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Efficient Resource Allocation in Cognitive Radio Networks Considering Time Varying Constraints

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Abstract: Wide spread acceptance of wireless technologies has given rise to increase in demand for bandwidth. Cognitive radio was developed as a promising technique to overcome the scarcity of spectrum resources in wireless communication. The term cognitive radio is defined as an intelligent radio that can be programmed and configured dynamically. Particular portion of the spectrum can be used only by a specific user of communication systems i.e. Licensed user (or) primary user (PU). The secondary user is cognitive user (CR). There are two main paradigms to implement CR in practical, namely interweave and underlay techniques. The main motive of this paper is to design efficient resource allocation algorithms for both techniques that optimize average sum rate performance of cognitive network while considering time varying constraints such as probability of interference accounting for noisy and outdated channel. The resource allocation schemes can be obtained by weighted sum average rate maximization considering average power and probability of interference constraints these are categorized as average and instantaneous constraints. In every case the optimal resource allocation is a instantaneous channel state information function of cognitive radio to cognitive radio link and cognitive radio to primary user channel obtained via simple stochastic iterations.

Keywords: Cognitive radio, Spectrum management, time varying constraints, long term interference, short term interference constraints.

1. INTRODUCTION

Cognitive radio is defined as an intelligent radio that can be programmed and configured dynamically [1]. The cognitive radio changes its reception or transmission parameters after identifying the free channels available in surrounding radio spectrum for efficiently accommodating more parallel wireless communications. FCC assigns spectrum to licensed holders.Users who have no spectrum licenses are known as secondary users. Cognitive radio allocates the frequency bands to unlicensed users by adjusting operations to meet the Quality of service (QOS) required by the application for the signal environment [2]. In underlay transmission methodthe secondary users use the licensed band along with the active primary users but to keep the interference to the PU's under a predefined threshold level the SU's will control their power accordingly, where as in interweave transmission the SU's use the licensed band when no active primary user is present [3].

Spectrum sensing in cognitive radio is performed to know the surrounding radio environment such as PU's existence and usage of spectrumin geo graphical area and it determine the spectrum holes. Based on the spectrum sensing results, the process of identifying the best channel to meet the QOS to the user is known as spectrum management. It assigns that channel to the cognitive user. Scheduling coefficients, rate, power are the resources available for cognitive radio to adapt. In spectrum management by using some time varying constraints it identifies the best channel in the spectrum, but there are still few challenges in design faced by cognitive radio paradigm

- For controlling interference we need some extra constraints.
- The volatile nature of CR may cause outdated statistical channel state information.
- It is difficult to acquire instantaneous CSI of the PU.

For first design challenge, interference can inflicted by either through average (long term) transmit-power constraints or instantaneous (short term) constraints [4]. The instantaneous constraints have been focused as the second design challenge, handling these constraints is simple. Dual stochastic processesare specifically used for general wireless network, as they don't need channels statistics knowledge and their computational simplicity. For third design challenge outdated channel state information have been considered for SU's and to predict the actual CSI we use a very few incorporate mechanisms.

The motive of our work is to develop the algorithm of resource allocation to underlay and interweave schemes to account for noisy, outdated channel state information and also jointly limit the interfering probability with PU's. The short term constraints are grossly suboptimal or infeasible because of uncertain information over SU to PU channels. So the long term (average) constraints are used to overcome this problem and improving performance[5]. The instantaneous CSI is presumed to be perfect over the SU-SU channel, but the CSI could be outdated and noisy over SU-PU links.

The imperfections are captured by using a first order continuous markov model with AWGN noise. For tracking the CR-to-PU changing CSI these models can enable channel prediction and correction. The solution for resource allocation is obtained by performing a maximization of weighted sum average under probability of interference and average power constraints [1]. The constraints are of two types, they are Long term interference constrains and Short term interference constrains.

Under Instantaneous constraints the interference must be below a predefined limit for each time slot. In this the duality gap is zero even though not all formulations are convex. The optimal RA scheme is a function of channel state information of the cognitive radio to cognitive radio links and the CR-to-PU channel and lag range multipliers are obtained using stochastic iterations [6]. By extending the present situations with greater than one cognitive radio network are of interest, but it is left for next generation.

The purpose of our work is to get Instantaneous channel state Information (CSI) of primary user, by using some stochastic iteration. By knowing the CSI of primary user it is easier to allocate the frequency bands to the cognitive users by adjusting the rate and power of a primary user [1],[2]. Another objective is that to reduce the interference occurred in the channel. In any channel Interference is the most common problem. In cognitive Radio the Interference is occurred while allocating the spectrum bands to the cognitive users because no perfect CSI of primary users. This Interference is removed by using some Interference constraints such as Instantaneous and average constraints. Sometimes these are also called as short term and long term constrains. The space between PU's and SU's is small in instantaneous constraints where as the average constraints means the space between

PU's and SU's is large [7]. The target of this paper is allocating the resources to the secondary user by knowing the Instantaneous channel state of the primary user without any Interference.

