

Resource Allocation and Receiver Localization for Underlay CRs Using Interference Tweets

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Abstract- Cognitive radio network provides re-utilization of unused portions of the licensed spectrum. Such that primary users do not affect harmful interference from the transmission of secondary users. Therefore, to analyze the effect of interference across primary user and their minimization have become an important criterion in cognitive network. This paper attempts to provide localization technique based on Bayesian approach gives exact location of primary user. The conventional localization technique provides information related to coverage region of primary user so we cannot estimate accurate location. Secondary users opportunistically share a fixed spectrum resource with different probability of interference constraints. The proposed algorithm shows increased network utility with optimize performance of secondary network.

Keywords- Cognitive radio network; cross layer optimization; receiver localization; interference tweet.

I. INTRODUCTION

With the emergence of new wireless applications and devices, there is excessive demand for radio spectrum. Due to the scarcity of radio spectrum and the under-utilization of assigned spectrum, Federal Communications Commission (FCC) has started to review their spectrum allocation policies for selection of best available spectrum band. Cognitive radio systems are radios with the ability to exploit their environment to increase spectral efficiency and capacity. As spectral resources are more limited the FCC has recommended that greater spectral efficiency could be realized by deploying wireless devices that can coexist with primary users, generating minimal interference.

The main purpose of localization of primary user (PU) receiver is to optimize performance of secondary network by reducing the interference across primary user. Bayesian approach is based on 1-bit interference tweet. So after resource allocation if PU is interfered, one can find out its location and limit the interference to those locations.

The rest of paper is organized as follows. Section II presents the methodology which involves block diagram of the system. In section III, CSI model is presented which is to account for CSI imperfections. A simplified resource allocation problem is formulated in section IV. Section V shows all numerical results. Conclusions and future work in section VI wrap-up this paper.

II. METHODOLOGY

The proposed system involves following steps as shown in Fig.1. After resource allocation communication will takes place in between secondary users. There is receiver map as a tool to locate a primary user receiver. The location is tracked using recursive Bayesian approach, which is based interference

tweet. Receiver map as a tool for unveiling areas where PU receivers are located, with the objective of limiting the interference inflicted to those locations.

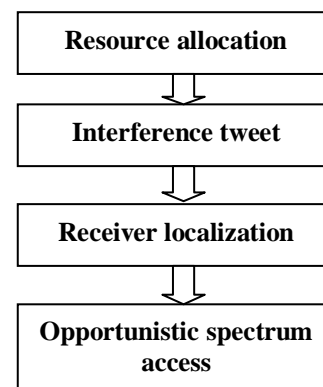


Fig.1. System Model

III. MODELING

A. State information of primary and secondary channel

Consider a multi-hop secondary user (SU) network with M no. of nodes. $\{U\}_m^M = 1$ deployed in area ACR2. Based on the output of the spectrum sensing stage such as maximum tolerable power, probability of interference across primary user, average link gain, coverage region etc. SUs implement adaptive RA, [1] while protecting the PU system from excessive interference.

When resources are shared in a hierarchical setup, the available channel state information (CSI) over different SU network is different. Here, we assume the state of the SU-to-SU

channels is already known. The instantaneous gain of link $U_m \rightarrow U_n$ is denoted as $g_{m,n}$.

Suppose now that PU transmitters communicate with Q PU receivers located at $\{x^{(q)} \in A\}_{q=1}^Q$. With $h_{m,x^{(q)}}$ is the instantaneous channel gain between U_m and position $x^{(q)}$. Here we can obtain average link gain based on locations $\{x^{(q)} \in A\}_{q=1}^Q$, but the instantaneous value of the primary link cannot perfectly be determined due to random fast fading effects. Therefore, SU m may cause interference to PU q . Next, it is assumed that only $\{h_{m,x^{(q)}}\}$ i.e. the joint distribution of processes is known to the SU network, which is denoted as $\phi_h(\{h_{m,x^{(q)}}\})$ [2]. Let I be the maximum instantaneous interference power tolerable by the PUs, the secondary network can determine the interference probabilities at each location $x^{(q)}$. For instance, if U_m is scheduled to access the channel with a transmit-power P , the probability of causing interference to PU receiver q is $\Pr\{p_{h_{m,x^{(q)}}} > I\}$.

