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Interference Reduction Using Coupled Detection and Estimation in Cognitive Radio Networks

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Abstract
The project aims in designing a system which A new spectrum sharing strategy based on coupled detection and estimation is proposed for cognitive radio networks. it consists of the following steps. First the secondary user (SU) listens to the spectrum allocated to the primary user(PU) to find the state of the PU and transmits if the PU is inactive. However, if the PU is active, the SU estimates the PU location and then makes a decision about the reliability of the estimate.

The SU transmits via beam forming, with a null in the estimated direction of the PU, only when the estimate is classified as reliable. Therefore, the proposed method is able to trade-off throughput for reduced interference at the PU. We formulate this problem mathematically and derive the optimum strategy that maximizes the throughput of the cognitive radio system under average interference power constraint at the PU. Finally, we provide simulation results to demonstrate the performance of the proposed spectrum sharing strategy

Keywords: ***cognitive radio, spectrum sensing, spectrum sharing, Beam forming, coupled detection and estimation.***

1. Introduction
The heavy usage of wireless communications in personal, commercial, and governmental capacities, efficient spectrum utilization has become a prime research topic. The Federal Communications Commission (FCC) governs spectrum usage and allocates specific ranges to licensed users. However, some spectrum ranges are overcrowded, while some are under-utilized. The overcrowded spectrum reduces overall quality of service for users in that allotment. A potential solution to this problem is cognitive radios, which performs two major tasks. First, it searches the spectrum and determines which parts are unoccupied, a technique known as spectrum sensing. Second, it ascertain a method of assigning secondary users to the unoccupied spectrum without interfering with the primary users. Cognitive radio networks could drastically change the way wireless communications operate in the future by dynamically allocating spectrum usage and ultimately, provide a better quality of service to users. Cognitive radios can be largely classified into four main tasks: spectrum sensing, spectrum decision, spectrum sharing, and spectrum mobility.1.Spectrum sensing aims to detect the unused spectrum and sharing it without harmful interference with other users. 2. Spectrum management captures the best channel to establish communication. 3. Spectrum mobility maintains the channel in case the PU is detected. 4.

Spectrum Sharing distribute the spectrum among the secondary users according to the usage cost [1]. A major challenge in cognitive radio is that the secondary users need to detect the presence of primary users in a licensed spectrum and quit the frequency band as quickly as possible if the corresponding primary radio transpire in order to avoid interference to primary users.

PROBLEM FORMULATION
A. System Model
The schematic diagram of a Cognitive Radio Network is illustrated in Fig. 1, where M SUs are randomly distributed with uniform distributions over a disk

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D(O,RSU) , centered at O with radius RSU. The distant secondary user (DSU) as well as the primary user are located in the same plane as that containing D(O,RSU). The PU and DSU are randomly distributed with uniform distributions in the ring S(O, Ri, Ro) centered at O with the inner radius Ri>RSU and the outer radius Ro>Ri. The locations of the PU, the DSU and the mth SU in polar coordinates are denoted by θ=[r, φ]T, θDSU= [rDSU, φDSU]T and θm=[rm,φm]T respectively.

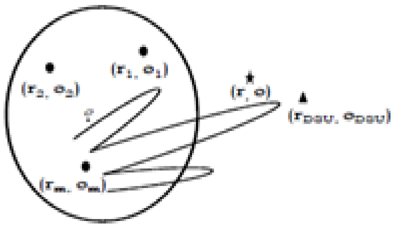

Fig. 1. Schematic diagram of the Cognitive Radio Network.

The following assumptions are:

A1: All locations are static during the observation period.

A2: The DSU and the PU are in the far field of the CR network.

A3: There is no multipath or shadowing, i.e., the effect of signal scattering is negligible.

A4: All the SUs are equipped with antenna arrays and can perform beamforming in an intended direction.

A5: All the SUs are aware of the locations of other SUs operating in the network.

A6: The PU is engaged in bidirectional communication with another PU.

A7: The SUs in the network cooperate to detect and localize the PU.

The SU first detects the presence or absence of the PU. If the PU is inactive, the SU transmits using this licensed band. However, if the PU is active, the SUs cooperatively localize the PU. Based on this information, the SU transmits using this licensed band via beamforming, such that the average interference at the PU is less than or equal to a predetermined level. The goal is to maximize the capacity of the CR network, subject to the interference constraint at the PU.

UNCOUPLED DETECTION AND ESTIMATION (EXSISTING TECHNIQUE)

Conventionally, detection and estimation processes are performed separately. Assuming that the SUs cooperate in a centralized manner to detect and estimate the PU, the detection problem is a binary hypothesis problem with hypothesisH0 denoting that the primary user is inactive and hypothesis H1denoting that the primary user is active.

$$H0: \; X = V$$
$$H1: \; X = p(\theta)^T s + V$$

SPECTRUM SENSING

A key problem in cognitive radio is that the secondary users need to detect the presence of primary users in a licensed spectrum and quit the frequency band as quickly as possible if the corresponding primary radio emerges in order to avoid interference to primary users. The technique is called spectrum sensing, which is a fundamental problem in cognitive radio.

In CR communication, spectrum sensing is a key element and it should be performed before an unlicensed user is allowed to access a vacant licensed channel. The essence of spectrum sensing is a binary hypothesis-testing dilemma:

H0: Primary user is absent

H1: Primary user is in operation.