The remaining paper is planed as follows in section 2presents the channel modelling i.e imperfect primary channel state information and functioning situations. In section 3 accounts for RA optimization problem. Various Interference constrains and design of algorithms are in section 4. Numerical example and simulation results in section 5.[8]

2. CHANNEL MODELLING

Consider a Cognitive Radio (CR) Network contains 'M' secondary users with various bands let it be k. For easy purpose we assume that every band is allocates license for each primary users and has its identical bandwidth and cognitive radio contain network controller (NC) it gather the Information of channel needed to resource allocation.

A. CSI

Channel state information contains the information about the channel and this information is accessible to every user in the network. CSI is heterogeneous i.e it is varies for PU's and SU's. It has 2 reasons one is it has a different CSI links for both primary and CR users and second is on designing of resource allocation the impact of channel state information is different. The channel state information of cognitive radio is perfectly know i.e. the gain of secondary users links will available. Mathematically the instant control gain of the channel between m^{th} cognitive transmitters of the instant declining coefficient is dividing by the power of noise at the k^{th} link when the transmitters of the primary users are located at large distance from the users. Otherwise it becomes square of the magnitude of the instant fading coefficient is divide by the addition of instant interference power and noise power due to the k^{th} transmitter of primary user. The channel information of the primary user is not known perfectly since it is impossible to sense all the frequency bands on each and every instant of time. This assumption well suited when the cost of sensing the PU is large when compared to the cognitive radio user sensing. Since there are so many number of primary users are there in the spectrum and sometimes the PU are may be at the great distance from the CR user.

Interweave means CR use channels where there is no primary user is active and underlay means CR users the frequency band when PU is also active. The perfect and imperfect CSI of both settings can be shown below.

1. **Imperfect and perfect channel state information of primary user in interweave network:** In the interweave network the NC checks the every band in the spectrum is used or not. By using a variable a_k we can know the occupancy of the network. Mathematically it is given by

$$a_k[n] = 1,\ k^{\text{th}} \text{ PU is active at instant '}n\text{'}$$
$$= 0,\ \text{otherwise.}$$

The 2×1 belief vector $f_{ak}[n] := [pr\{a_k[n]=0\}, pr\{a_k[n]=1\}]^{\mathrm{T}}$ in real time the belief vector can be estimated. For example while estimating imperfect channel state information of the primary user we can also estimate the resultant principle vector. Let $s_k[n]$ is a changeable it can be denoted by

$$s_k[n] = 1,\ \text{if the } k^{\text{th}} \text{ band is sensed at instant } n$$
$$= 0,\ \text{otherwise}$$

Let $\tilde{a}_k[n]$ is the perhaps noisy measurement of $a_k[n]$ obtained at an instant n, if $s_k[n] = 1$. In imperfect CSI there are two types (1) outdated CSI ($s_k[n] = 0$) (2) noisy CSI. Noisy CSI occurs when the sensing process $a_k[n] \neq \tilde{a}_k[n]$. For outdated CSI we need a mode for capturing the dynamics of $a_k[n]$ across time. For easy purposewe are assumed to follow a first order markovprocess. The alteration chance template Q with $(i, j)^{th}$ entry $Q_{ij} := pr\{a_k[n] = i \mid a_k[n-1] = j\}$ for $i, j = 0, 1$. To identify the errors in the sensing process, we consider the probabilities of false alarm and miss detectioni.e.

$$P_{MD} := \{\tilde{a}_k[n] = 0 \mid a_k[n] = 1\}$$

$$P_{FA} := \{\tilde{a}_k[n] = 1 \mid a_k[n] = 0\}$$

These miss detection (MD) and false alarms are used to form the 2×1 vectors $q_1 := [1 - P_{FA}, P_{MD}]^T$ and $q_0 := [P_{FA}, 1 - P_{MD}]^T$

To obtain instantaneous belief vector we can estimate the recursive Bayesian. The belief $f_{a_k}[n]$ is as follows

- If $s_k[n] = 0$, then $f_{a_k}[n] = Qf_{a_k}[n-1]$
- If $s_k[n] = 1$ and $\tilde{a}_k[n] = 0$ then predict the belief vector as $[n]f_{\tilde{a}_k}[n] := Qf_{a_k}[n-1]$;

$$[f_{a_k}[n]]l = ([q_0]l[f^{\wedge}{}_{a_k})[n]]l/(q_0^T f^{\wedge}{}_{a_k}[n]) \tag{1}$$

- If $s_k[n] = 1$ and $Q_{\tilde{k}}[n] = 1$,

$$[f_{a_k}[n]]l = ([q_1]l[f^{\wedge}{}_{a_k}[n]l]/(q_1^T f^{\wedge}{}_{a_k}[n]) \tag{2}$$

Let Γ_k be the time taken among two changes of $a_k[n]$.

