WIDEBAND SPECTRUM SENSING USING SUBNYQUIST TECHNIQUES FOR COGNITIVE RADIO NETWORKS

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Abstract- **A wideband spectrum has several narrowbands within it. These narrow bands are basically used for wireless communications. Some of the narrowbands may be occupied and some may not be occupied.The users who have already occupied a band are called primary users.The users waiting to occupy an empty band are called secondary users. In this paper, we are proposing a technique to show bands which are already occupied and the bands which are not occupied-the bands available for the secondary users.**

Keywords: Wideband Spectrum, Primary User, Probability of Detection,Probability of False Alarm, SNR.

1. INTRODUCTION

The fast growing use of wireless devices and services during past years has imposed increasing stress on the available limited spectrum resources. The existing spectrum policy, based on allocating a fixed frequency band to individual wireless devices, has proven to be very ineffective, causing spectral congestion in some bands and underutilization of the available spectrum in others. Cognitive radio (CR) which allows secondary users (SUs) to access unused radio spectrum (white space) is a promising solution to this underutilization of spectrum problem.The cognitive radio technique utilises spectrum sensing that involves monitoring the spectrum usage and detecting whether the narrow bands are occupied by the primary users(PUs) or they are left unoccupied.

Recently, wideband spectrum sensing is receiving considerable interest where SUs perform spectrum sensing in a wide range of frequency band (a wide frequency band is composed of several narrow bands) in search of more access chances.. However, the implementation of wideband spectrum sensing at the SU has some difficulties, e.g., the need for a complex front end, high sampling rate, and fast digital signal processing. Meanwhile, compressed sensing is a new field that offers powerful tools for recovering sparse signals from a few linear measurements, significantly reducing the sampling rate as when compared to the conventional Nyquist sampling framework.

This has motivated the usage of compressed sensing techniques to solve the wideband spectrum sensing problem. Sub-Nyquist spectrum sensing (SNSS) based on compressed sampling has been considered in this paper. The wideband spectrum sensing approach uses sparsity recovery techniques that is derived from compressed sensing. In this paper we propose a compressive sensing algorithm based on a validation approach.

A practical compressed sampling framework based on a modulated wideband converter (MWC) is proposed in this paper.The MWC framework describes the input signals as a union of shift-invariant subspaces.It processes the input signal in multiple channels simultaneously. In each channel, the input signal is multiplied by a periodic ± 1 sequence, then passed through a low pass filter. After that, the filtered signal is passed through an Analog to Digital Converter for sampling.

By the means of frame construction and solving a multiple measurement vectors problem, the signal support can be estimated directly without a full signal recovery. The MWC-based SNSS has the advantages of being able to adaptive to different types of signals, fast signal support recovery and low computational load. Most existing SNSS methods take into consideration that PUs exist in their corresponding frequency bands.However there are cases where the band is originally empty but there exists some noise (called wwhite noise).This leads to a phenomenon that is called “false alarm“

In such cases, a direct application of the aforementioned SNSS methods is inappropriate, due to the absence of a sparse signal, and would lead to several problems: (1) high false alarm rate—SNSS methods are likely to provide incorrect spectrum sensing results, causing a high false alarm probability and making the vacant spectrum bands to be underutilized and a waste of computational cost and energy. In this paper, we propose a pre-decision algorithm, referred to as the Pairwise Channel Energy Ratio (PCER) detector, which is integrated with the MWC framework for SNSS. The PCER algorithm is to determine the presence/absence of PU signals prior to signal support recovery. Only if the PU signals are detected in the concerned frequency band will the function of signal support recovery be activated to estimate the location of the occupied bands; otherwise, signal support recovery is bypassed. It is necessary to point out that the proposed predecision algorithm can also be extended to other compressed sampling framework besides the MWC.

We model this predecision problem as a binary hypothesis testing and construct a test statistic with compressed samples to detect the PU signals. By exploiting the statistical properties of the test statistic, we derive the decision threshold and the probability of detection in closed form, following the Neyman-Pearson criterion. Theoretical derivation and numerical simulation show that our PCER detector is robust to noise uncertainty.