The probability of correct detection Pd, probability of false alarm Pf and probability of Miss detection Pm are the key metric in spectrum sensing, given respectively as:

Pd = Prob {Decision = H1/H1}

Pf = Prob {Decision = H0/H0}

Pm = Prob {Decision = H0/H1}

COOPERATIVE SPECTRUM SENSING BASED ON ENERGY DETECTOR

We investigate cooperative spectrum sensing in a centralized CR network consisting of an access point or base station1 and a number of CR users. In this network, each CR user sends its sensing data to the base station

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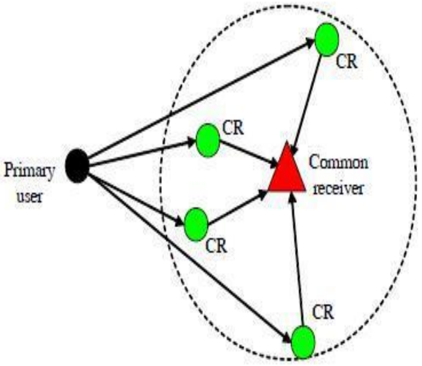
periodically via the common control channels while the base station combines the sensing data from different CR users and makes a decision on the presence or absence of the primary user Soft combination of the observed energies from different cognitive radio users is investigated. Based on the Neyman-Pearson criterion, we obtain an optimal soft combination scheme that maximizes the detection probability for a given false alarm probability.



System Model of Cooperative Spectrum Sensing

Energy Detection

Energy detector based approach, also known as radiometry or periodogram, is the most common way of spectrum sensing because of its low computational and implementation complexities. In addition, it is more generic (as compared to methods given in this section) as receivers do not need any knowledge on the primary users' signal. The signal is detected by comparing the output of the energy detector with a threshold which depends on the noise floor .

Let us assume that the received signal has the following simple form:

$$Y(n)=s(n)+w(n) \qquad (1)$$

where s(n) is the signal to be detected, w(n) is the additive white Gaussian noise (AWGN) sample, and n is the sample index. Note that s(n)=0 when there is no transmission by primary user.

The decision metric for the energy detector can be written as

$$M = \sum_{n=0}^{N} |Y(n)^2|$$

The performance of the detection algorithm can be summarized with two probabilities: probability of detection PD and probability of false alarm PF.

PD is the probability of detecting a signal on the considered frequency when it truly present. Thus, a large detection probability is desired. It can be formulated as

$$PD = Pr(M > \lambda_E \mid H1) \qquad (5)$$

PF is the probability that the test incorrectly decides that the considered frequency is occupied when it actually is not, and it can be written as

$$PF = Pr(M > \lambda_E \mid H0) \qquad (6)$$

PF should be kept as small as possible in order to prevent under utilization of transmission opportunities. The decision threshold λ_E can be selected for finding an optimum balance between PD and PF.

NEYMAN PEARSON METHOD

Based on the Neyman-Pearson criterion, we obtain an optimal soft combination scheme that maximizes the detection probability for a given false alarm probability. Therefore, the Neyman-Pearson criterion is applied here, which is equivalent to the likelihood ratio test (LRT). Let Y = (Y1, Y2, ⋯ , YN), then the corresponding likelihood ratio between hypotheses H0 and H1 is expressed as

$$L(X) = \frac{pr\left(\frac{Y}{H0}\right)}{pr\left(\frac{Y}{H1}\right)} > Y \qquad (7)$$

The Neyman – Pearson (NP) detector decides $\mathcal{H}1$ if the likelihood ratio exceeds a threshold ϒ or

$$L(y) = \frac{pr\,(x/H1)}{pr\,(x/H0)} > \Upsilon$$

Where L(y) $\gtrless \eta$

$$L(y) = \frac{\frac{\int fx}{H1},\theta\left(\frac{x}{H1},\theta\right)P\theta(\theta)d\theta}{\frac{fx}{H0\left(\frac{x}{H0}\right)}}$$

$$\int L\boldsymbol{X}|\boldsymbol{\theta}(\boldsymbol{X}|\boldsymbol{\theta})P\boldsymbol{\theta}(\boldsymbol{\theta})d\boldsymbol{\theta}$$

P (H1; H1) and in keeping with the signal detection problem is called probability of detection. It is denoted by pd.This setup is termed the neyman-pearson (NP) approach to hypothesis testing or to signal detection. We wish to maximize p_d= p (H1; H1) subject to the constraint P_{fa} = p (H1; H0) =α

$$P_{FA} = P(H1, H0)$$
$$= Pr\{x[0] > \Upsilon; H0\}$$
$$= \int_{\Upsilon}^{\infty} 1/\sqrt{2\Pi} \exp(-\tfrac{1}{2}t^2)\, dt$$
$$= Q(\Upsilon)$$
$$Pd = p(H1; H1)$$
$$= pr\{x[0] > \Upsilon; H1\}$$
$$= \int_{\Upsilon}^{\infty} 1/\sqrt{2\Pi} \exp(-\tfrac{1}{2}(t-1)^2)\, dt$$
$$= Q(\Upsilon-1) = Q(2) = 0.023$$

The test statistic T(x) = $(\frac{1}{N}\sum_{n=0}^{N-1} x(n))$ is a Gaussian under each hypothesis.