Sometime locations $\{x^{(q)} \in A\}_{q=1}^Q$ are generally uncertain. For this, let $z_{x^{(q)}}$ is a binary variable having value 1 if PU receiver q is located at $x \in A$. Let $G = \{x_g\}$ are grid points representing potential locations for the PU receivers. Instead of $\{z_{x^{(q)}}\}$, the idea is to use the probabilities $\beta_{x^{(q)}} = \Pr\{z_{x^{(q)}} = 1\}, \forall x \in G$, to identify areas where a PU receiver q is more likely to reside, and limit the interference accordingly.

The PU system is protected by setting $I = -70$ dB and $i^{\max} = 0.05$. Let, sets $s = \{\phi_h\} \cup \{\beta_{x^{(q)}}\}$ and $g = \{g_{m,n}\}$ are Statistical primary state information (PSI) and available secondary CSI, respectively.

IV. RESOURCE ALLOCATION BASED ON INTERFERENCE CONSTRAINTS

Application-level data packets are generated at the SUs, and routed throughout the network to the intended destination(s). Packet streams are referred to k . The each flow for the destination is denoted by $d(k)$. Packet arrivals at U_m , for each flow k , are modelled by a stationary stochastic process with mean $a_m^k \geq 0$.

There are some notations are used for further calculation:

At the medium access layer, let $w_{m,n}$ be the binary scheduling variable such that, $w_{m,n} = 1$ for U_m transmits to its neighbouring node U_n , otherwise zero. Assume that one secondary link is scheduled per time slot, it as follows

$$\sum_{(m,n) \in \mathcal{E}} w_{m,n}(g,s) \leq 1$$

Where, $\mathcal{E} = \{(m,n) : n \in N_m, m = 1, \dots, M\}$ represents the set of SU-to-SU link [6].

At physical layer, instantaneous rate and transmit power variables are coupled, and this rate power coupling is modelled. Let average transmit-power of U_m is,

$$\bar{p}_m = E_{g,s}[\sum_{n \in N_m} w_{m,n}(g,s) p_{m,n}(g,s)] \dots \dots \dots (1)$$

Where $E_{g,s}[\cdot]$ denotes expectation with respect to random variable g, s . Powers transmitted by the SUs have to obey two different constraints. First, the instantaneous power $p_{m,n}$ cannot exceed a pre-defined limit p_m^{\max} . Second, the average power satisfies $\bar{p}_m \leq p_m^{\max}$. The binary variable $i^{(q)}(\{p_{m,n}, s\})$ represents interference inflicted to the PU system as,

$$i^{(q)}(\{p_{m,n}, s\}) = \sum_{x \in G} \prod_{(m,n) \in \mathcal{E}} \{ \sum w_{m,n}(g,s) p_{m,n}(g,s) h_{m,x^{(q)}} > I \} z_x^{(q)} \dots \dots \dots (2)$$

Where $\prod_{\{x\}}$ the indicator function ($\prod_{\{x\}} = 1$ if x is true, otherwise zero). If $i^{(q)}(\{p_{m,n}, s\}) = 1$ then one or more PU receivers are interfered. Finding the condition for stochastic resource allocation, let us consider $\bar{i}[t]$ be the interference across PU, as [7]

$$\bar{i}[t] = 1/t \sum_{\tau=1}^t i(\{p_{m,n}[\tau], s[\tau]\}) \dots \dots \dots (3)$$

And running average of interference is, $\bar{i}[t] = 1/t \sum_{\tau=1}^t i[\tau]$

Reported in graph of Fig.3. So as $t \rightarrow \infty$

A. Optimal adaptive resource allocation

Some values for have been designed for optimal solution of resource allocation. Whenever primary user receiver is interfered, they generate information related to their location. Some of primary users are more frequently interfered than others. [9]

Assuming the optimal multipliers $\{\lambda_m^{k*}, \pi_m^*, \theta^*\}$ are available.