2. **Imperfect and perfect CSI of primary user in underlay networks:** In underlay setup the network controller know about the gain of the network controller (NC) CR-PU channel i.e in this case the CSI of primary user is varied. Specially, here channel state information gives information about the squared fading coefficient between m^{th} cognitive radio and the k^{th} primary user divided by power of noise and it indicated by $h_{k,1}^m$ (where subscript '1' indicates that the link involves primary receiver). $h_{k,2}^m$ is the noise power (where subscript '2' indicates that the link involved in secondary receiver). Where $h_{k,2}^m$ contain interference power while $h_{k,1}^m$ does not contain interference power [9]. The reason is because the PU's interfering power is a state variable where as the secondary user's interference power is aintend variable. In perfect CSI at an instant an $h_{k,1}^m[n]$ is perfectly known where as in imperfect CSI only the $h_{k,1}^m[n]$ distribution is accessible. The principle state then consists of aincreasing and prospect density functions are denoted by $F_{hk,1}^m[n](h)$ and $f_{hk,1}^m[n](h)$ respectively.

The Boolean variable $s_k^m[n] = 1$ if h_k^m, is sensed at direct n,

= 0, otherwise.

Let $h^{\sim m}_k[n]$ is the possibly noisy measurement of $h_k^m[n]$. It is obtain only when $s_k^m[n] = 1$. As in the previous example in primary CSI in underlay network also consist of two types of imperfections. They are 1) out dated CSI (at instant n $s_k^m s_k^m$ [n] = 0) 2) noisy CSI (It occur because the errors in process of sensing $h^{\sim m}_{k,1}[n] \neq h_{k,1}^m[n]$). The time evolution of $h_k^m[n]$ is markovian with $q_k^m(h_{new}, h_{old})$ where $h_{k,1}^m[n+1] = h_{new}$ and $h_{k,1}^m[n] = h_{old}$. The Probability Distribution Function (PDF) of $h_k^m[n] = h$ is $f_k^m(h, n)$. It follows that $f_k^m(h, n+1) = \int q_k^m(h, x) f_k^m(x, n)dx$. For accounting errors in the sensing process we assumed that the memory less additive noise mode i.e.

$$h^{\sim m}_{k,1}[n] = h_{k,1}^m[n] + v_k^m[n].$$

$v_k^m[n]$ is the white noise and its PDF is $f_{vk}^{\ m}\ (v)$ it is independent of $h_{k,1}^m[n]$. By using these operating conditions, the belief $f_{hk}^{\ m}[n]$ and it is estimated by using recursive bayes.

If $s_k^m[n] = 0$, then $f_{hk}^{\ m}\ [n+1](h) = \int q_k^m\ (h, x)\ f_{hk}^{\ m}\ [n](x)\ dx$

If $s_k^m[n] = 1$, $f\wedge_{hk}^{\ m}\ [n+1](h) = \int q_k^m\ (h, x)\ f_{hk}^{\ m}\ [n](x)\ dx$

$$f_{h_{[n+1]}}(h) = \frac{f\wedge_{hk}^{\ m}[n+1](h) f_{v_k}^m (h - h^-)}{f\wedge_{hk}^{\ m}[n+1](x) f_{v_k}^m (x - {}^{\sim}h)\, dx} \tag{3}$$

In the above equation the denominator was a finite sum, where as in the earlier slice the number of ignored states is finite. For the left over cases, an estimated technique should be used.

Before going to the allocation of resources to the secondary users move towards, it is value reiterating the major points up to now. The Channel State Information model is different for both main and lesser users. The inferior Channel State Information consists of cognitive radio-to-CR link gains, which gives main interference. The main channel state information is formed by primary usermovement or cognitive radio-to-primary user channel gain in which do not contain any lesser interference. The lesser channel state information is perfectly known where as the CSI of primary user is uncertain, so that the instantaneous information is probabilistic.

B. Allocation of Resources to Secondary Users

In this section we introduce the design variables as a function of the overall channel state information and is denoted by h. The Boolean preparation changeable $w_k^m[n] = 1$, if the m^{th} CR scheduled to transmit over k^{th} band.

= 0, otherwise.

When $w_k^m[n] = 1$, Let p_k^m denote that it is a short term power can be transmitted to the m^{th} CR over the kth band. Under capacity constrains both instantaneous rate variable and instantaneous power variables are coupled. This can be represented by the function $c_k^m(h_{k,2}^m, p_k^m).\, c_k^m(h_{k,2}^m)$, Is given by Shannon's capacity formula where k_k^m is the gap of SNR and it is depend on coding scheme.

The lesser user network operates in a block-by-block fashion, per each time slot n to finding the w_k^m and p_k^m the NC uses current CSI. Therefore h depends on n and $\{w_k^m, p_m^k\}$ depends on h, and the w_k^m, p_k^m vary across time. Therefore both instantaneous rate and power rates are in the function of 'h'. They are $w_k^m[h]$ and $p_k^m[h]$

For the cognitive radio arrangement the aim is to build up adaptive RA algorithms by neglecting the interference problem. While doing this an optimaltrouble will set and solve in next section. Initially we see devoid of interference constraints after then with interference constrains will be in section 4.

The optimal problem for adaptive resource allocation: To develop the optimal problem with resource allocation, it is careful to determine the accessing of variables, accessing of metric and that must be satisfied with relative constraints. In II-B we observe $\{w_k^m, p_k^m\}$ as accessing variables and accessing of metric is the cognitive radio weighted sum-average rate and it is denoted as c. It is given by $c := \sum_{k,m} \mathrm{E}_h[\beta^m w_k^m(h) c_k^m(h_{k,2}^m, p_k^m(h))]$.

