RSS Based Localization Algorithm for Cognitive Radio Networks

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Abstract— Knowledge of primary user node in Cognitive Radio Networks could enable several features such as spatio temporal sensing, location aware routing etc. In this paper concepts of Cramer Rao bound is used to achieve acceptable accuracy, here RSS measurements are utilized to localize primary user node. Multiple primary user problems is addressed by using Clustering algorithm. Results are simulated for RSS only for different parameters like Number of Nodes (N), number of antennas(Na), samples(Ns), channel shadowing variance and correlation distance(Xc).

Keywords: CRN (Cognitive Radio Networks),RSS (Received signal Strength),DOA(Direction of arrival),WSN(Wireless Sensor Networks),CRB(Cramer Rao Bounds).

I. INTRODUCTION

A Cognitive Radio is an intelligent system which has capability to change its transmission like Modulation type, Transmission power ,bandwidth, frequency etc. and it can also change reception parameters dynamically with the help of software hence it is also known as “Software Defined Radio”.CR must have hunch to detect unused part of spectrum and temporarily utilize these bands for opportunistic users, since Cognitive radio’s operate as secondary users hence they does not have any predefined bands for communication. In December 2003 FCC (Federal Communication Commission) issued a notification proclaiming that CR is the Right candidate for efficient spectrum utilization and opportunistic sharing.

According to Oxford dictionary the word “Cognition” means the psychological result of perception, learning and reasoning or we can simply say learning by understanding. There are two main characteristics of cognitive radio they are as follows.

Cognitive Capability

Cognitive Capability is the ability of device to get the information about the unused spectrum in the radio environment so as to provide the cognitive users with best operating parameters to use the spectrum efficiently without causing any interference to other users. This capability makes it versatile and efficient to interact with the real radio environment in order to detect appropriate communication parameters that are necessary for cognitive users to use.

Re-configurability

It’s the ability of the device to become versatile to dynamically changing radio environment without change in its hardware components. Cognitive radio can be programmed to be used as transmitter or receiver, also in different frequency or cognitive radio can use different modulation techniques with variable transmission power with respect to the communication link. A software defined radio (SDR) system can dynamically tune to any frequency and can receive any modulation over a range of frequency spectrum using the programmable hardware which is controlled by software.

There are several localization algorithms in WSN however they are not applicable for CRN because of subtle difference i.e. in WSN each and every node may localize every other node whereas in CRN only Secondary users will localize Primary user node in any case primary user will not localize Secondary user nodes. Previous work carried on CRN localization are Hybrid TOA/DOA-Based Location Estimation in Sensor Networks[1],Weighted Centroid Localization algorithm[2], Stansfield localization algorithm[3],CRB based primary user centric localization algorithm[4].
II. SYSTEM MODEL AND BACKGROUND

Assume there are N Cognitive Radio’s (Secondary Users) and M Primary user nodes (M=3 in model considered for simulation). Let \( P_1 = [X_{p1}, Y_{p1}] \), \( P_2 = [X_{p2}, Y_{p2}] \), \( P_3 = [X_{p3}, Y_{p3}] \), ……, \( P_m = [X_{pm}, Y_{pm}] \), and \( S_1 = [X_{s1}, Y_{s1}] \), \( S_2 = [X_{s2}, Y_{s2}] \), \( S_3 = [X_{s3}, Y_{s3}] \), ……, \( S_N = [X_{SN}, Y_{SN}] \). Here clustering of nodes is used i.e all the nodes will first find the distance W.R.T all primary users and opts any one primary user which is very near to it. In the figure 1.1 only three Primary user is considered and clustering is illustrated, it is for sure that each and every node will fall in any one of the clusters each and every node will localize primary user which is inside its cluster not the primary user in other cluster detailed Clustering algorithm is explained in Section IV.

4. All nodes which opts primary user 1 forms cluster (similarly it applies for other two nodes as well).
5. By Clustering method nodes which opted primary user 1 as its nearest node Calculates Mean Square error W.R.T only Primary user 1(positions of other two nodes are not considered for localization).
6. Root Mean Square Error is calculated by using FIM (Fisher Information Matrix) equations in section III for RSS ONLY CRB .

