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Advanced Cluster Based Spectrum Sensing in Broadband Cognitive Radio Network

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***Abstract*—**A radio spectrum higher data rates is a challenging task that requires inventive advances prepared for giving better methodologies for using the open radio spectrum. The issue of applying the Cognitive radio technique successfully is how to sense exactly and quickly whether or not the Primary User (PU) exists, and searching for the spectrum holes to provide the Secondary User (SU). The proposed system focus on Advanced Cluster Based Spectrum Sensing (ACBSS) algorithm which combines hierarchical data-fusion idea with jointly compressive reconstruction technology. To validate the efficiency and effectiveness, we compare the ACBBSS with Independent Compressive Sensing (ICS) and Joint Compressive Sensing (JCS) in the detection probability, false-alarm probability and algorithm execution time under the situation of unusual SNR and compression ratio. The majority of existing work has focused on **Single band Cognitive Radio**, multiband cognitive radio represents great promises toward implementing efficient cognitive networks compared to single-based networks. This has primarily motivated the introduction of Multiband Cognitive Radio (MB-CR) paradigm, which is also referred to **wideband CR**. In addition, it helps contribute seamless handoff from band to band, which get better the link maintenance and reduces data transmission interruptions.

Keywords*—Cluster, ICS, JCS, Cognitive Radio Technique, Single and Multiband, ACBSS*

I. INTRODUCTION

Radio Frequency (RF) spectrum is a valuable but tightly regulated resource due to its unique and important role in wireless communications. With the proliferation of wireless services, the demands for the RF spectrum are constantly increasing, leading to scarce spectrum resources. On the other hand, it has been reported that localized temporal and geographic spectrum utilization is extremely low[1]. Currently, new spectrum policies are being developed by the Federal Communications Commission (FCC) that will allow secondary users to opportunistically access a licensed band, when the Primary User (PU) is absent. Cognitive Radio [2], [3] has become a promising solution to solve the spectrum scarcity problem in the next generation cellular networks by exploiting opportunities in time, frequency, and space domains. Cognitive radio is an advanced software-defined radio that automatically detects its surrounding RF stimuli and intelligently adapts its operating parameters to network infrastructure while meeting user demands. Since cognitive radios are considered as secondary users for using the licensed spectrum, a crucial requirement of cognitive radio networks is that they must efficiently exploit under-utilized spectrum (denoted as spectral opportunities) without causing harmful interference to the PUs. Furthermore, PUs has no obligation to share and change their operating parameters for sharing spectrum with cognitive radio networks. Hence, cognitive radios should be able to independently detect spectral opportunities without any assistance from PUs; this ability is called spectrum sensing, which is considered as one of the most critical components in cognitive radio networks. Many narrowband spectrum sensing algorithms have been studied in the literature [4] and references therein, including matched-filtering, energy detection [5]. While present narrowband spectrum sensing algorithms have focused on exploiting spectral opportunities over narrow frequency range, cognitive radio networks will eventually be required to exploit spectral opportunities over wide frequency range from hundreds of megahertz (MHz) to several gigahertz(GHz) for achieving higher opportunistic throughput.

CLUSTER

Cluster analysis based only on information within a group be similar (or related) to one another and different from (or unrelated to) the groups. The greater the similarity within a group and the greater the difference between groups the better or more distinct the clustering. Cluster analysis related to other techniques that are used to divide number of nodes into groups. A partition clustering is simply a division of the set of groups into non overlapping clusters such that each group of nodes is in extremely one subset. We obtain a hierarchical clustering is a set of nested clusters contains as a tree. Each node in the cluster in the tree except for the leaf nodes is the union of its children sub clusters and root the tree is containing cluster in the Dynamic Spectrum Management solves the issue of spectrum underutilization in wireless communication in a better way [11]. It provides a highly reliable communication. In this the unlicensed systems (Secondary users) are allowed to use the unused spectrum of the licensed users (Primary users).

