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Consensus BasedCooperative Spectrum Sensing in Mobile Ad Hoc Networks with Cognitive Radio

Mrs. V. V. Joshi[1], Gaurav Kumbharde[2], Jagrup Prasad[3]

Professor, Department of Electronics and Telecommunication, Sinhgad Academy of Engineering, Pune, India[1]

Student, Department of Electronics and Telecommunication, Sinhgad Academy of Engineering, Pune, India[2,3]

Abstract: Cognitive radio network (CRN) is an intelligent system that gives solution to underutilization of spectrum by detection of spectrum holes. For this purpose, important tasks including spectrum sensing, spectrum analysis and spectrum decision are required to be performed. Spectrum sensing is the crucial step as it provides fast and reliable detection of primary users (PU) and helps in evasion of disturbance to their transmission. Different methods of enhancements in local sensing scheme have been proposed in the literature. However, cooperative spectrum sensing schemes are preferred as they provide significant gains in CRN performance by countering shading effects. The consensus-based distributed cooperative spectrum sensing (CDCSS) scheme depends on energy detection for local sensing.

Keywords: Cognitive Radio, Spectrum Sensing, Cooperative Spectrum Sensing, Primary Users. Cognitive Radio Network.

I. INTRODUCTION

The need of accessing spectrum resource is increasing day to day. Cognitive radio is one way to make available the limited resources to the users [1–3]. Cognitive radio basically senses the spectrum holes and uses the licensed spectrum when the primary user is not using. The two main objectives of spectrum sensing are efficient detection of spectrum holes and avoidance of interference with primary user [4-6]. Spectrum can be sensed either locally or cooperatively. In cooperative spectrum sensing, each cognitive user shares their local observations to the rest and they cooperatively make a decision. In ad-hoc network, there is no any central entity. Advancement has been done making the cognitive radio non-stationary which is called mobile ad-hoc network (MANET). In MANET each node will be in motion and they cooperatively make a common decision. In self-organization of nodes, the major responsibilities are topology organization, neighbour discovery, and topology reorganization [7]. Since the nodes are always in motion therefore, the information regarding velocity, acceleration, coordinates etc. of each node must be circulated to each node. The main contributions of this paper are as follows.

1) A consensus-based distributed spectrum sensing for CR-MANETs is proposed.
2) Random walk mobility model (RWMM) is used in CRN for the movement pattern of nodes.
3) Through the simulation, the proposed scheme is compared with existing consensus algorithm and EGC-rule scheme.

II. BACKGROUND AND RELATED WORK

The CR cycle is divided into four broad fields of research to cope with spectrum utilization challenges: (1) the spectrum sensing that determines which portion of the spectrum is available, (2) the spectrum decision that picks the best vacant channel, (3) the spectrum sharing that allows user’s coordinated access to channel, and (4) the spectrum mobility that allows vacating the channel when a PU is detected.

A. Spectrum Sensing:

Spectrum sensing means sensing of holes that means sensing of the spectrum which is vacant. This process can be done into two ways i.e. non-cooperative and cooperative. Further, non-cooperative is divided into three categories, energy detection, matched filter detection, and cyclostationary detection [8–11]. The wireless system is always affected by the environment hence it is difficult for single cognitive user to sense the spectrum due to noise uncertainty, shading and fading. To overcome such problem, cooperative spectrum is opted by researchers. These methods give more accurate results as uncertainty can be minimized [12]. A gradient based distributed cooperative spectrum sensing method was proposed for CRAHNs [13]. The gradient field changes with the energy sensed by CRU, and the gradient is calculated based on the components, which include energy sensed by CRUs and received from neighbours. The proposed scheme was evaluated on the basis of reliable sensing, convergence time, and energy consumption. This scheme consumes less energy compared to existing consensus-based approach.

In [14], a consensus-based spectrum sensing scheme is presented. This scheme is fully distributive where local sensing information obtained by CRUs is sent to their neighbours. Information from neighbours is used by CRUs, and consensus algorithm is applied for stimulating new state for consensus variable. This process is continued

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till the individual states converge to a common value. Like [20], our proposed scheme is also for distributed network. The existing consensus algorithm required each node to have a prior knowledge of the upper bound of the maximum degree of the network. Our proposed algorithm is not only fully distributive and robust against SSDF attacks but also does not require prior knowledge of degree of the network.

Further, this new algorithm is applied on mobile nodes. For nodes motion, mobility models are investigated. Sensing data falsification (SSDF) attacks are also dealt with by researchers by excluding those nodes from neighbours list that give very much deviation from mean value.

III. MODELLING PHILOSOPHY

This section deals with the model of the spectrum sensing system. a model is prepared which includes the sensing of spectrum and sharing of information in CRUs through CDCSS. Furthermore, this section also includes the movement topology of the spectrum sensing system.

The spectrum sensing is of two types, first is local spectrum sensing in which any can sense the spectrum and the information is shared to all nodes, and the second is cooperative spectrum sensing in which cooperative decision is taken by the CRUs. In local spectrum sensing, energy detection method is applied. The mathematical model is proposed i.e

$$x\{t\} = \begin{cases} n\{t\} & \ldots\ldots T0 \\ h * p\{t\} + n\{t\} & \ldots\ldots T1 \end{cases}$$

Where, x{t} is the received signal, n{t} is the white Gaussian noise, p{t} is information signal and h is amplitude gain of PU. The two results shown T0 and T1 indicates availability of primary user.

If the received signal contains only noise i.e.n{t} which means the PU is absent which is T0 and if the received signal is noise plus some information i.e. p{t} +n{t} which means the PU is present which is T1.

