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Receiver Localization for Cognitive Radio Networks using Interference Constraints

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Abstract—Opportunistic spectrum access technique provides utilization of unused portions of the licensed spectrum for reuse.Such that primary users do not affect harmful interference from the transmissions of secondary radios .Therefore, it is important to analyse the effect of cognitive network interference due to secondary spectrum reuse. We consider a scenario in which cognitive radios i.e secondary users opportunistically share a fixed spectrum resource with different probability of interference constraints. Secondary network variables are optimized by exploiting channel statistics and maps that pin point the area where primary receivers are likely to reside. The receiver location is tracked using Bayesian approach, based on 1-bit message referred as “interference tweet”

Keywords — Average interference, Bayesian estimation, channel state information, cognitive radio network, interference tweet, receiver localization, resource management

1. 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 has started to review their spectrum allocation policies for selection of bestavailable spectrum band. Therefore, opportunistic spectrum access along with a cognitive radio (CR) technology provides promising solution to resolve this problem [10]. This technique has capability to share wireless channel with licensed user in an oppourtunistic manner. This can be realized with the help of efficient spectrum management techniques. User in the CR network must determine: which portions of the spectrum are unused, select the best available channel, co-ordinate access to this channel with other users and vacate the channel when a licensed user is detected

2. METHODOLOGY

The projected localization system involves following steps as shown in Fig.1.There is receiver map as a tool to locate a primary user receiver. The location is tracked using recursive Bayesian estimator, which is based on 1 bit message, also called as 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. These maps are tracked using a recursive Bayesian estimator [8], which is based on a 1-bit message broadcasted by the PU system whenever the instantaneous interference across a PU receiver exceeds a given tolerable level.

Here two interference announcement strategies are considered:

1. The primary user (PU) broadcasts the message to notify the interference has occurred.
2. The generic message is transmitted if at least one of the PU receivers is interfered.

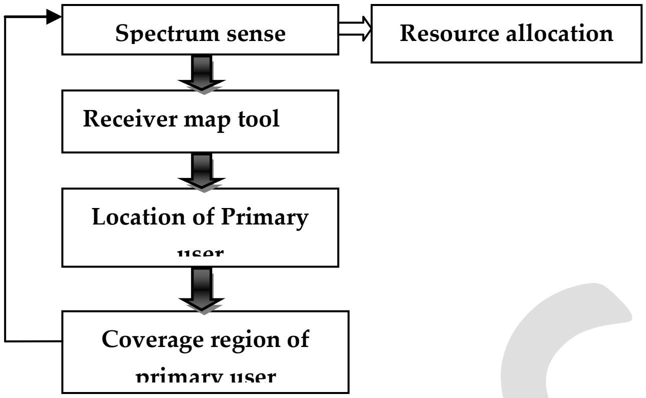

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Fig.1.System flow chart

3. SYSTEM MODEL

3.1 State **information of primary and secondary channel**

Consider a multi-hop secondary user (SU) network with M no. of nodes. $\{\mathrm{U}\}_{m}^{M}$ =1 deployed in area A ∈R2. Here, assume that SUs share a flat-fading frequency band with main PU system in an underlay setup. Based on the output of the spectrum sensing stage such as max. Tolerable power, probability of interference across primary users, 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. The accuracy of the CSI is typically depends on whether PUs or SUs are involved [2]. Here, we assume the state of the SU-to-SU channels is already known. The instantaneous gain of link $U_m \to U_n$ is denoted as $g_{m,n}$ and it is given by the squared magnitude of the small-scale fadi ng realization scaled by the average signal-to-interference- plus-noise ratio (SINR) [3].

Suppose now that PU transmitters communicate with Q PU receivers located at $\{\mathrm{x}^{(\mathrm{q})} \in \mathrm{A}\}_{q=1}^{Q}$. With $h_{m,x^{(\mathrm{q})}}$ is the intantaneous channel gain between U_m and position $x^{(\mathrm{q})}$.Here we can obtained average link gain based on locations $\{\mathrm{x}^{(\mathrm{q})} \in \mathrm{A}\}_{q=1}^{Q}$,but the instantaneous value of the primary link cannot perfectly determined due to random fast fading effects. Therefore, SU m may cause interference to PU q. Next, it is assumed that only $\{h_{m,x(\mathrm{q})}\}$ i.e. the joint distribution of processes is known to the SU network, which is denoted as $\phi_h(\{\mathrm{h}_{m,x^{(\mathrm{q})}}\})$ [3]. Let I be the maximum instantaneous interference power tolerable by the PUs, the secondary network can determine the interference probabilities at each location $x^{(\mathrm{q})}$. 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 $\Pr\{\mathrm{ph}_{m,x^{(\mathrm{q})}} > I\}$.