We have then

$$P_{fa} = pr\{T(X) > \Upsilon; H0\}$$
$$= Q\left(\frac{\Upsilon}{\sqrt{\sigma^2/N}}\right)$$

And

$$P_d = pr\{T(X) > \Upsilon; H1\}$$
$$= Q\left(\frac{\Upsilon - A}{\sqrt{\sigma^2/N}}\right).$$
$$= Q\left(Q^{-1}(PFA) - \frac{\sqrt{NA^2}}{\sigma^2}\right)$$

ESTIMATION OF PRIMARY USER BASED ON RECEIVED SIGNAL STRENGTH (RSS)

In cognitive radio secondary users should not only be aware of the presence of a primary user but also of its location. With the knowledge of the user locations secondary users can adjust their transmission parameters in terms of power, frequency and direction to lower the interference with the primary users. Usually the secondary users perform RSS measurements related to the localization of the primary user and send the measurement data to a base station for further analysis.

For the localization the base station combines all the measurements and extracts the primary user location. That is why their transmit powers and corresponding locations have to be estimated based on measurements of the Received Signal Strength (RSS). In cognitive radios, unlicensed users implement spectrum sensing and localization not to interfere with licensed users.

$\boldsymbol{p(\theta)}$ = [$p1(\boldsymbol{\theta})$,$p2(\boldsymbol{\theta})$, ...$pM(\boldsymbol{\theta})$] is the received power vector. *pm* is the received signal strength (RSS) at the *mth* SU and is modelled as $pm(\boldsymbol{\theta}) = \frac{c0pT}{dm(\boldsymbol{\theta})\beta}$Watt.

where *PT* is the PU transmit power (assumed to be known), β is the known path loss exponent and *c*0 is the constant average multiplicative gain at reference distance.

Also, $d_m(\boldsymbol{\theta})$ is the distance between the i_{th} SU and PU and is given by,

$$d_m(X,Y) = \sqrt{(X - Xm)^2 + (Y - Ym)^2}$$
m=1,2..............N

The ideal value at the i_{th} cognitive radio node is equal to the ideal received power p_i^{ideal}

$$p_m^{ideal} = c_0 \frac{P_t}{dm^{\beta}} \quad m = 1,2.........N$$

p_t is the isotropic radiated powers of the primary transmitter, constant of the factors effecting RSS is c_i,the path of loss exponent is β, the distance between the primary transmitter and the cognitive radio nodes is d_i.In each cognitive radio node is holed equation (2). it can be extended to all nodes and expressed in matrix form as

$$\begin{pmatrix} 2x_1 & 2y_1 & \left(\frac{c_1}{p_{t,1}^{ideal}}\right)^{2/\beta} - 1 \\ 2x_2 & 2y_2 & \left(\frac{c_2}{p_{t,2}^{ideal}}\right)^{2/\beta} - 1 \\ 2x_n & 2y_n & \left(\frac{c_n}{p_{t,n}^{ideal}}\right)^{2/\beta} - 1 \end{pmatrix} \begin{pmatrix} x \\ y \\ (p_t)^{2/\beta} \end{pmatrix} = \begin{pmatrix} x_1^2 + y_1^2 \\ x_2^2 + y_2^2 \\ x_n^2 + y_n^2 \end{pmatrix} \quad (11)$$

The least squared method can be used to solve this equation. The solution of equation (11) is provided the position of the primary transmitter and its isotropic radiated power

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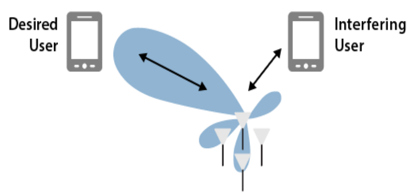
$$w=\begin{pmatrix} 2x_1 & 2y_1 & \left(\frac{c_1}{p_{t,1}^{ideal}}\right)^{\frac{2}{\beta}}-1 \\ 2x_2 & 2y_2 & \left(\frac{c_2}{p_{t,2}^{ideal}}\right)^{\frac{2}{\beta}}-1 \\ 2x_n & 2y_n & \left(\frac{c_n}{p_{t,n}^{ideal}}\right)^{\frac{2}{\beta}}-1 \end{pmatrix}$$

$$\emptyset=\begin{pmatrix} x \;\; y \\ (x^2+y^2) \\ (p_t)^{\frac{2}{\beta}} \end{pmatrix},\ v=\begin{pmatrix} (x_1^2+y_1^2 \\ x_2^2+y_2^2 \\ x_n^2+y_n^2 \end{pmatrix}$$

SHARING THE SPECTRUM BY PLACING A NULL IN THE ESTIMATED DIRECTION (DIRECTION OF PRIMARY USER) USING BEAM FORMING

CRN employs beamforming in order to steer a null towards the PU and the desired direction towards the secondary user . The main objective of the CRN is to weight each node to maximize power towards the SU receiver while limiting power in the direction of the PU. Array beamforming refers to an array of local antennas that are equally spaced and can be weighted to achieve the desired radiation pattern. Antenna arrays can be used for directional of arrival (DOA) estimation and for interference avoidance by steering nulls toward unintended receivers and steering beams towards intended receivers.