In the above equation E_h is the overall channel state information expectation. β^m is the priority coefficient, it is user dependent. The value of β^m must be greater than zero. In the accessing variables $\{w_k^m\}$ is corresponds to the set $\{0, 1\}$ and another variable $\{p_k^m\}$ must be greater than zero. Therefore in the spectrum for each band k, the cognitive radio transmits is

$$\sum_k w_k^m(h) \leq 1 \tag{4}$$

In the above equation the sum of $w_k^m(h)$ value is equal one it implies one cognitive user can access the channel, while it is'0' it means no user access the channel. Because the links of cognitive radio to cognitive radio are poor or due to the more interference on primary user [10], [11]. The maximum long term power is:

$$E_h\left[\sum_k w_k^m(h) p_k^m(h)\right] \leq p^m \tag{5}$$

under these conditions, the best resource allocation emerges the solution

$$c^* := \max_{\{w_k^m(h), p_k^m(h)\}} \sum_k [\beta^m w_k^m(h) c_k^m(h_{k,2}^m, p_k^m(h))] \tag{6(a)}$$

where the calculation of the accessing variables on h has been accurate.

A) optimization of resource allocation in the absence of interference constraints:

In the equation (6) it is non convex, by using karush –kuhn-tucker(KKT) conditions, it can be transformed into convex one. In fact, the biasedamount rate accessing of uplink channel is the problem in (6). Π^m is the lagrange multiplier. Finallylagrange multiplier $\Pi^m[n]$ is set to a constant value Π^{m^*}, similar to this value it maximizes the dual function associated with for this alternative methods are used. These methods are attractive only for the cognitive radio setup considered here and it will be seen in section 4.

C. Interference Constraints

Various set of interference constraints are considered to arrive at the optimal model to achieve optimum RA algorithm. Two major things to consider is to understand the type of data collected, data considered can be short term or long term.

Instantaneous interference: Short term data is otherwise called instantaneous data is easy to solve considering its very nature of simplification. Instantaneous data are more restrictive in nature which does not favour cognitive diversity.

Average interference: Long term data is otherwise called average data of constraints, it is not easy to solve for optimization problems. Dual approach is required to solve the optimization problem in long term constraints, Factors like interweave, underlay setup presence is important to look out for before solving the optimization problem [12],[13].

Instantaneous: To stay the interference to the main network under control, the most interference is $\breve{O}_k$ € (0,1). Since the section is focus on short term interference constraints.

In this short term there are two types: (1) interweave and (2) underlay.

Interweave: In this, the meddling occurs when $a_k[n] = 1$ i.e., k^{th} primary user lively larger than the k^{th} band and also $\Sigma_m w_k^m[n] = 1$ i.e one cognitive radio transmits larger than k^{th} band. The probability of limitation can written a $pr\{a_k[n]\Sigma_m w_k^m[n] = 1 \mid n\} \leq \breve{O}_k$ and this above equation can be written as

$$E_{ak}[n][1_{\{a_k[n]\Sigma_m w_k^m[n]=1\}}] \leq \breve{O}_k$$

where, $\Sigma_m w_k^m[n]$ is a boolean and this can be re written as

$$\Sigma_{ak}[n][1_{\{a_k[n]=1\}}]\Sigma_m w_k^m[n] \leq \breve{O}_k$$

thus $\Sigma_m w_k^m[n] = 1$ only if $[f_{ak}[n]] \leq \breve{O}_k$ that implies (1) in this no need to dualize the constraint (2) the control share plays negative position in the meaning of interference. The cognitive radio be able to broadcast only if the chance of the channel being busy is less than $\breve{O}_k$. Suppose the main channel state information is outdated and noisy, such a probability depends on the earlier size. Over the CSI is perfect $[f_{ak}[n]]$ is either zero or one.

Underlay Networks: In this underlay network, the nosiness occurs when the external control at the primary user unpaid to cognitive radio transmission exceeds a still Γ_k.

If $w_k^m[n] > 0,$ the limit in the direction of be there content on each time n is

$$\Pr\{p_k^m[n]h_{k,1[n]}^m > \Gamma_k \mid n\} \leq \breve{O}_k$$

In other style, the nosiness restraint cab be written as a summit control constraint. This constraint is very suitable, since even as the creative constraint is not curved, the highest summit rule constraint is convex [14]. Because negative multiplier is introduce for this constraint.

Long term interference constraints: In this long term interference constraints is also known as average constraints. In this also there are two types: (1) Interweave and (2) underlay.

Average constraints in interweave: Compare to the prior section the instantaneous interference constraints are simple to switch. Here, the average probability of interference with primary user is considered for the interweave [15].