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

Here we assume that PU receiver has its mobility pattern. Next, the PU system is protected by setting I = −70 dB and $i^{\max}$ = 0.05. Here, Rayleigh-distributed small-scale fading is also simulated [3]. Let, sets $s = \{\phi_h\} \cup \{\beta_{x^{(q)}}\}$ and g $= \{g_{m,n}\}$ are Statistical primary state information (PSI) and available secondary CSI, recpectively.

3.2 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 $d(\mathrm{k})$. Packet arrivals at U_m, for each flow k, are modeled by a stationary stochastic process with mean $a_m^k \geq 0$.

There are some notations are used for further calculation:

Let $r_{m,n}^k(\mathrm{g,s}) \geq 0$ is the instantaneous rate used for routing packets of flow k on link $U_m \to U_n$ during the state realizations g and s. Let $b_m^k[\mathrm{t}]$ are amount of packets of flow k that at time t are stored in the queue of node m. If queues are deemed stable [5], then satisfies the following condition,

$$\lim_{t\to+\infty}(1/t)\sum_{\tau=1}^{t}\mathrm{E}[\mathrm{b}_m^k[\tau]] \leq \infty$$

Next,

$$\{\mathrm{E}_{g,s}[\mathrm{r}_{m,n}^k]\}_{n\in N_m}$$

Specifies avg. amount of packets routed through each SU's outgoing link. Where, $N_m \subset \{1,\ldots,\mathrm{M}\}$ is a set of one hop neighboring nodes of U_m.

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 neighboring node U_n, otherwise zero. Assume that one secondary link is scheduled per time slot, it as follows

$$\sum_{(\mathrm{m,n})\in\varepsilon} w_{m,n}(\mathrm{g,s}) \leq 1 \qquad (1)$$

Where, $\varepsilon = \{(\mathrm{m,n}) : \mathrm{n} \in \mathrm{N}_m, \mathrm{m} = 1,\ldots\mathrm{M}\}$ represents the set of SU-to-SU link [9].

At physical layer, instantaneous rate and transmit power variables are coupled, and this rate power coupling is modeled here using Shannon's capacity formula [3]

$$C_{m,n}(\mathrm{g}_{m,n}, \mathrm{p}_{m,n}) = \mathrm{W}\ \log\,(1 + p_{m,n}g_{m,n} / \mathrm{k}_{m,n})$$

Where, $k_{m,n}$ represents the coding scheme-dependent SINR gap, and W is the bandwidth of the primary channel that is to be reused [3]. Let average transmit-power of U_m, is,

$$\overline{p}_m = E_{g,s}[\sum_{n\in N_m} w_{m,n}(\mathrm{g,s})\,\mathrm{p}_{m,n}(\mathrm{g,s})] \qquad (2)$$

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

$$i^{(q)}(\{p_{m,n}\},s)=\sum_{x\in G}\square_{\{\sum_{(m,n)\in\varepsilon} w_{m,n}(g,s)p_{m,n}(g,s)h_{m,x^{(q)}}>I\}} z_x^{(q)} \qquad (3)$$

Where $\square_{\{x\}}$ the indicator function ($\square_{\{x\}}$) =1 if x is true, otherwise zero). If $i^{(q)}(\{p_{m,n}\},s)=1$ then one or more PU receivers are interfered. Let $i^{\max}\in(0,1)$ denote the maximum long-term probability (rate) of interference [12].

Then, the following condition must satisfy

$$E_{g,s}=\sum_{(m,n)\in\varepsilon} w_{m,n}(g,s)\,i_{m,n}(p_{m,n}(g,s),s)]\le i^{\max} \qquad (4)$$

Finding the condition for stochastic resource allocation, let us consider $\bar{i}[t]$ be the interference across PU, as [10]

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

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 $t\to\infty$

Resource allocation will be takes place if:

1) $\bar{i}[t]\le i^{\max}$

2) $\overline{P}[t]\ge P^{*}-\delta(\mu)$, where $\delta(\mu)\to 0$ as $\mu\to 0$….. [6], [7]

4. NUMERICAL RESULTS

Fig.2 shows the scenario, in which M=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), mobile 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 [11]. Here Rayleigh-distributed small-scale fading is also simulated [4]. The SU system can estimate the PU source location, and of its coverage region by sensing phase ([1]–[4]). Now, the PU coverage region is then plotted by using equidistant grid points (marked with black squares in Fig.2).