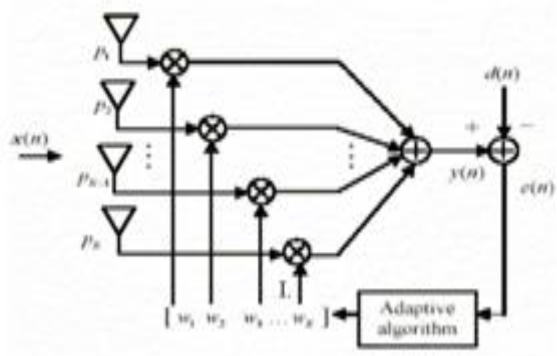
Beam forming

The array factor can then be found as the SU performs null steering beamforming for transmission to the SURx .

$$a(\phi)=[1, e^{\frac{-j\omega d\,\sin(\phi)}{c}}, \ldots e^{\frac{-j\omega(Na-1)d\,\sin(\phi)}{c}}]$$

where Na is the number of elements, L is the distance between neighboring elements in the array, and λ is the wavelength. If w = $[W_1 \ldots\ldots W_{NA]}{}^T$ is the weight vector, then the optimal weight vector W_{OPT}, which maximizes the received power at SURx (located in the direction φSURx) and produces a null at PU (located in the direction φ) satisfies the following

$$W_{OPT} = (\mathrm{I} - \mathrm{PA})\, a\emptyset_{SURX}$$



Antenna Array

where A = [aφ], I is the identity matrix and PA = $A(A^H A)^{-1}A^H$ is the projection matrix onto the subspace spanned by the columns of A. To calculate the weight vector wopt and to perform null steering beamforming, the location of PU should be accurately known. If we denote the estimate of φ by φˆ, then the weight vector $W^{\wedge}{}_{OPT}$, in the presence of PU localization error is given by,

$$\text{wˆ opt} = (\mathrm{I} - A(A^H A)^{-1}A^H)\, a\emptyset_{SURX}$$

The average interference to signal power ¯I2 = Eφˆ(I2), at the PU due to imperfect localization is given by the following theorem

LET, $y = a^H \varphi\text{ˆ} a\varphi_{SURX}$

$$= \frac{\sin[Na\frac{\pi l}{\lambda}((\sin\varphi SURx - \sin\varphi)\text{ˆ}]}{Na\sin[\frac{\pi l}{\lambda}(\sin\varphi SURx - \sin\varphi)\text{ˆ}]}\ e\, j\,(Na-1)\frac{\pi l}{\lambda}(\sin\varphi SURx - \sin\varphi)$$

COUPLED DETECTION AND ESTIMATION (PROPOSED TECHNIQUE)

The procedure is capable of controlling the estimation error (more specifically in trading-off detection performance for improve destination performance in a jointly optimal manner), and hence provides better control of the interference generated at the PU.As shown in the previous subsection, if the PU localization

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estimate is poor, the average interference at the PU increases. Thus, the final decision whether to transmit via beamforming or not, should depend in some manner on the quality of the location estimate, or more specifically a coupled detection and estimation procedure followed by censoring of SU transmissions is desirable.

Let P(δNP1(X)=1) denote the probability of deciding H1,given an observation X. Since, the first level test is a Neyman-Pearson test, we have

$$\zeta_1^{NP}(X) = \begin{cases} 1 & \dfrac{F_{(X/H_1)}(X/H_1)}{F_{(X/H_0)}(X/H_0)} \geq ¥_{NP} \\ 0 & \dfrac{F_{(X/H_1)}(X/H_1)}{F_{(X/H_0)}(X/H_0)} < ¥_{NP} \end{cases} \quad (25)$$

Also, let P(q1r(X)=1)denote the probability of decidingH1r, i.e., whether the estimate is reliable, given the decision of first level test is δNP1(X)=1. The optimal decision rule for the hypothesis test H1rvs.H1u will depend on the coupled cost function chosen and its derivation will be presented next. Note that P(δ1NP(X)=1)P(q1r(X)=1)is the probability of taking a decision in favor of H1r for a given X, since we must decide in favor of H1in the first step (with probability P(δ1NP(X)=1)) and then we must decide in favor of H1r in the second step (with probability P(q1r(X))=1).Let the posterior cost function for estimation be defined as,

$$C_P(X) = E_\Theta[(\Theta^{\sim}(X) - \Theta)]^T(\Theta^{\sim} - \Theta)] \quad (26)$$

The posterior cost Cp(X) may also be represented in terms of the conditional likelihood ratio as :

$$C_P(X) = \frac{\int \|(\Theta - \Theta^{\sim}(X)\|^2 L_{X/\Theta}(X/\Theta)\, f_\Theta(\Theta)d\Theta}{\int L_{X/\Theta}(X/\Theta)\, f_\Theta(\Theta)\, d\Theta} - \|\Theta^{\sim}(x)\|^2 \quad (27)$$

Let P(D=H1r) denote the probability of deciding an estimate to be reliable, given that the first level NP test has decided in favor of H1. If βNP denotes the probability of missed detection corresponding to the first-level NP test, then the probability of reliable detection will be upper bounded by 1−βNP.For any β such that 1> β ≥ βNP, the constraint 1−β≤P(D=H1r)controls the fraction of initial decisions in favor of H1,for which the estimate is classified as reliable. Also, when β=βNP, the performance of the coupled procedure, is identical to an uncoupled procedure because in this case all the estimates are considered to be reliable. Next, a constrained optimization problem may be formulated as below:

The fraction of reliable estimates may be defined as,

$$\mu = \frac{1-\beta}{1-\beta^{NP}} \quad (29)$$

The above optimization problem minimizes the coupled cost function (combining both detection and estimation performances) subject to a constraint that at least a fraction μ of the initial decisions which are classified asH1are also declared as reliable estimates, H1r. The optimal test forH1r vs.H1u is given by:

$$q_1^{NP}(X) = \begin{Bmatrix} 1 \; for & C_P(X) \leq \varsigma \\ 0 \; for & C_P(X) > \varsigma \end{Bmatrix} \quad (30)$$

where ς is selected to satisfy the following constraint with equality:

$$P(\varsigma \geq C_P(X)) = 1 - \beta \quad (31)$$

P(ς ≥Cp(X))denotes the probability of Cp(X)≤ ς, i.e. ,whether the estimate is reliable, given the decision of the first level test isδNP1(X)=1.βis the controlling parameter that provides flexibility to trade detection power for estimation accuracy. Note that if β=βNP, all the estimates are deemed reliable and μ=1. However, if 1> β ≥ βNP, then μ≤1, and it implies that for some of the estimates Cp(X)>ς, and these estimates are deemed unreliable and transmission is censored.

Therefore, as we reduce the value of μ, ς reduces, and the quality of the estimates, which are deemed reliable, improve) accuracy in a jointly optimal manner. Hence, decreasing μ reduces the average interference at the PU but also reduces the throughput of the secondary users.

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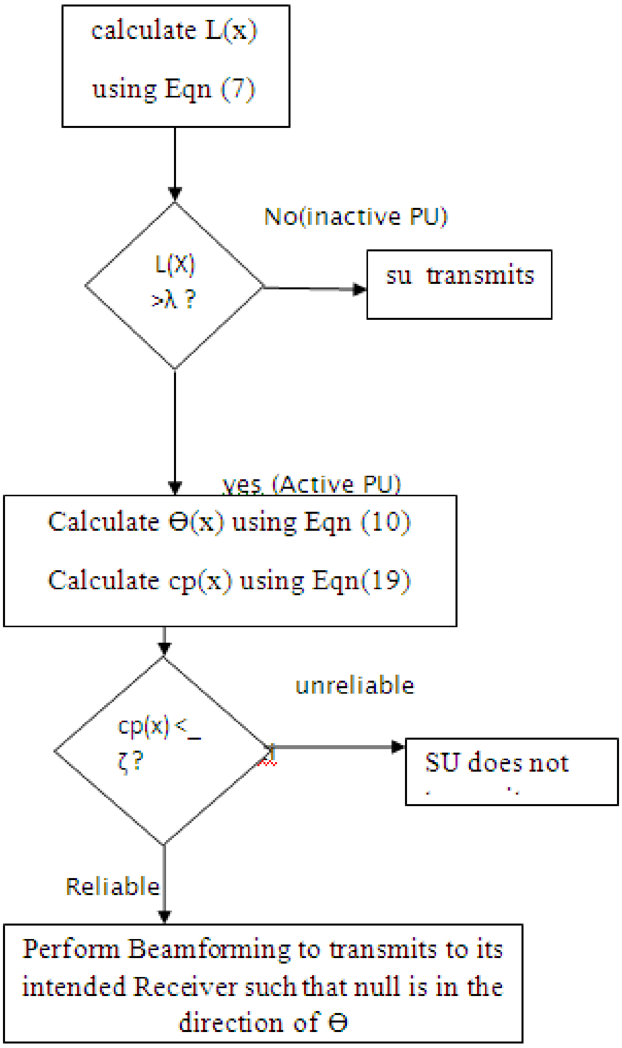
FLOWCHART OF COUPLED DETECTION AND ESTIMATION



OPTIMUM SPECTRUM SHARING STRATEGY

Assuming the coexistence of PU and SU, the transmission rates of SU and PU are given by, $r_s=\log_2(1+P_s/\sigma_s^2)$ and $r_p=\log_2(1+P_p/\mu.I+\sigma_p^2)$. Here P_s/σ_s^2 and P_p/σ_p^2 are the received SNRs at SU and PU respectively, I is the average interference at the PU due to the SU and μ is the fraction of reliable estimates (as defined in Equation (20)). The interference to the secondary user because of the primary user is assumed to be negligible. As perfect spectrum sensing is not possible in practice, there will be four different transmission rates based on the actual status of the primary users and the decision of the secondary users. Let r_{00} denote the transmission rate when PU is inactive and no false alarm occurs; r_{01} denote the transmission rate when PU is inactive and false alarm occurs; r_{10} denote the transmission rate when PU is active and miss detection occurs and r_{11} denote the transmission rate when PU is active and no miss detection occurs. Hence we have:

- $r_{00}=\log_2(1+P_s/\sigma_s^2)$,
- $r_{01}=\mu*\log_2(1+P_s/\sigma_s^2)$,
- $r_{10}=\log_2(1+P_s/\sigma_s^2)+\log_2(1+P_p/I_2+\sigma_p^2)$ and
- $r_{11}=\mu\log_2(1+P_s/\sigma_s^2)+\log_2(1+P_p/\mu*I_1+\sigma_p^2)$.