III. MATHEMATICAL BACKGROUND

A. RSS only Bound

The PDF of \( \hat{\phi} \) is given as follows:

\[
\begin{align*}
\log(p(\hat{\phi}|p)) &= \log\left(\left(2\pi\right)^{\frac{N}{2}} \det(\Omega\hat{\Omega})^{-\frac{1}{2}}\right) \\
&= \frac{1}{2} (\hat{\phi} - \tilde{\phi})^T \Omega^{-1} (\hat{\phi} - \tilde{\phi}) \\
\end{align*}
\]

The RSS ONLY FIM is derived as follows:

\[ F_{\Phi} = \frac{1}{2} E_{\Phi} \left[ \frac{\partial^2}{\partial x_p} \left( \Phi - \tilde{\Phi} \right)^T \Omega^{-1} \left( \Phi - \tilde{\Phi} \right) \right] \]  

\[ \{ F_{\Phi} \}_{11} = \frac{\partial}{\partial x_p} \left( \Phi - \tilde{\Phi} \right)^T \Omega^{-1} \frac{\partial}{\partial x_p} \left( \Phi - \tilde{\Phi} \right)^T \]

\[ = \eta^2 \Delta x^T D^{-2} \Omega^{-1} D^{-2} \Delta x \]
\begin{align*}
\{\Phi\}_{22} &= \frac{\partial}{\partial y_p} (\hat{\phi} - \bar{\phi})^T \Omega^{-1} \frac{\partial}{\partial y_p} (\hat{\phi} - \bar{\phi})^T \\
\text{RMSE}_{\text{RSS, CRB}} &= \sqrt{\frac{\mathbb{E}\left[\{\Phi\}^{-1}_{11} + \{\Phi\}^{-1}_{22}\right]}{\Omega}} \\
\text{Mean Square Error for RSS only CRB is given as}
\end{align*}

\begin{align*}
\Omega_s &= \sigma_e^2 e^{-\text{norm}(\mathbf{S}, \mathbf{S})}/Xc \\
\text{Note: For RSS only Bound this would just be single Value for the model considered in this paper.}
\end{align*}

6.2 Mean square Error for all the nodes are individually calculated W.R.T its Primary user mean of all the errors would give final mean square error (Concepts of Fisher Information is utilized for mean square error estimation)

6.3 Let F_RSS be Fisher information matrix obtained from previous section however for final matrix some addition is done because to avoid singularity of matrix.

\begin{align*}
F_{\text{RSS}} &= F_{\text{RSS}} + (\text{no of nodes in cluster}) \times \text{identity_mat of order 2*2.}
\end{align*}

V. SIMULATION

Below Figures indicate the results of algorithm mentioned, they are simulated for specific values of correlation distance (Xc), Number of antennas (Na) shadowing variable (\(\sigma_s\)) and Number of Nodes (N). values are mentioned below figures for reference. RAND function in MATLAB is used for simulation hence graphs plotted for same parameters mentioned in this paper might not match with graphs provided however Root mean square error will be in same range for any number of Nodes.

![RSS Rmse v/s No of nodes with Xc=30,Na=1 and sigma_s=6](image_url)
Fig 5.2: RSS Rmse v/s Correlation distance with N=100,Na=1 and sigma_s=6

Fig 5.3: RSS Rmse v/s No of antennas with N=100,Xc=30 and sigma_s=6

Fig 5.4: RSS Rmse v/s shadowing variable with N=100,Na=1 and sigma_s=6

VI. CONCLUSION
From Simulation Results its articulate that RSS only error is very less compared to conventional algorithm [4] for different parameters considered. Advantages of Modified algorithm:

1. Lesser number of Nodes are present in each cluster hence localization is easy compared to Primary User Centric model.
2. Since more than one Primary user is present hence all node clusters might have fair chance of using primary users

REFERENCES

AUTHOR’S PROFILE

Raghavendra Prasanna.K received his B.E. degree in Electronics and Communication from Ballari Institute of Technology in 2012 and currently pursuing M.Tech in DSCE, advised by Prof Rajeswari.P. His Research interests include Spectrum Sensing and Localization in Cognitive Radio Networks

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