\pi$ difference (30) is given by

$\max_{|w_1|, \ldots, |w_{NS}|} \min \{ \sum_{i=1}^{Ns} lamda_i^2 |w_i|^2 P_S, (\sum_{i=1}^{Ns} |h^T_{D,S} V_i||w_i|^2 P_S + \gamma *_{D,R} \}$ (32)

Assume $\alpha_i = |w_i|^2$; $\beta_i = |h^T_{D,S} V_i|$

Then the optimal problem in (32) is given by

$\max_{\alpha_1, \ldots, \alpha_{NS}} \min \{ \sum_{i=1}^{Ns} lamda_i^2 \alpha_i P_S, (\sum_{i=1}^{Ns} \beta_i \sqrt{\alpha_I})^2 P_S + \gamma *_{D,R} \}$ (33)

s.t. $\sum_{i=1}^{Ns} \alpha_I = 1$. If we know α value ,then we can find w*, capacity. The equation as 4 pairs of solution with μ_1^*, μ_2^*, e_1 and e_2. Then $\mu_1^* = |\mu_1^*|$;

$\mu_2^* = |\mu_2^*|$; (34)

$e_1 = h_1^-$; (35)

$e_2 = h_2^-$ (36)

$(h_2^H h_1 / h_1) h_1^-$ (37)

and

$w_s^* = \mu_1 e_1 + \mu_2 e_2$ (38)

If we know w* value, we can calculate achievable information rate by using the above system model equation.

III. RESULTS AND DISCUSSION

SIMULATION RESULTS

The simulation results have been given in this chapter. 100 channel realizations have been used for simulations in matlab. Then SNR values from -10 to 20 dB has been used

A. Transmission Without Relay

The graph is plotted between the transmit SNR(dB) and achievable rate (bits/sec). The information is transmitted from source to destination without using the primary user antennas. In without relay, the throughput increases linearly as transmit SNR (dB) increases.

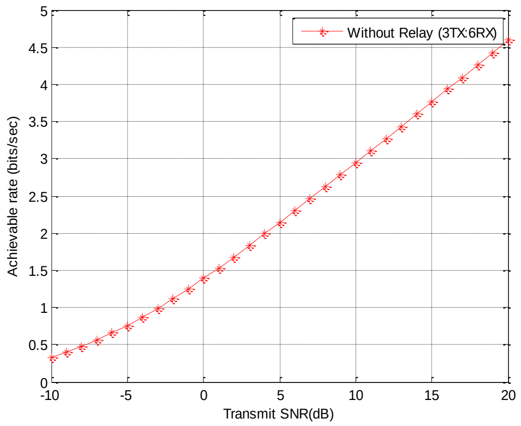

Figure 4 : Transmission without relay

B. Transmission With Relay

The graph is plotted between the transmit SNR (dB) and achievable rate (bits/sec). The information is transmitted from source to destination with using the primary user antennas. In with relay, the throughput increases linearly as transmit SNR (dB) increases.

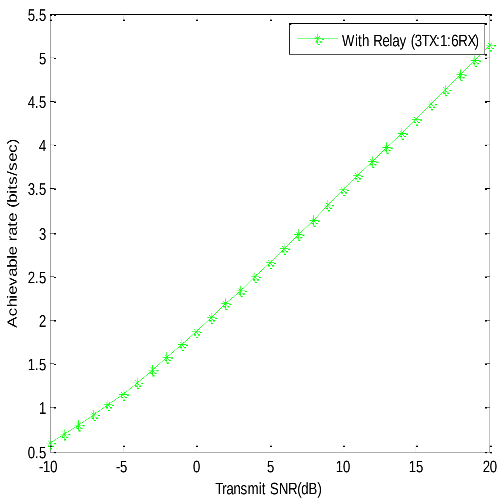

Figure 5: Transmission with relay

C. Joint Beamforming Without GA

Joint beamforming is used to reduce the interference between the primary and secondary user which causes negative effect on them. The graph is plotted between the transmit SNR (dB) and achievable rate (bits/sec). In joint beamforming without using genetic algorithm, the throughput increases linearly as transmit SNR (dB) increases.

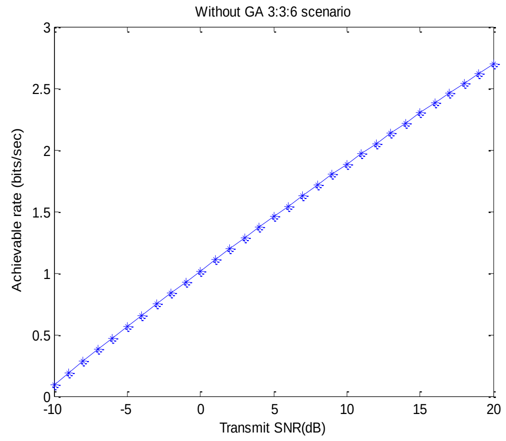

Figure 6: Joint beamforming without GA

D. Joint Beamforming With GA

The main purpose of genetic algorithm is used to determine the sub optimal channel allocation. In this graph, the channel is allotted in random manner. Based on the channel allocation, we select the channel with highest throughput rate (best case). The following graph is plotted between the transmit SNR and achievable rate.