I_1 is the average interference at the PU when PU is active and no miss detection occurs (SU transmits via null steering or constrained beamforming) and I_2 is the average interference at the PU when PU is active and miss detection occurs (SU transmits via unconstrained beamforming). Assuming that data transmission and spectrum sensing are performed at the same time the optimization problem that maximizes the throughput of the proposed spectrum sharing cognitive radio system under average interference power constraint at PU can be formulated as follows,

$$\max_{\mu} C=P(H_0)(1-P_f)r_{00}+P(H_0)(P_f)r_{01}+P(H_1)(1-P_d)r_{10}+P(H_1)P_d r_{11} \quad (32)$$

subject to

$$P(H_1)(1-P_d)\, I_2+ P(H_1)P_d\, \mu\, I_1 \le \Gamma \quad (33)$$

Γ is the maximum tolerable average interference at the PU.

The problem discussed above is a convex optimization problem over the variable μ. Let κ be the non-negative Lagrange dual variable associated with the constraint given in Equation (22), then the partial Lagrangian of the problem is given by,

$$f(\mu, \kappa) = \alpha_0\, r_{00} + \alpha_1\, r_{01}+\beta_0\, r_{10}+ \beta_1\, r_{11}- \kappa\,(\beta_0\, I_2+\beta_1\mu\, I_1- \Gamma) \quad (34)$$

and the Lagrangian dual function as

$$q(\kappa)=\sup_{\mu} f(\mu, \kappa)$$

where

- $\alpha_0=P(H_0)(1-P_f)$,
- $\alpha_1=P(H_0)P_f$,
- $\beta_0=P(H_1)(1-P_d)$and

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- β1=P(H1)Pd.

In general, the probability of detection will be high, therefore,β0is assumed to be negligible in this work. After applying the Karush-Kuhn-Tucker (KKT) conditions, the optimal value o f μ is given by

$$\mu = \frac{[\sqrt{H} - G]^{+}}{2} \qquad (35)$$

where(x)+denotes max(x,0)and

$$H = \left(\frac{P_p{}^2}{I_1}\right) + \frac{\beta_1 P_p}{\log_2(e)\{(\beta_0 + \beta_1)\}rs - k\beta_1 I_1}$$

$$G = \frac{P_p + \sigma_p^2}{I_1}$$

The following algorithm calculates the optimal value of μ:

Algorithm: Optimal spectrum sharing strategy.

1) Initialize κ.

2) Repeat:

- calculate μ using Equation (29);

- update κ using the gradient method;

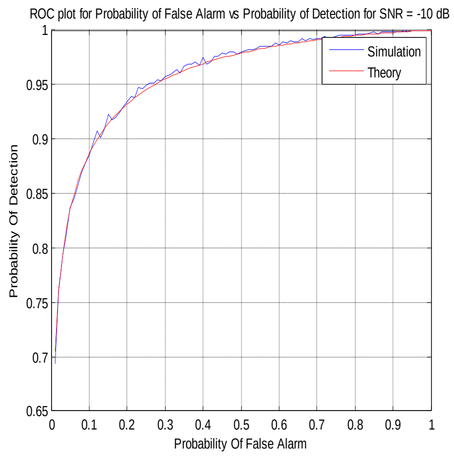
3) Until κ converges.

Once, the optimal value of μ is found, β and ς can be found

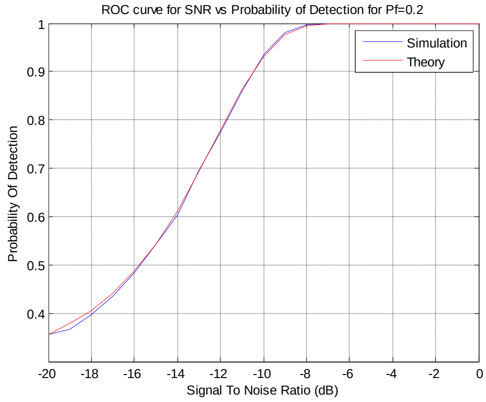
using equations (19) and (23) respectively.

Results

1. ROC plot for probability of false alarm Vs probability of detection for SNR=-10db



2.SNR Vs Probability of Detection for p_{fa} = 0.2



ESTIMATION OF PRIMARY USER

xtx3=1450;

ytx3=1000;

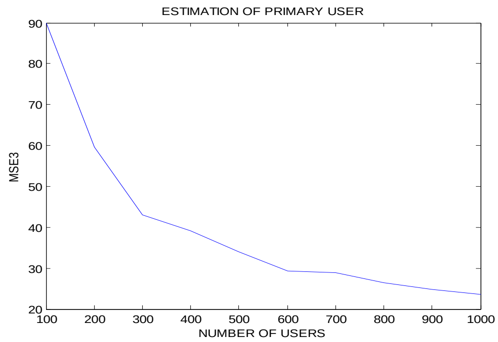
%EIRP of Transmitter 3 in Watts

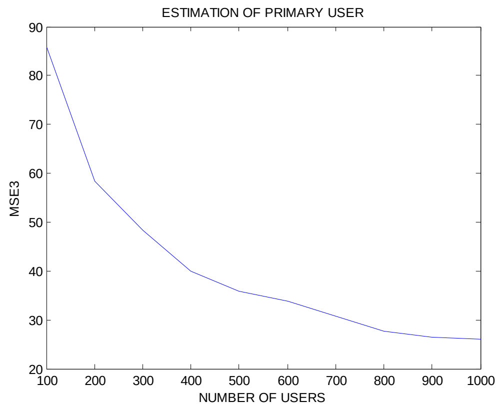
Ptx3=3;