The optimization trouble is rounded and it shows the next two belongings: (1) it be able to be there optimally attempt with zero duality gap (2) It is effectively solvable. Preliminary by means of formulation, bring to mind the interference of instantaneous prospect in the interweave consists

$$\Pr\{\Sigma_m w_k^m[n] a_k[n] = 1 \mid n\} \leq \breve{O}_k$$

or

$$\mathrm{E}_{ak[n]}\left[1_{ak[n]\Sigma_m w_k^m[n]=1}\right] \leq \breve{O}_k$$

In this durable constraint record instants are both measured.

$$\mathrm{E}_h\left[1_{\{ak\Sigma_m w_k^m(h)=1\}}\right] \leq \breve{O}_k$$

In this above equation the LHS side represents the prospect of the primary user life form on the go. The prologue of a fresh multiplier implies that the tie-value pointer wants to be defined as

$$\Psi_k^m(p_k^m[n]) := \beta^m c_k^m(h_{k,2}^m[n], p_k^m[n]) - \Pi^m[n]p_k^m[n] - \theta_k[n]\Sigma_{ak}[n]\left[1_{\{ak[n]=1\}}\right]$$

If the primary channel state information is imperfect, then $\mathrm{E}_{ak[n]}[1_{\{ak[n]=1\}}] = [f_{ak[n]}]_2$ when perfect.

Hence, the main distinction among instantaneous and average solutions for the interweave is the technique in which development decisions are completed. Main focal point is earliest on the primary user. Only the interfering caused to the primary user is below threshold.

Long term interference in underlay: The probability of the average constraint with primary users in the underlay is dialyzing it. In this the trouble at has two striking kind:

1. In twin field the crisis can be separated.
2. The functions causing non- convexity, the effects can be modified explain the duality gain is zero.

For long term constrain moment directs should live accounted used for, next to by means of the cognitive radio source interference [16]. This preserve exist marks as

$$\mathrm{E}_h\left[\Sigma_m w_k^m(h)\mathrm{L}_{\{p_k^m(h)h_{k,1}^m(h)>\Gamma_k\}}\right] \leq \breve{\mathrm{O}}_k$$

As in the interweave container opening of a innovative multiplier varies the lagrangian construction and as a result the line-superiority pointer has to be customized for that reason as

$$\Psi_k^m\left(p_k^m[n]\right) := \beta^m c_k^m\left(h_{k,2}^m[n], p_k^m[n]\right) - \Pi^m[n]p_k^m[n] - \alpha_{k[n]}\Sigma_{h_{k,1}[n]}^m\left[1_{\{p_k^m[n]h_{k,1}^m[n]>\Gamma_k\}}\right]$$

$\Sigma_{h_{k,1}[n]}^m\left[1_{\{p_k^m[n]h_{k,1}^m[n]>\Gamma_k\}}\right]$ Corresponds to $1 - \mathrm{F}_{h_{k,1}[n]}^m\left(\frac{\Gamma_k}{p_k^m[n]}\right)$ when channel state information (CSI) is imperfect. $1_{\{p_k^m[n]h_{k,1}^m[n]>\Gamma_k\}}$ When channel state information (CSI) is perfect.

Once $\{p_k^{m*}[n]\}_{m=1}^{\mathrm{M}}$ are obtained finding $\{w_k^{m*}[n]\}_{m=1}^{\mathrm{M}}$.

In other words, because in the dual domain the problem can be separated across users and channels, lagrangian does not require optimizing a non-convex problem over a 2MK dimensional space but instead, MK closed forms and MK one-dimensional non-convex problems must be solved [1], [16], [17].When channel state information is perfect, power optimization is straight forward. When the primary channel state information is imperfect, evaluating $f_{h_k^m[n]}$ is monotonic the optimization is non-convex [1], [18]. In this holder, all of them can be originate and the international most favourable can be next certain.

3. SIMULATION RESULT

The simulated parameters we considered as follows $\beta^m = 1$, $p^m = 2$, $\mathrm{K}_k^m = 1$, $\breve{\mathrm{O}}_k = 4\%$, $\Gamma_k = 0.5$.The secondary amplitude links are Rayleigh distributed function, and SNR for all users and bands average is $\mathrm{E}_h[h_{k,2}^m] = 9$. The primary user of channel state information model is $h_{k,1}^m[n] = \mathrm{H}_{k,1}^m[n]|^2$ [1], [19].

The complex Gaussian distribution function with mean zero and variance is unity and low pass equivalent is $\mathrm{H}_{k,1}^m[n]$. Here the amplitude is Rayleigh distributed because they has independent of real and imaginary parts, so thatThe time association model is $\mathrm{H}_{k,1}^m[n] = \sqrt{\rho}\mathrm{H}_{k,1}^m[n-1] + \sqrt{[1-\rho]}\, z_k^m[n]$, the ρ value is 0.95 and here $z_k^m[n]$ is white Gaussian noise, the complex Gaussian distribution function with mean zero and variance is unity. The noise measurement of $\alpha_k^m[n]$ is complex Gaussian distribution function with zero mean and variation is 0.01. The network controller senses $\mathrm{H}_{k,1}^m[n]$ at every $\mathrm{N}_h = 6$ slots [1], [2].