Furthermore, it does not require any prior knowledge of the PU signal. Some spectrum sensing techniques has been proposed to overcome noise uncertainty. The algorithms proposed in, employ the covariance matrix of the signal samples and eigenvalue decomposition is required.
The cyclostationarity-based spectrum sensing in needs to know the cyclic frequency of the signal as a prior knowledge; otherwise exhaustive search has to be carried out. In recent work of Sun [40], particle filtering technology is used to design a spectrum sensing technique to overcome noise uncertainty. However, the above-mentioned spectrum sensing algorithms are designed in the conventional Nyquist sampling framework and are not suitable for the MWC-based SNSS framework in this paper. With the PECR pre-decision algorithm, the presence/absence of PU signals is determined before signal support recovery, which avoids unnecessary computational overhead and high false alarm probability caused by incorrect support recovery. As a result, the functions of compressed sampling, signal detection and signal recovery are integrated, making the SNSS more useful for wideband spectrum sensing.

2. APPROACH

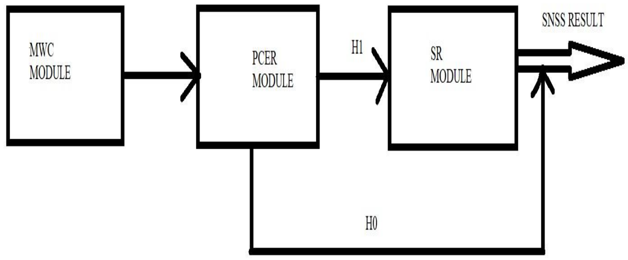

Figure: Working Model

The above Figure depicts the process that we use for sensing.
MWC Module- Modulated Wideband Converter.
PCER Module-Pairwise Channel Energy Ratio Detector.
SR Module- Support Recovery Module.

3. TYPES OF SPECTRAL SENSING\

Interweave Network Model

In the interweave network model,the secondary users are not allowed to occupy the energy bands already occupied by the licensed Primary users.Methods are being developed that will allow the secondary users to opurtunitiscally access an energy band that is not occupied by the Primary User. In these networks, the Cognitive Radio has to identify the energy bands that are unoccupied at that particular instant at a particular geographic location.So the Cognitive Radio will primarily decide whether that particular energy band is occupied or unoccupied.So spectrum sensing is the basic underlying model for the Interweave Network Model.The spectral sensing will also be able to detect the spectral holes, which means that those particular bands are empty.The spectral sensing senses the bands and after sensing it leaves the bands that are occupied by the primary licensed usersThe problem of wideband spectral sensing is that in that case the entire wideband needs to be sensed, and in case of narrowband sensing only a particular narrowband needs to be sensed.

The Interweave Network Model is studied as per the diagram given below

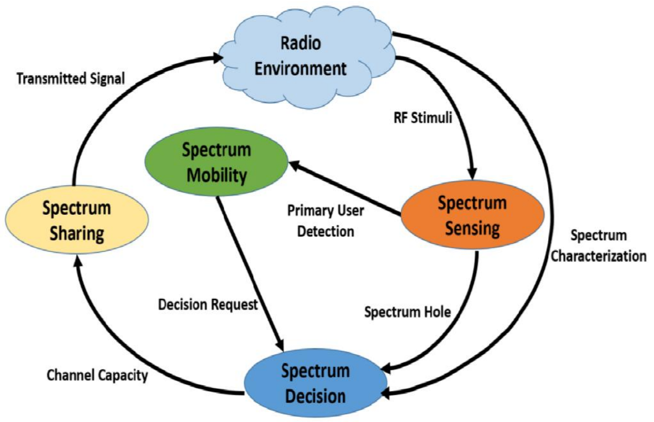

Figure : Interleave Network Model

This shows the Interweave network Model.