%Coordinates of the nodes

x=[750 800 150 300 200 1000 600 700 150 400 150 800 500 100 150];

y=[200 150 200 200 400 500 400 400 550 700 50 100 250 300 150];





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SPECTRUM SHARING VIA BEAMFORMNG

The CRN employs beam forming in order to steer a null towards the PU and the desired direction towards the secondary user.

s0 = (sin (-20*pi/180));

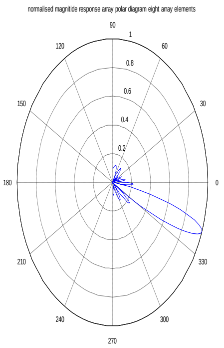
s1 = (sin (40*pi/180));

POLAR PLOT

Desired signal (φ = -20°)

Null at = 40°

No. of antenna arrays=10

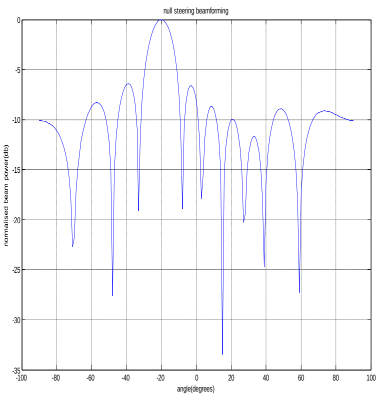


Rectangular plot

Desired signal (φ = -20°)

Null at=40°

No. of antenna arrays=10



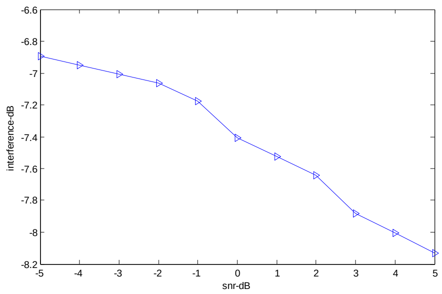
INTERFERENCE Vs SNR

N= [90.5 90 89.5 89 88 86 85 84 82 81 80];

SNR_dB = -5:1:5;

I2(k)=([ad'*(I-p)*(b1*b1')*wopt]/((ad'*wopt)^2))*N(k)

As the SNR increases MSE Decreases

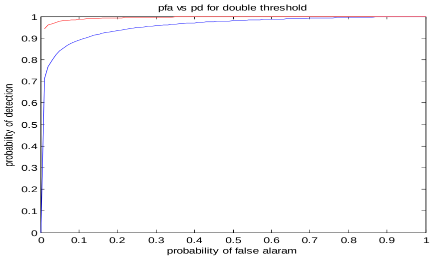


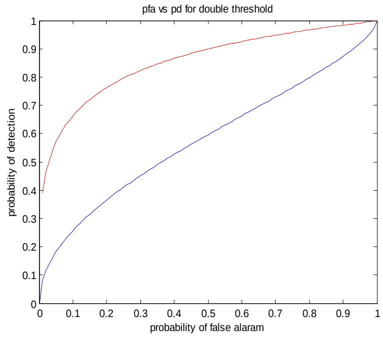
RESULTS FOR PROPOSED METHOD

ENERGY DETECTION

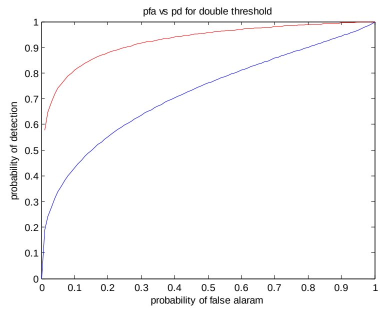
ROC plot for probability of false alarm Vs probability of detection for SNR=-10db

As the probability of false alarm increases the probability of detection increases, when compared to existing technique the probability of detection performance increased from 0.7 to 1.





ROC plot for probability of false alarm Vs probability of detection for SNR=-20db



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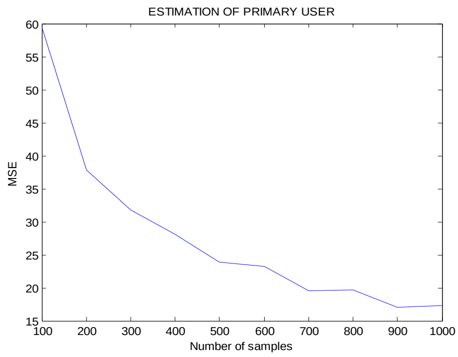
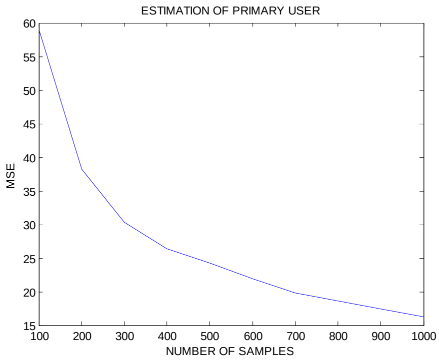
ESTIMATION OF PU