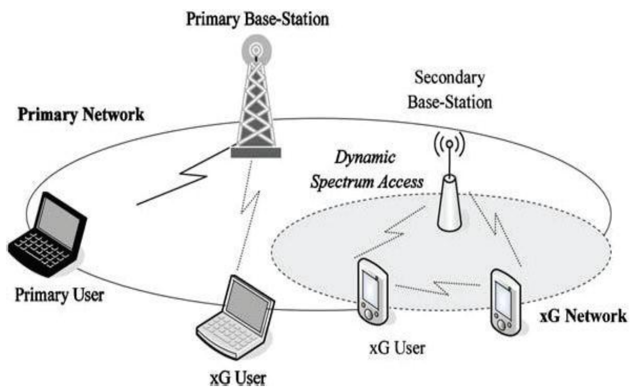

Fig 1.1 Dynamic Spectrum Access in Cognitive Radio

Cognitive radio (CR)will change its transmission parameters like waveform, protocol, operating frequency, networking etc., based on the interaction with environment in which it operates[2].Figure 1.1 shows the Dynamic Spectrum Accessin Cognitive Radio, there exist temporally unused spectrum holes in the licensed spectrum band. Hence, Next Generation (xG)networks can be deployed to exploit these spectrum holes through cognitive communication techniques. Although the main purpose of the xG network is to determine the best available spectrum, xG functions in the licensed band are mainly aimed at the detection of the presence of primary users (PUs). Where the xG network coexists with the primary network at the same location and on the same spectrum band. Thus, the interference avoidance with primary users is the most important issue, in this architecture.

Due to multipath fading, shadowing, and varying channel conditions, uncertainty affects all the cognitive radio processes. Measurements taken by the SUs during the sensing process are uncertain. Decisions are taken based on what has already been observed using the SUs knowledge basis, which may have been impacted by uncertainty. This can lead to wrong decisions, and, thus the cognitive radio system can take wrong actions. Thus, uncertainty propagation influences the cognitive radio performance and mitigating it is a necessity.

A Cluster based spectrum sensing for CRN. The proposed system a wide-band spectrum sensing algorithm, called Advanced Cluster Based Spectrum Sensing, which combines hierarchical data-fusion idea with jointly compressive reconstruction technology.

II. RELATED WORK

Chi-Min Li and Szu-Hsien Lu [1] explained Energy based maximum like hood spectrum sensing method for the cognitive radio. The concept of cognitive radio (CR) has been proposed. The fundamental concept of the CR relies on the spectrum sensing and re-configurability. Two kinds of users can be classified in the CR analysis: one is the primary user (PU) and the other is the secondary user (SU). PUs denotes the users that have the right or license to legally use a specific frequency, sub-carrier or frequency band. In the CR, if the PU has no data transmitted in the allocated frequency band, the SU can perform the spectrum sensing and transmits its own data in that frequency band.

Fatima Salahdine, Naima Kaabouch and Hassan El Ghazi[2] explained one-Bit Compressive Sensing Vs Multi-Bit Compressive Sensing for Cognitive Radio Networks. Compressive sensing has been proposed as an alternative solution to scan the spectrum by reducing the sensing time and the sampling rate.

Mohsen Riahi Manesh, Adnan Quadri, Sriram Subramaniam, and Naima Kaabouch[3] An Optimized SNR Estimation Technique Using Particle Swarm Optimization Algorithm. SNR estimation methods can be classified into two categories: data-aided and non-data aided approaches. Data aided estimation techniques require the information about the properties of the transmitted data sequences (pilot). These techniques are normally able to provide an accurate estimate of SNR. However, in time varying channels, they need to employ larger pilot information to enable the receiver to track the channel variations.

Fatima Salahdine and Hassan El Ghazi[4] explained A real time spectrum scanning technique based on compressive sensing for cognitive radio network. Cognitive radio has been proposed to overcome the spectrum scarcity issue and enable dynamic spectrum utilization. It allows unlicensed users, Secondary Users (SUs), to use the free spectrum when the owner, Primary User (PU), is absent during a period of time.