The optimal average transmit power \bar{p}_m^* of node U_m is,

$$\bar{p}_m^* (\Pi_m^*) = \arg \max_{0 < \bar{p}_m < \bar{p}_m^{\max}} -J_m(\bar{p}_m) + \Pi_m^* \bar{p}_m$$

Where $J_m(\bar{p}_m)$ be a non decreasing function representing the cost incurred by U_m when its average transmit power is \bar{p}_m .

The optimal exogenous rates $\{a_m^{k*}\}$ are,

$$a_m^{k*} (\lambda_m^{k*}) = \arg \max_{a_m^{k, \min} < a < a_m^{k, \max}} V_m^k(a) - \lambda_m^{k*} a$$

Where $V_m^k(a_m^k)$ denote non decreasing, utility function with exogenous rate a_m^k .

The optimal rates $\{r_{m,n}^{k*}[t]\}$, scheduling variable $\{w_{m,n}^*[t]\}$

and instantaneous transmit power $p_{m,n}^*[t]$ are given as,

$$r_{m,n}^{k*}[t] = H_{\{k \in k_{m,n}[t] w_{m,n}^*[t] C_{m,n}(g[t], p_{m,n}^*[t])\}}$$

$$w_{m,n}^*[t] = H_{\{(m,n) = \arg \max_{(i,j) \in \mathcal{O}_{m,n}} (g[t], p_{m,n}^*[t], d^*)\}}$$

$$p_{m,n}^*[t] = [\arg \max_p \varphi_m(g[t], p, d^*)]_0^{p_m^{\max}}$$

Algorithm 1: Resource allocation & receiver localization

1. Perform following step [9]

$$B_X^{(q)} [[t-1] = \sum_{x' \in G_X} \Phi_{x,x'}^{(q)} [t] B_X^{(q)} [[t-1] | t-1]$$

2. Acquire SU-to-SU channels
3. Obtain optimal exogenous rate, optimal rate, optimal average transmit power.
4. Obtain $w_{m,n}^*[t]$, optimal instantaneous transmit power at instant t.
5. Update multipliers λ_m^{k*}, π_m^* .
6. Receive interference tweet
7. Update third multiplier θ^* , using the observed tweet message
8. Perform last step

$$B_X^{(q)} [t | t] = \frac{\Pr\{i^{(q)}[t] = o \mid z_X^{(q)}[t] = 1, H_t^{(q)}\} B_X^{(q)} [t | t-1]}{\Pr\{i^{(q)}[t] = o \mid H_t^{(q)}\}}$$

V. SIMULATION RESULTS

The simulation studies involve the deterministic small network scenario as shown in the Fig.2. The proposed technique is implemented with MATLAB. There are 12 SU transceivers (marked with red circles) are placed over 450 * 450 m and cooperate in routing packets to the sink node U_{12} . One data flow is considered, and traffic is generated at SUs $N_s = \{1, 2, 3, 4, 7, 8\}$. A PU transmitter (marked with a cyan triangle) communicates with 2 PU receivers (cyan rhombus) using a power of 3 dB. The first PU receiver is located at $x^{(1)} = (x = 250, y = 280)$, static, and it is served by the PU source during the entire simulation interval $t \in [1, 10^4]$. The second PU is located at $x^{(2)} = (130, 240)$ and it is served by the PU source only during the interval $[1, 6 * 10^3]$. The PU system is protected by setting $I = -70$ dB and $i^{\max} = 0.05$ [8]. Here Rayleigh-distributed small-scale fading is also simulated [3]. The SU system can estimate the PU source location, and of its coverage region by sensing phase ([1]-[3]). Now, the PU coverage region is then plotted by using equidistant grid points (marked with black squares in Fig.2).