The activity model of primary user is simulated with following parameters. $\mathrm{Q}_{00} = 0.95$, $\mathrm{Q}_{01} = 0.10$, $\mathrm{Q}_{10} = 0.05$, $\mathrm{Q}_{11} = 0.90$; $\mathrm{P}_{\mathrm{FA}} = 3\%$ and $\mathrm{P}_{\mathrm{MD}} = 2\%$; and the network controller senses $a_k[n]$ for every $\mathrm{N}_a = 3$ slots.. The developed optimality and feasibility scheme has been established hypothetically.

The cognitive radio implementing nine different schemes of resource allocation these schemes are power, interference probability for an interweave and average weighted sum rate. The nine schemes are S1, S2, S3, S4, S5, S6, S7, S8, and S9. The first three are short term or Instantaneous interference constrains. S1) knows true CSI and it is genie-aided, S2) it is developed for CSI imperfection, S3) this scheme implementing RA where error free in imperfect CSI, so its sets a $a_k[n + n_a] = \overline{a_k}\,[n]$ and $h_{k,1}^m[n + n_h] = \overline{h}_{k,1}^m[n]$, for $n_a = 0, 1, ..., \mathrm{N}_{a-1}$, $n_h = 0, ..., \mathrm{N}_{h-1}$. Another three is S4, S5, S6 are the counterparts of S1, S2, S3 under a average interference. S7) the primary CSI has no instantaneous information. S8) it ignoring the interference constrains.

Constraints are done by the novel schemes and ignoring the channel state information and cognitive radio to primary user channels are used to perform the output of the suboptimal schemes based on the static knowledge. Long term constraints $s2$ yield a higher maximum than instantaneous interference $s1$, when $s2$ satisfy the constraints tightly than only $s1$ satisfies the long term the stochastic interference constraints [2], [20]. The probability of interference is estimated by the novel algorithms is updates it state corresponds to the actual one.

Table 1 is for an interweave setup and Table 2 is an underlay setup. The interweave setup is not appropriate for an additional scheme of $s7$, but it is used in underlay setup cognitive radio networks. Higher sum rate are achieves in underlay schemes than the interweave scheme. In underlay have more opportunities in cognitive radio that is the secondary user have transmit low power sufficiently do not cause interference even if the primary user is act. In the table C1, C2, C3 are the comments assigned to each scheme in the network. Where C1 is the Instantaneous interference constrains (STIC) enforced long term constraint. C2 is the Instantaneous interference constraints (STIC) often violated. C3 is the average interference constraints (LTIC) violated. In Figure c the values of instantaneous power multipliers are depend on the requirement of number of users and the system.

TABLE I

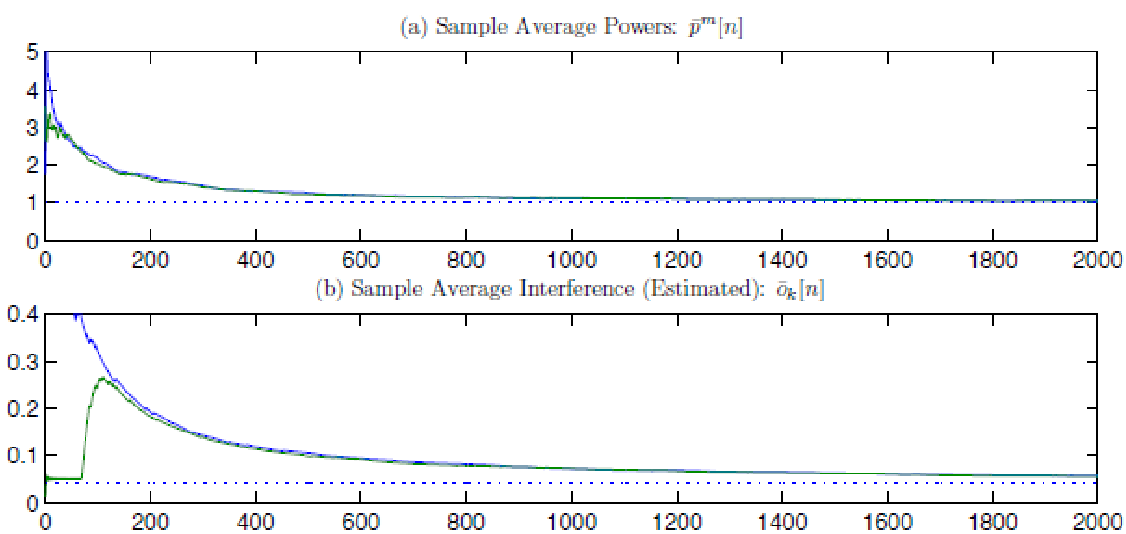
INTERWEAVE CR WITH $N_a = 3$, $N_h = 6$, $P_{FA} = 1\%$, $P_{MD} = 2\%$, $\breve{o}_k = 4\%$, $\mathrm{Var}\{v_k^m[n]\} = 0.01$, $\Gamma_k = 0.5$. MEANING OF CODES USED IN ROW "COMMENTS": C1=STIC ENFORCED, LONG-TERM $\bar{o}_k$ SHOWN FOR ILLUSTRATIVE PURPOSES; C2=STIC OFTEN VIOLATED; C3=LTIC VIOLATED.