Fatima Salahdina, Naima Kaabouch and Hassan El Ghazi[5] Bayesian Compressive Sensing with Circulate Matrix for Spectrum Sensing in Cognitive Radio Network. Compressive sensing has been proposed as a low cost solution to speed up the scanning process and reduce the computational complexity. It involves three main processes: sparse representation, encoding, and decoding. During the first process, the signal, S, is projected in a sparse basis. During the second process, S is multiplied by a sampling matrix, of MxN elements to extract M samples from N of the signal, S, where M << N. In the last process, the signal is reconstructed from the few M measurements.

Serhan Yarkan [6] explained A Generic Measurement Setup for Implementation and Performance Evaluation of Spectrum Sensing Techniques: Indoor Environments. DEMAND for wireless communications along with related services, applications, and new technologies is expected to be increasing in the near future. Such aggressive growth causes many wireless technologies to coexist with recently emerging ones. Technologies operating on Industrial, Scientific, and Medical (ISM) band exemplify this anticipation very well. Bluetooth-enabled devices, Wi-Fi (IEEE 802.11b/g/n) technologies, ZigBee-based (IEEE 802.15.4) systems, cordless telephones, home microwave ovens, and baby-monitoring devices all operate on ISM band (at 2.4GHz). Because ISM band is unlicensed (but regulated) and presents amiable wireless propagation characteristics, it is easy to foresee that the number of technologies operating in it will increase. Although such a coexistence in the Radio Frequency (RF) spectrum as in ISM band implies a scarcity, measurements show that the RF spectrum is underutilized in general [6].

Hongjian sun[7] explained Wideband spectrum sensing for cognitive radio networks. Cognitive radio has emerged as one of the most promising candidate solutions to improve Spectrum utilization in next generation cellular networks [7]. A crucial requirement for future cognitive radio networks is wideband spectrum sensing: secondary users reliably detect spectral opportunities across a wide frequency range. In this article, various wideband Spectrum sensing Algorithms are presented, together with a discussion of the pros and cons of each algorithm and the challenging issues. Special attention is paid to the use of sub-Nyquist techniques, including compressive sensing and multichannel sub- Nyquist sampling techniques.

Zhi Tian, Yohannes Tafesse, Brian M. Sadler [8] explained Cyclic Feature DetectionWith Sub-Nyquist Sampling for Wideband Spectrum Sensing. Cognitive radio networks, efficient and robust spectrum sensing is a crucial enabling step for dynamic spectrum access. Cognitive radios need to not only rapidly identify spectrum opportunities over very wide bandwidth, but also make reliable decisions in noise-uncertain environments. Cyclic spectrum sensing techniques work well under noise uncertainty, but require high-rate sampling which is very costly in the wideband regime. This paper develops robust and compressive wideband spectrum sensing techniques by exploiting the unique sparsity property of the two-dimensional cyclic spectra of communications signals. To do so, a new compressed sensing framework is proposed for extracting useful second-order statistics of wideband random signals from digital samples taken at sub-Nyquist rates. The time-varying cross-correlation functions of these compressive samples are formulated to reveal the cyclic spectrum, which is then used to simultaneously detect multiple signal sources over the entire wide band.

Shree Krishna Sharma, Eva Lagunas, Symeon Chatzinotas and Bjorn Ottersten[9] explained Application of Compressive Sensing in Cognitive Radio Communications. This survey paper focuses on the application of CS to CR communications. Spectrum scarcity is one of the most important challenges faced by today's wireless operators to provide high data rate services to a large number of users. In this context, CR communication has been considered as a potential candidate to address the spectrum scarcity problem in the future generation of wireless communications, i.e., 5G. The concept of CR was firstly proposed by J. Mitola in the late 1990's [9] and after its conception, several researchers and industrial/academic/regulatory bodies have been working towards the implementation of this technology. It has a wide range of application areas ranging from Television Whitespaces (TVWSs) [9] to satellite communications [9].