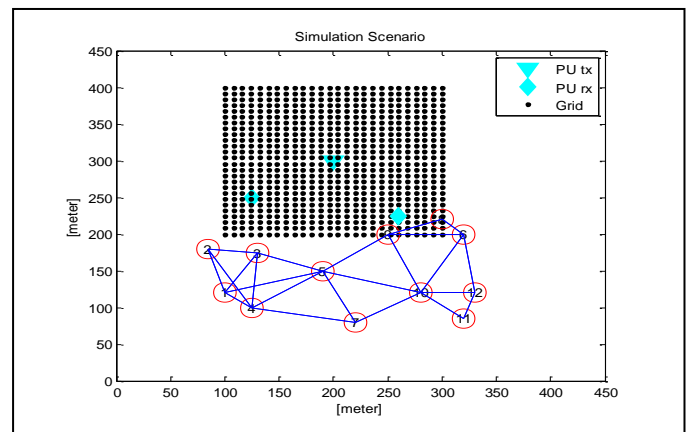
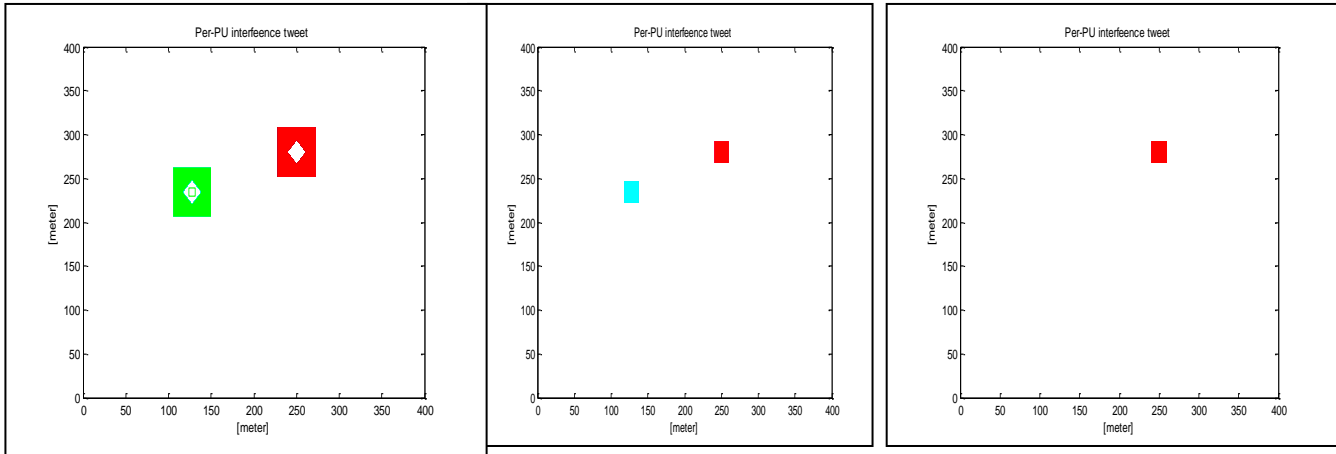