This received signal is then passed through band pass filter which has bandwidth B and cut-off frequency fc. Then it is fed to squaring device and then to an integrator for T time period.

Now we have a predefined value λ. This value is then compared. The output Y of the energy detection has the distribution [15]

$$Y = \begin{cases} \chi 22Z \ldots\ldots T0 \\ \chi 22(2\gamma) \ldots\ldots T1 \end{cases}$$

where$\chi 22Z$ represents central chi-square distribution and$\chi 22(2\gamma)$ represents non-central chi-square distribution, each with $2Z$ ($Z = TW$) degree of freedom and a non-centrality parameter of 2γ for the latter distribution.

Here, γ represents SNR. So in short in local observation each MN is represented as i will detect the energy after every T seconds and take measurement Yi.

IV. CONSENSUS-BASED DISTRIBUTIVE COOPERATIVE SPECTRUM SENSING

The local information is shared throughout the mobile networks (MN) which are also nodes in consensus based spectrum sensing. This information is circulated through a common channel called as common control channel (CCC).The common control channel also provides several other network operations that include neighbour discovery, topology change, channel access negotiation, and routing information updates.Since, the nodes are moving randomly therefore the coordinates of each node must be updated continuously and must be known to each node. Cooperative sensing is an iterative process where each MN sets (0) = Yi as the starting value of local state variable at time instant k = 0.An average consensus is ensured if 0 <S` < 1/Δ. S` denotes the step size which can be calculated by Δ. Δ represents the degree of network. Δ can be calculated from following equation:

$$\Delta \sim N^{1/\alpha - 1},$$

Where, N is the number of nodes and $\alpha$is a constant factor that can have a value between 2 and 3. As nodes are mobile, nodes with a distance greater than a certain limit are not considered as neighbours, which changes the degree of node (Δ) and makes step size (S`) a variable factor instead of constant value.

V. NETWORK TOPOLOGY USING RANDOM GRAPH

Network topology is used as a reference. Here, 10 nodes are taken as an example. For the communication between each nodes a link has to be established which is a bidirectional link. When nodes are connected through a path, then the graph is said to be connected. The nodes must be greater than 2. In fixed graphs, the nodes face certain problems such as fading of signals, which may cause link failures and packet errors. Such problem can be solved by using random graph in which the link will go down if nodes will move away. The graph is shown below:

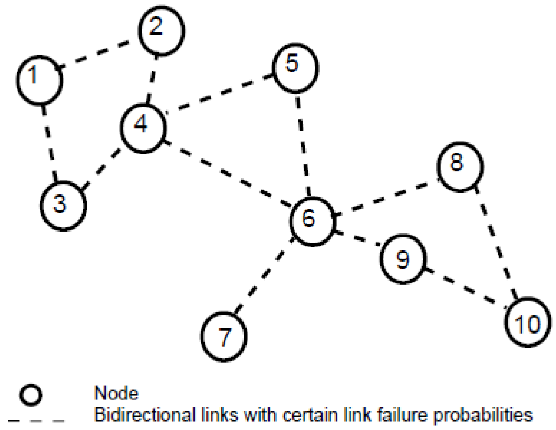

Figure (a): Network Topology of 10 MNs

VI. SIMULATION RESULTS

In this paper, we have compared CDSS with consensus algorithm given in Yu et al. [20], for distributed network, while, for centralized network, it was compared with EGC rule which is a soft combining rule.

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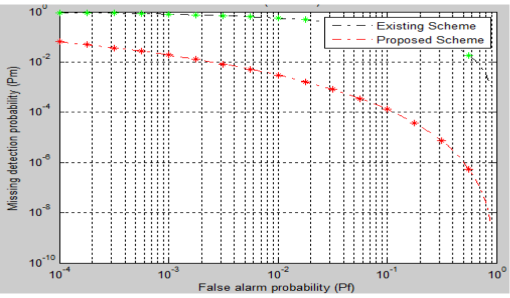
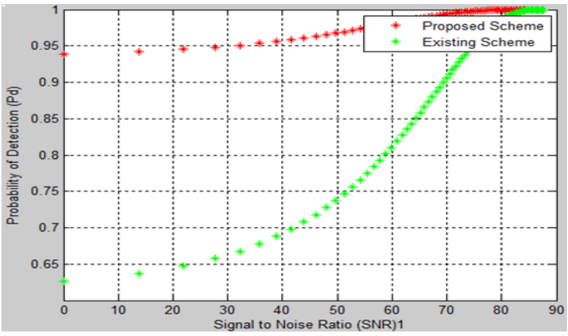
Result 1:



The plots shown above are compared for SNR 10-15dB. New scheme has lower Pf (Probability of False alarm) compared to EGC rule equivalent plot. This will result in less interference to PU(Primary User), thus improving PU's transmission and causing more efficient and reliable spectrum sensing.

Result 2:



From result, it is clear that, in terms of average SNR, proposed scheme has considerable improvements for performing detection. For Pd> 0.95, CDCSS required a lesser average SNR than existing proposed scheme. While the SNR required for Pd>0.95 is approx. 50 for proposed scheme it is much more than 70.

VII. CONCLUSION

Thus in this paper we have proposed consensus based cooperative spectrum sensing. Cooperative spectrum sensing is more efficient method. The local spectrum sensing is energy based spectrum sensing. We have also plotted the graph of missing detection probability v/s false alarm detection. In the second result, we have plotted the graph of probability of detection v/s S/N ratio.

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