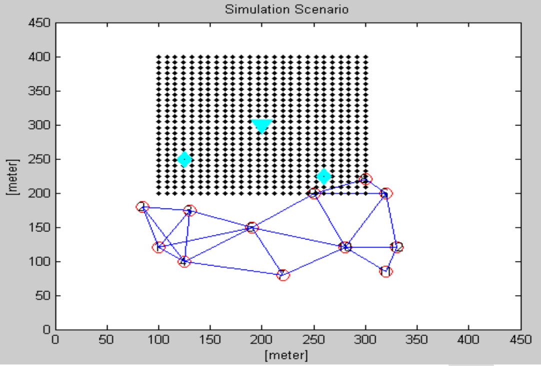
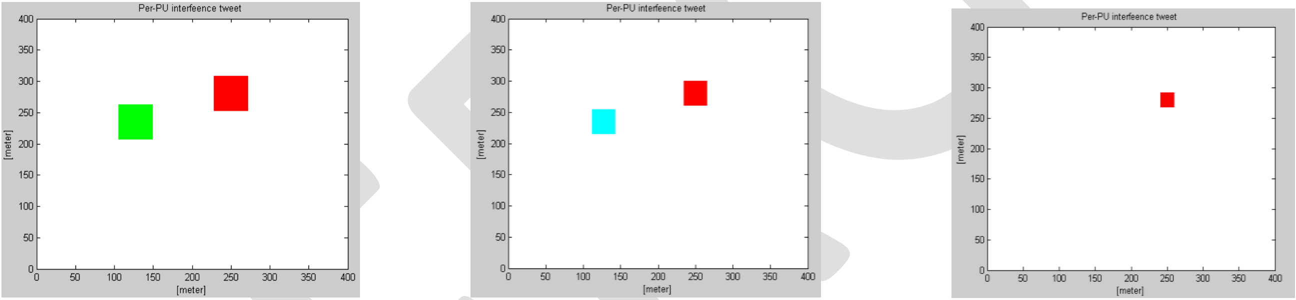


Fig.2.Simulated Scenario

Performance of the receiver localization scheme can be accessed through the maps shown in Fig.3. Maps (a), (b), (c), (d) are acquired at different time instant such that t=100, t=1000, t=6000, t=10000.So it is possible to estimate the area where PU receivers are likely to reside. Clearly, as time goes by localization accuracy improves.



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

Fig.3. Per-PU interference tweet across each primary receivers (PU Rx1=(x = 250, y = 280) and PU Rx2=(x=130, y= 240)) at different instant of time, such as (a) t = 100, (b) t =1000 (c) t =6000, (d) t =10000 .Simulation interval t € [1, 10^4]. The second PU is mobile and it is served by the PU source only during the interval [1, 6*10^3].

at instant (t)		100	500	1000	3000	5000	10000
Instantenous interference	at PU Rx.1	1.9237	3.7691	4.1572	1.6896	2.3190	2.9115
	at PU Rx.2	1.4161	3.5836	1.0497	1.2300	0.6769	0.9645

Table.1.Instantaneous interference across both primary user receivers at different instant of time

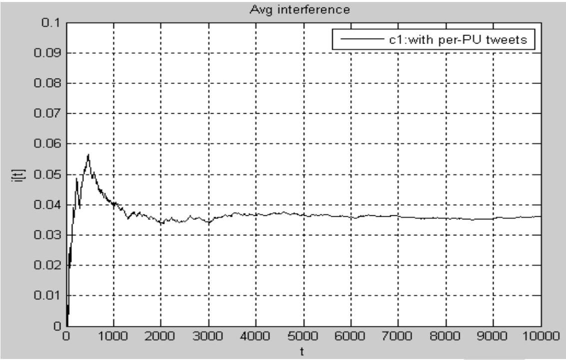


Fig.4.Average interference rate with primary user tweets

The joint resource allocation algorithm is based on location of primary receiver. Bayesian estimator givers information about location of primary sources.Whenever PU receiver is inflicted by interference, tweet message is broadcasted by them. Fig.4 shows rate of average interference across primary receiver.

5. CONCLUSION

For milti-hop cognitive radio network dynamic cross layer resource allocation techniques were designed.A Bayesian estimator is used to track unknown location of primary receivers.The inputs to the estimator were interference notification broadcasted by primary system and transmitting power across secondary system. The optimal solution gives how to manage the resources at different layers which is a function of the perfect CSI and uncertain CSI of the SU-to-SU links and the SU-to-PU links respectively.We can also calculate average interference rate for whole system i.e. nothing but system wide interference constraints.

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