	S1	S2	S3	S4	S5	S6	S7	S8	S9
$(1/M)\sum_m \bar{p}_m$	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.5
$\bar{c}$	16.3	6.9	16.8	17.6	16.9	17.8	5.3	23.1	17.6
$(1/K)\sum_k \bar{o}_k$ (actual)	0.0%	0.05%	3.6%	4.0%	4.0%	7.3%	4.0%	39.6%	39.9%
$(1/K)\sum_k \bar{o}_k$ (estimated)	0.0%	0.05%	0.0%	4.0%	4.0%	4.0%	4.0%	−−	−−
Comments	C1	C1	C1,C2			C3		C2, C3	C2, C3

TABLE II

UNDERLAY CR WITH $N_a = 3$, $N_h = 6$, $P_{FA} = 1\%$, $P_{MD} = 2\%$, $\breve{o}_k = 4\%$, $\mathrm{Var}\{v_k^m[n]\} = 0.01$, $\Gamma_k = 0.5$. MEANING OF CODES USED IN ROW "COMMENTS": SEE TABLE I.

	S1	S2	S3	S4	S5	S6	S7	S7'	S8	S9
$(1/M)\sum_m \bar{p}_m$	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.2	1.0	0.5
$\bar{c}$	21.4	20.3	21.5	22.8	21.5	22.8	13.1	11.2	23.1	17.6
$(1/K)\sum_k \bar{o}_k$ (actual)	0.0%	3.2%	14.4%	4.0%	2.7%	17.0%	4.0%	3.9%	37.5%	14.1%
$(1/K)\sum_k \bar{o}_k$ (estimated)	0.0%	3.4%	0.0%	4.0%	4.0%	4.0%	4.0%	4.0%	−−	−−
Comments	C1	C1	C1,C2			C3		C1	C2, C3	C2, C3



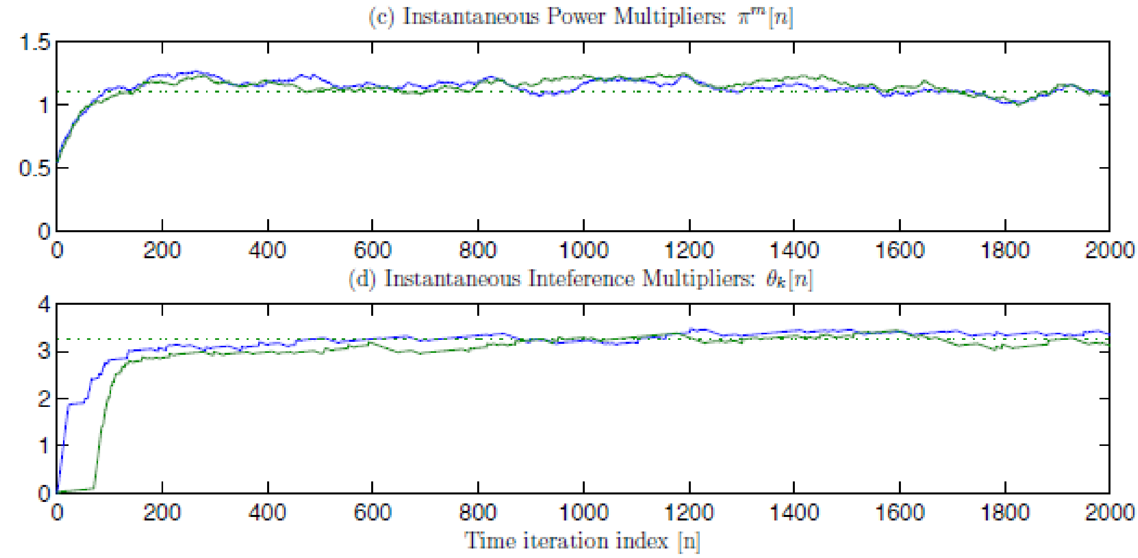


Figure 1: Output Response

In Figure 1 we consider four subplots, each depict over time evolution of a different subset of simple average $\bar{p}_m[n]$ and subplot(b) simple average interference estimated $\breve{O}_k[n]$, subplot(c) instaneous power multipliers and $\Pi^m[n]$ and subplot(d) is instantaneous interference multipliers $\theta_k[n]$ we consider two unlicensed users so we provide the frequency to the two unlicensed users here the Figure shows the two waveforms lines these are user 1 and user 2. The Figure (a) shows the simple average power and it always should be 1 because the power consumption is less than 1. Figure (b) shows the average interference (estimated) is also be decrement to 1 because every system need less interference i.e. less than 1. Figure (c) shows the instantaneous power multiplier it always should be 1 and Figure (d) shows the interference multiplier it instantaneous increases 0 to 3. In the results we plotted only $m = 1, 2$ users with the corresponding $k = 5, 6$ channels are plotted and these are differentiate by two different colours. Where the dashed lines represents constant (optimal) values.