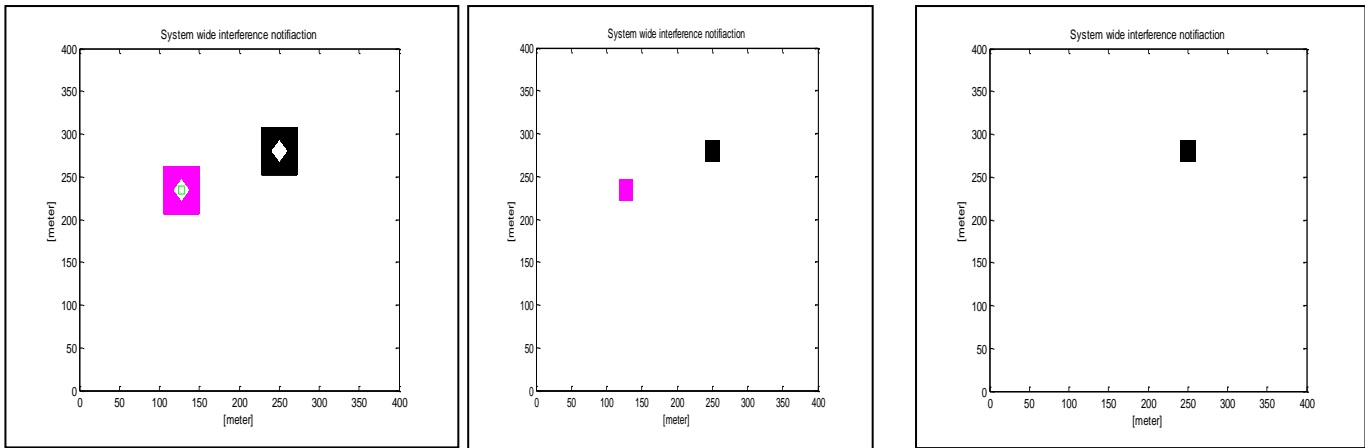
Fig.2 Simulated Scenario

Fig.3. shows interference notification across each primary receiver. Whenever PU is getting interfered due to secondary user, they broadcast interference announcement message, also called as tweet. Initially both receivers are interfered. So by optimizing network parameter such transmit power, rate of data transmission etc. secondary users can limit interference across primary users.



(a) Interference tweet at instant= 100 (b) interference tweet at instant= 1000 (c) interference tweet at instant= 10000

Fig.3. Per-PU interference tweet across each primary receiver



(a) Interference tweet at instant= 100 (b) Interference tweet at instant = 1000 (c) Interference tweet at instant= 10000

Fig.4. System wide interference notification across each primary receiver

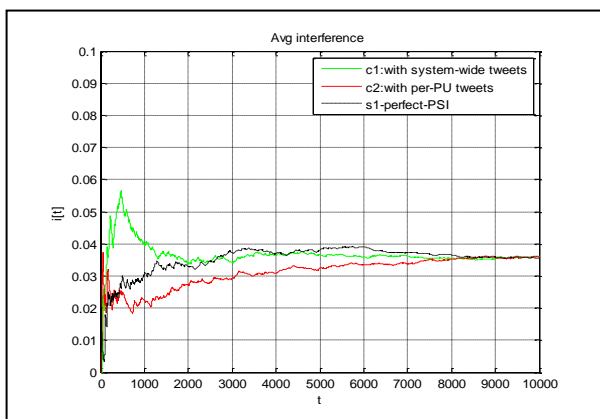


Fig.5.Average interference rate

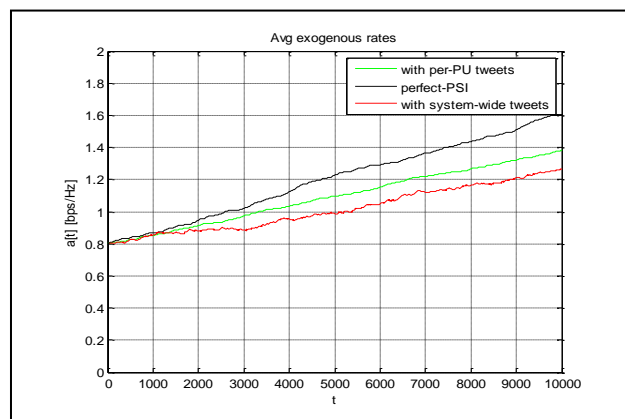


Fig.6. Average exogenous rate

There are number of reasons behind occurrence of interference across PU. It may due to secondary user transmission or due to system parameters. Fig.4. shows Interference at different instant due to system parameters. Both receivers are initially interfered.

At last our system reduced it to very negligible amount. Fig.5. gives average amount of interference tweet across each PU, system wide tweets and perfect PSI. Average exogenous rates for above three results are shown in Fig.6.

VI. CONCLUSION

Resource allocation and localization of PU for cognitive network were designed. A Bayesian approach was developed to estimate the unknown location of the PU receiver. The inputs to the Bayesian estimator were the power transmitted by the secondary system and a binary interference notification broadcasted by primary user system. Proposed System increases network utility as well as improves the performance of secondary network.

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