III. METHODOLOGY

ACBSS ALGORITHM

STEP 1: Initialize the head node's location H and set the convergence threshold values C.
STEP 2: Alternately update the Membership Grade and H until MAX then output the clustering result and H.
STEP 3: Use the optimal expression E to choose among the compressive measurement matrix of nodes and output the optimal result.
STEP 4: Solve the optimization problem Q.
STEP 5: Extract from Q ans and make summation about it, and then output
STEP 6: Calculate the statistical value and then make decisions about all channels' occupation.

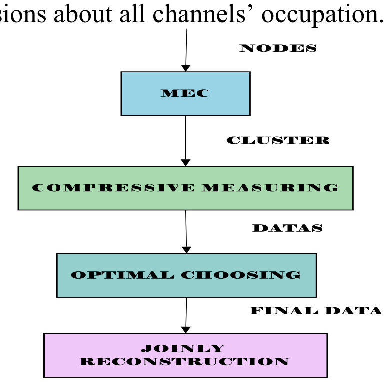

Fig 3.1 Execution Process of ACBSS Algorithm

EXECUTION PROCESS

For ACBSS, firstly, it uses the Maximum Entropy Clustering (MEC) to divide all the sensing nodes into several clusters. Secondly, each node within one cluster locally acquires the compressive measurement and sends them to head node. Thirdly, each head node chooses the optimal measurement data from all received data, and then sends the chosen data to the fusion center. The rule is to select the measurement data of biggest absolute value to keep the spectrum occupancy situation maximally. Finally, fusion center uses the joint reconstruction scheme to reconstruct wide-band spectrum. The execution process is depicted in Figure 3.1.

Advantages

- The data processing pressure can be reduced
- The signal sensed by near CR users are of much greater relevance which can ensure jointly reconstruct accurately,
- The dynamic change of head nodes during the sensing stage will be conducive to the loading balance and lifetime extension of CRN.

ICS AND JCS

In order to verify the validity of ACBSS, we compare it with ICS and JCS, so in this section we will introduce the ICS and JCS.

For ICS, the nodes use the sensed compressive measurement data to reconstruct the wide-band spectrum independently, and then it makes decisions about the channels' occupation situations by spectrum analysis and sends the result to the fusion center. Lastly, according to some decision rule, the fusion centre does the final decisions to finish the fusion of all received decisions.

In this algorithm, what the node sends is not compressive quantity data but simple spectrum assessment so the energy consumption is low. In fusion centre the calculation for assessment fusion is much lower than that of the joint reconstruction, so the computing time is shorter. But for the spectrum sensing is done by single CR user, the false-alarm prospect is high and fault-tolerance ability is poor.

For JCS, the nodes first send the sensed compressive quantity data to the fusion centre directly, then the fusion center jointly reconstructs the wide-band spectrum, then the spectrum decisions are made by thresholding the recovered spectrum. In this algorithm, the fusion centre needs to know the quantity from all the CR users, which will cause the network congestion. Hence, JCS are not suitable for large scale CRN.

IV. Results and Discussion

In this Result & discussion, it compares the performance of the proposed ACBSS with that of ICS and JCS. We consider the wide-band spectrum of interest ranges from 0 to 60 MHz, containing 60 channels of 1MHz and encode it as ch1 ch2 ch3 ch4 = { 1 2 60 , ,..., } , so Q = 60 . In one sensing circle, there are three major users communicating with the centre frequency of 9.5 MHz, 29.5 MHz and 49.5 MHz respectively, and their signal bandwidth is 1 MHz. Simultaneously, there are 6 CR users correspond with three kind of centre frequency: 19.5 MHz, 39.5 MHz and 54.5 MHz, and their signal bandwidth are 1 MHz as well. In the other words, there are only 6 out of 60 channels being in use. The number of nodes are I = 12. The communication uses BPSK modulation signal, and the number of BPSK symbols is 2. The Nyquist sampling frequency is Sf = 128 MHZ, and the Nyquist sampling number is N =256. The compressive sampling number is $M = \alpha N$. The compression ratio is $1-\alpha$. The random measurement matrix Φi is Gaussian distributed. The uncovered basis Ψ is Fourier transformation matrix with the order N. The decision threshold of unusual factor is an experience value which is set by arithmetical averaging of 100 experiment results. The noise is white Gaussian Noise (GWGN).