4. CONCLUSION

For spectrum management we have to develop resource allocation algorithms for secondary users of both interweave and underlay settings over fading links. Here we reduce the problem of dynamically changing of channel state information and interference. These algorithms were obtained as the solution of weighted sum rate maximization to maximum probability of interference and average power. These interference terms was multiplied by Lagrange multipliers. This algorithms include the estimating the probability of instantaneous interference constraints and Lagrange multiplier values. These multiplier values are depending on the system and requirement of primary and secondary users. The alternative interference constraints, distributed implementations are not observed in our future works these problems will be handled.

REFERENCES

[1] Marques, Antonio G., Luis M. Lopez-Ramos, Georgios B. Giannakis, and Javier Ramos. "Resource Allocation for Interweave and Underlay CRs Under Probability-ofInterference Constraints", IEEE Journal on Selected Areas in Communications, 2012.

[2] Marques, Antonio G., Georgios B. Giannakis, Luis M. Lopez-Ramos, and Javier Ramos. "Stochastic resource allocation for cognitive radio networks based on imperfect state information", 2011 IEEE International Conference on Acoustics Speech and Signal Processing (ICASSP), 2011.

[3] Submitted to Guru Nanak Dev Engineering College

[4] Helmers, R.. "A non-parametric estimator for the doubly periodic Poisson intensity function", Statistical Methodology, 200710

[5] Li, Xue, Ruolin Zhou, Qian Han, and Zhiqiang Wu. "Cognitive radio network interference modeling with shadowing effectvia Scaled Student's t distribution", 2012 IEEE International Conference on Communications (ICC), 2012.

[6] "IEEE-ICDCS conference proceeding", 2012 International Conference on Devices Circuits and Systems (ICDCS), 03/2012

[7] Antonio G. Marques. "Adaptive underlay cognitive radios with imperfect CSI and probabilistic interference constraints", 2011 4th IEEE International Workshop on Computational Advances in Multi-Sensor Adaptive Processing (CAMSAP), 12/2011

[8] Cognitive radio: Brain-Empowered wireless communications, simonhaykin, life fellow, IEEE

[9] IEEE Standards Supporting Cognitive Radio and Networks, Dynamic Spectrum Access, and Coexistence Matthew Sherman, Apurva N. Mody, Ralph Martinez, and Christian Rodriguez, BAE Systems, Electronics & Integrated Solutions Ranga Reddy, U.S. Army RDECOM CERDEC S&TCD SEAMS

[10] A. Mody et al., "Recent Advances in Cognitive Communications," IEEE Commun. Mag., Special Issue on Network-Centric Military Communications, Oct. 2007

[11] L. Musavian and S. Aissa, "Fundamental capacity limits of cognitive radio in fading environments with imperfect channel information," IEEE Trans. Commun., Vol. 57, No. 11, pp. 3472–3480, Nov. 2009

[12] A. Ribeiro, "Ergodic stochastic optimization algorithms for wireless communication and networking," IEEE Trans. Signal Process., Vol. 58, No. 12, pp. 6369–6386, Dec. 2010.

[13] S. A. Jafar and S. Srinivasa, "Capacity limits of cognitive radio with distributedand dynamic spectral activity," IEEE J. Sel. Areas Commun., Vol. 25, No. 3, pp. 529-537, Apr. 2007

[14] H. A. Suraweera, P. J. Smith, and M. Shafi, "Capacity limits and performance analysis of cognitive radio with imperfect channel knowledge," IEEE Trans. Vehic. Tech., Vol. 59, No. 4, pp. 1811 – 1822, May 2010.

[15] R. Urgaonkar and M. Neely, "Opportunistic scheduling with reliability guarantees in cognitive radio networks," IEEE Trans. Mobile Comp., Vol. 8, No. 6, pp.766–777, Jun. 2009

[16] R. Zhang, "On peak versus average interference power constraints for protecting primary users in cognitive radio networks," IEEE Trans. Wireless Commun., Vol. 8, No. 4, pp. 2112-2120, Apr. 2009.

[17] S. Shellhammer, "Sensitivity Requirements for Sensing Wireless Microphones," IEEE 802.22 contrib., Doc #: IEEE 802.22-07/0290r3, July 10, 2007

[18] A. Mody, "Spectrum Sensing of the DTV in the Vicinity of the Pilot Using Higher Order Statistics" IEEE 802.22 contrib., Doc #: IEEE 802.22-07/0370r3, Aug. 15, 2007.

[19] FCC Notice of Proposed Rule Making FCC 04-113, May 25, 2004.

[20] J. Mitola and G. Q. Maguire, "Cognitive Radio: Making Software Radios More Personal," IEEE Pers. Commun., Vol. 6, No. 4, Aug. 1999, pp. 13–18.

[21] Non orthogonal Multiple Access in Large-Scale Underlay cognitive radio networksYuanwei Liu; Zhiguo Ding; MagedElkashlan; Jinhong yuanIEEE transcations on Vehicular Technology 2016

[22] Energy Efficiency-based Desicion Making in cognitive radio networksHongningLi;Qingqi Pei; Leilei Xu China communications 2016

[23] Spectrum Map and its Application in Resource management in cognitive radio networks SaptarshiDebroy; ShameekBhattachrjee; Mainak Chatterjee IEEE transactions on cognitive communication and networking 2015