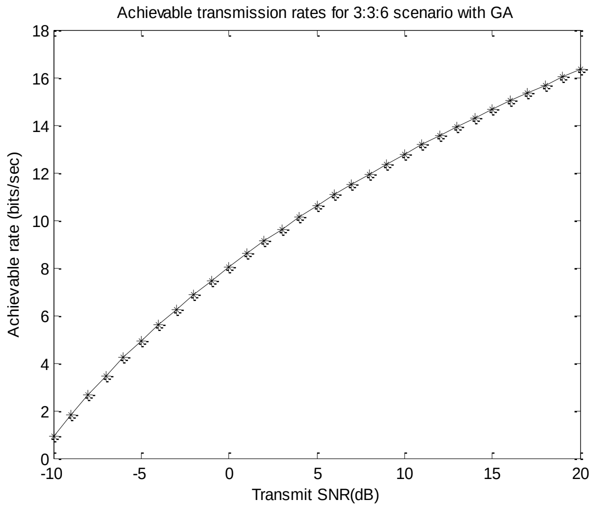

Figure 7: Joint beamforming with GA

E. Comparative Graph

Among all those, the joint beamforming using Genetic Algorithm has the highest achievable rate.

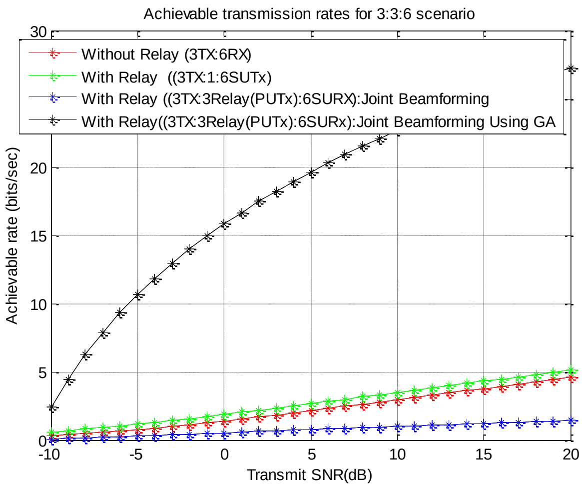

Figure 8: Comparative Graph

IV. REFERENCES

[1] Spectrum policy task force, spectrum policy task force report, Federal Communications Commission ET, 2002.

[2] S. Haskin, “Cognitive radio: brain-empowered wireless communications,” IEEE J. Sel. Areas Common., vol. 23, no. 2, pp. 201–220, Feb. 2005.

[3] R. Qiu, Z. Hu, H. Li, and M. Wicks, Cognitive Radio Communication and Networking: Principles and Practice. Wiley, 2012.

[4] C. Yi and J. Cai, “Two-stage spectrum sharing with combinatorial auction and stackelberg game in recall-based cognitive radio networks,” IEEE Trans. Communes., vol. 62, no. 11, pp. 3740–3752, Nov. 2014.

[5] C. Yi and J. Cai, “Multi-item spectrum auction for recall-based cognitive radio networks with multiple heterogeneous secondary users,” IEEE Trans. Veh. Technol., vol. 64, no. 2, pp. 781–792, Feb. 2015.

[6] A. Ghazanfari, A. tolli and H. Pennanen, “Sum power minimization for cellular systems with underlay d2d communications,” in Proc. CROWNCOM, Jun 2014, pp. 45-50.

[7] K. Illanko, K. Raahemifar and A. Anpalagan, “Sun-channel and power allocation for multiuser OFDM with rate constraints using genetic algorithm,” in Proc. IEEE PavRim, Aug. 2009, pp. 571-575.

[8] B. Ye, M. Nekovee, A. Pervez and M. ghavami, “TV white space channel allocation with simulated algorithm as meta algorithm,” in Proc. CROWNCOM, Jun 2012, pp. 175-179.

[9] B. H. Wang, H. T. Hui and M. S. Leong, “ Decoupled 2d direction of arrival estimation using compact uniform circular arrays in the presence of elevation-dependent mutual coupling,” IEEE Trans. Antenna Propagation vol.58, no. 3, pp. 747-755, Mar 2010.

[10] G.K. Soon, T. T. Guan, C. K. On, R. Alfred and P. Anthony, “A comparison on the performance of crossover techniques in video game,” in Proc. IEEE ICCSCE, Nov. 2013, pp. 493-498.

[11] A. J. Monticelli, R. Romero and E. N. Asada, “Fundamentals of Simulated Annealing,” John Wiley and Sons. Inc., 2007.

[12] D. Thompson and G. Bilbro, “sample-sort simulated annealing,” IEEE Trans. Syst. Man Cybern. B. Cybern, vol. 35, no. 3, pp. 625-63, Jun 2014

[13] S. H. Moon, C. Lee, S. R. Lee and I. Lee, “Joint user scheduling and adaptive intercell interference cancellation for MISO downlink cellular systems,” IEEE Trans. Veh. Technol., vol. 62, no. 1, pp. 172-181, Jan 2013