4.1 Detection Performance versus SNR

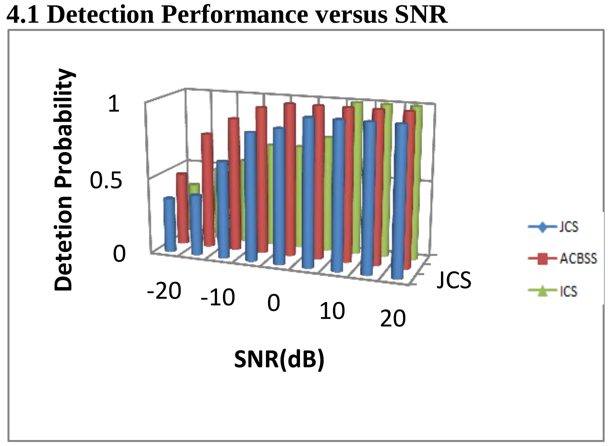

Fig 4.1 (a) Detection Performance versus SNR

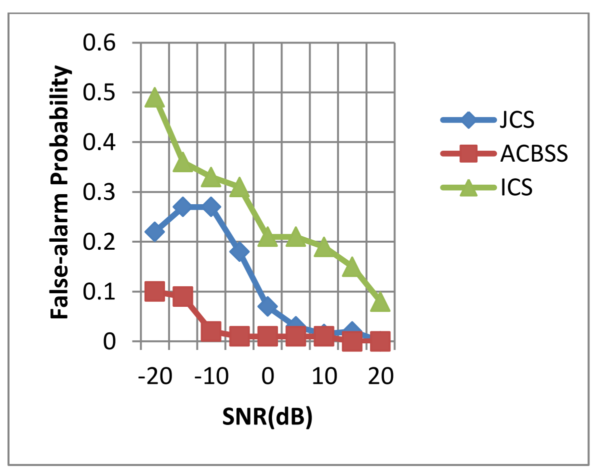

Fig 4.1 (a) False Alarm Performance versus SNR

The set of compression rate as1 0.5 − = α , that is the sampling number M is 128, and consider the SNR of interest in the range of [-20dB, 20dB], with an interval of 5dB. Times of test in each SNR, and the statistical average value of detection probability and false-alarm probability for these three algorithms are shown in Figure 4.1.

4.2 Detection Performance versus Compression Rate

In this set the SNR as 20dB, and consider the compression rate of interest as 0.5, 0.75, 0.875, 0.9375, and 0.96875 respectively, times of test in each compressive ration, and the statistical average value of detection probability and false-alarm probability for these three algorithms are shown in Figure 4.2.