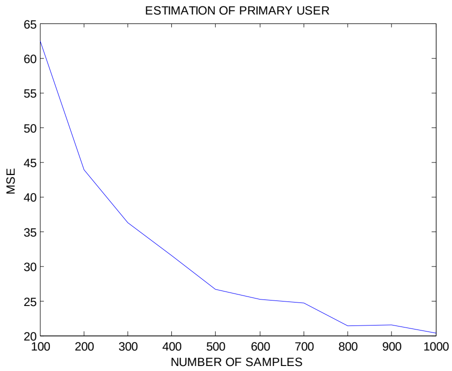
xtx3=1200;
ytx3=1100;
%EIRP of Transmitter 3 in Watts
Ptx3=3;
%Coordinates of the nodes
x=[750 800 150 300 200 1000 600 700 150 400 150 800 500 100 150];
y=[200 150 200 200 400 500 400 400 550 700 50 100 250 300 150];
%Ideal RSS values at each node
I_RSS=[-86.02 -86.11 -90.73 -89.62 -89.48 -80.06 -85.74 -84.70 -89.38 -86.37 -91.43 -86.59 -87.71 -90.69 -90.96];



xtx3=1350;
ytx3=900;
%EIRP of Transmitter 3 in Watts
Ptx3=3;
%Coordinates of the nodes
x=[750 800 150 300 200 1000 600 700 150 400];
y=[200 150 200 200 400 500 400 400 550 700];
%Ideal RSS values at each node
I_RSS=[-87.65 -87.71 -91.86 -90.85 -90.69 -82.54 -87.38 -86.48 -90.54 -87.79];



xtx3=1050;
ytx3=1200;
%EIRP of Transmitter 3 in Watts
Ptx3=3;
%Coordinates of the nodes
x=[750 800 150 300 200 1000 600 700 150 400];
y=[200 150 200 200 400 500 400 400 550 700];
%Ideal RSS values at each node
I_RSS=[-84.17 -84.28 -89.51 -88.26 -88.17 -76.99 -83.87 -82.64 -88.13 -84.84];

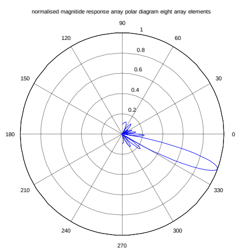


Spectrum sharing via beamforming

The CRN employs beamforming in order to steer a null towards the PU and the desired direction towards the secondary user.
s0 = (sin (-20*pi/180));
s1 = (sin (40*pi/180));

POLAR PLOT

Desired signal (φ = -20°)
Null at = 40°
No. of antenna arrays=10



Rectangular plot

Desired signal (φ = -20°)
Null at=40°
No. of antenna arrays=10

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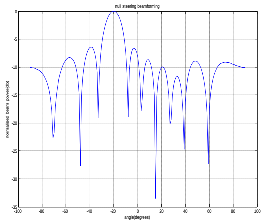
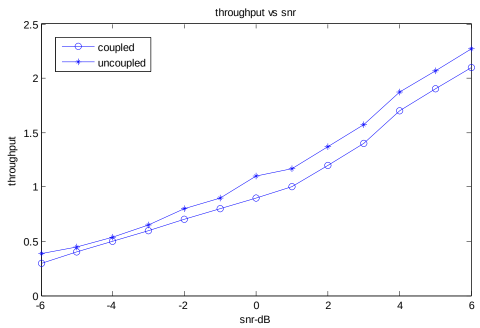


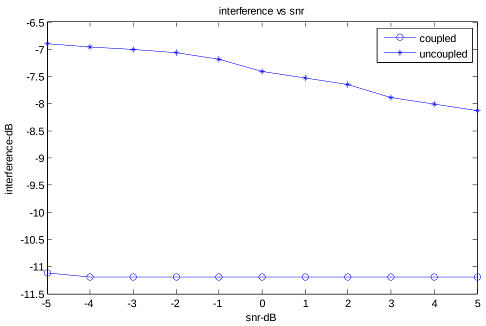
THROUGHPUT VS SNR

c1 = [0.3 0.4 0.5 0.6 0.7 0.8 0.9 1 1.2 1.4 1.7 1.9 2.1];
c2= [0.39 0.45 0.54 0.65 0.8 0.9 1.1 1.17 1.37 1.57 1.87 2.07 2.27]
u=0.9;
u=1;
snr_db = -6:1:6;



INTERFERNCE VS SNR

n= [62 60 60 60 60 60 60 60 60 60 60];
n1=[90.5 90 89.5 89 88 86 85 84 82 81 80];
snr_db = -5:1:5;



4. ACKNOWLEDGEMENT

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CONCLUSION

- We first demonstrated that an uncoupled detection and estimation procedure is unable to control the interference at the PU under imperfect localization in cognitive radio networks.
- Cooperative spectrum sensing based on energy detector is used to detect the presence or absence of the PU it increases the probability of detection (Pd) for a given probability of false alarm (Pf).
- Estimation of PU is based on RSS Method .It is used to estimate the position of PU based on received signal strength. RSS-based PU localization scheme that uses the distance calibration, which reduces the localization error.
- Beamforming technique which has gained importance in wireless mobile communication system due to its ability to reduce the interference along the estimated direction . Weights are used to produce a beam in the direction of desired user (φ = -20°) and null in the direction of interference signal (40°).
- Spectrum-sharing strategy based on a coupled detection and estimation procedure is proposed for cognitive radio networks. The proposed technique used to check whether the estimate is reliable or not and controls the interference at the PU and maximizes the throughput of the CR network.
- In the future, we plan to incorporate the effects of shadowing and fading on the proposed censoring based spectrum sharing technique.

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