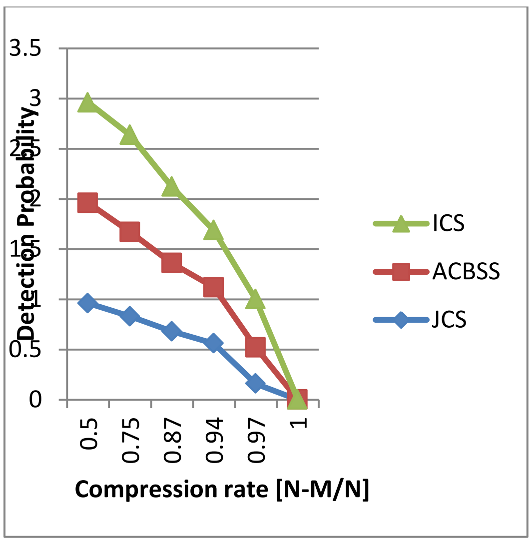

Fig 4.2 (a) Detection Performance versus Compression Rate

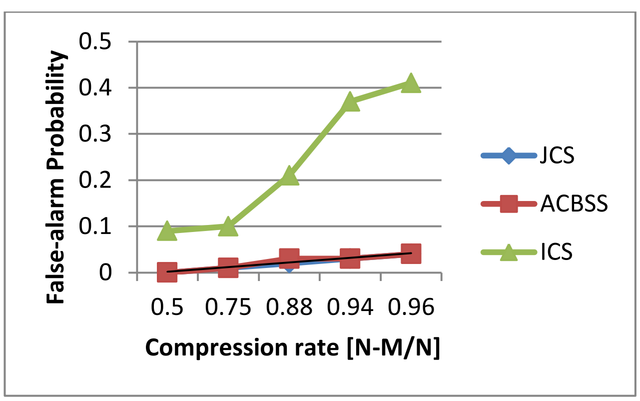

Fig 4.2 (b) False-alarm Versus Compression Rate

4.3 Algorithm Execution Time Comparisons

In this set the compression rate is 0.5, and consider the SNR of interest in the range of [-20dB, 20dB], with an interval of 5dB, the execution time of these three algorithms are show in Figure 4.3 (a).

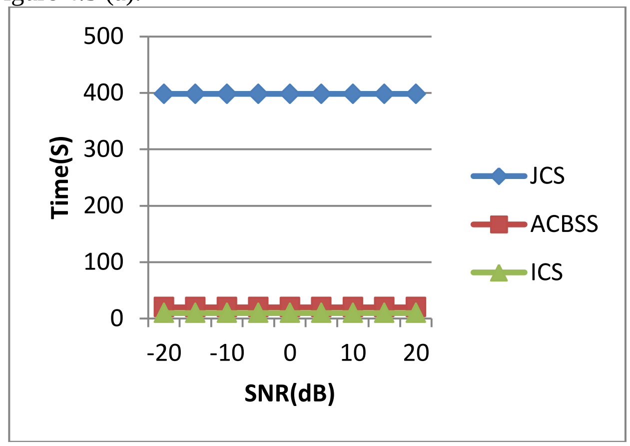

Fig 4.3 Algorithm Execution Time

IV. Conclusion and Future Scope

Cognitive radio network is a system able to learn from the environment and adjust its transmission parameters. With their awareness of the radio environment, SUs perform spectrum sensing to identify free channels in order to efficiency exploit these channels. As the sensing process requires a considerable amount of time, compressive sensing has been introduced as a low-cost solution to speed up the channels scanning process and improve the detection rate.

A novel algorithm called ACBSS is proposed to do wide-band spectrum sensing in CRN. Solution based on hierarchical data-fusion of clustering and jointly compressive reconstruction of CS to detect the wide-band spectrum holes are derived and tested. The ACBSS algorithm offers evident advantages over the conventional use of narrowband spectrum sensing technologies, in terms of both reliability and real-time in detecting dynamic spectrum of CRN. And a comparison between ACBSS and the other two wide-band spectrum sensing algorithms called ICS and JCS is given. From the simulation results, it is shown that ACBSS has much lower false-alarm probability than that of ICS, and also need less execution time than that of JCS.

For future directions, there are several interesting research directions related to the compressive sensing. For instance, advanced ADCs can be considered for future works. They are highly needed to support the high sampling rate presented in the cognitive radio networks with the high increase of wireless network services and mobile users. Moreover, hardware implementation is yet another future direction in terms of designing fast and inexpensive ADCs devises for signal sampling and integrating the compressive sensing algorithms on these devises. In addition, implementing in hardware the compressive sensing techniques is another direction to overcome the problems of synchronization, calibration, and uncertainty in measurements. In addition, developing new and efficient signal acquisition models based compressive sensing is an interesting direction of interest to cover all the signal models presented in real radio environments. Also, handling the uncertainty and the imperfections of real radio networks by designing practical compressive sensing techniques is an open door for researchers in this field.

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