The CR analyses the given spectrum. It can detect the spectral holes(unoccupied energy bands).This analysis about spectrum holes helps in the analysis stage of spectrum characterization.
In the spectrum analysis the characteristics of the spectral holes that were detected using spectral analysis are determined.The primatry user information, the bandwidth and the operating frequency of each of the detected spectral hole is analysed .Other parameters such as path loss, link layer delay, interference of the particular spectrum is detected.
Spectrum decision: A cognitive radio is used to determine the data rate, the transmission mode, and the bandwidth of the transmission.Then the user requirements are analysed and after a detailed study of the spectrum characteristics a particular band is chosen.Then the users need to be assigned to that particular unoccupied spectral band.
Because of dynamically changing topologies and other conditions,spectral selection should be done keeping in mind the routing protocols
Spectrum mobility can be defined as the ability of a CR to vacate the channel once a licensed user is detected.If a licensed primary user wants to use the channel, then the secondary user needs to be moved from that channel into another vacant channel.
The most important part of an Interweave Cognitive Radio Network is spectrum sensing.By spectrum sensing we can detect the channel occupancy and based on this the secondary users can opurtunistically use that channel.Thus spectral sensing can provide us a basic overview about spectral usage. It helps to gather information about the primary users temporally and geographically.

UNDERLAY MODEL

It is also termed as Spectral Sharing Network. In this model, the Primary Users and the Secondary Users are allowed to exist together.But, the Primary users are given a higher priority to use the spectrum over the secondary users.The sharing spectrum must be maintained under the primary users interference constraint.

OVERLAY MODEL

In the Overlay network model, the Primary User and the Secondary user can transmit concurrently. The assumption made in this model is that the primary message is known by the secondary transmitter in advance.

4. SPECTRUM SENSING

4.1 INPUT SIGNAL

We are taking a particular time interval and then generating a sinusoidal signal based on that particular time interval.Then we are adding some AWGN (Additive White Gaussian Noise) and plotting the signal against time.

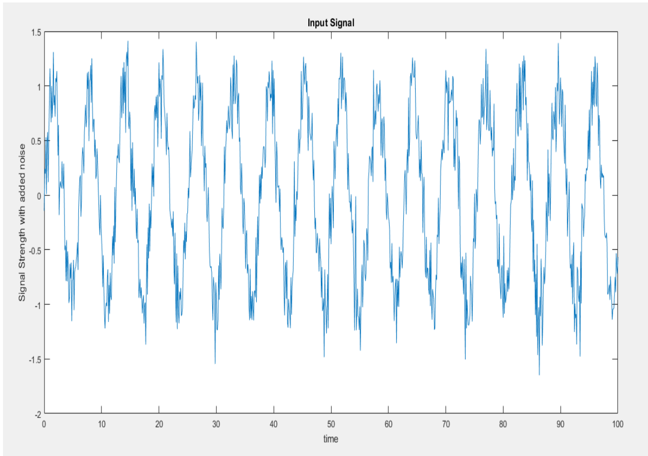

Figure: Input signal with added noise

4.2 : OPTIMIZATION

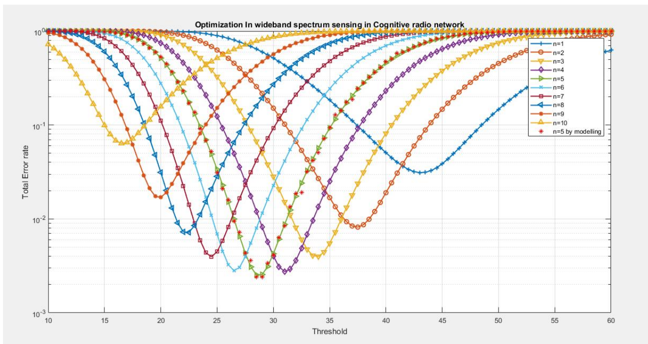

Figure : Total error rate vs threshold curve

Local spectrum sensing technique is Energy Detection and the SNR=10dB and n=10 samples are used. The figure shown is the threshold vs. total error rate using Energy Detection technique.The figure shows the total error probability versus threshold for different number of n=1, 2, 3, 4 ….10. We observe there are difference in the performance through using n=1 to 10.
Actually energy detection sets a threshold according to the noise and comparing with input of the energy detection data stream.. The ED mainly do the presence of a signal comparing the received energy with a known threshold derives the noise of signal.In this figure, we get the optimum value of 'n' out of 'K' CRs. We vary threshold value from 10 to 40.
n=5 by modelling signifies that for that particular band there is an error every 5 seconds.

4.3 ROC CURVE FOR PROBABILITY OF DETECTION VS PROBABILITY OF FALSE ALARM

The probability of detection is defined as the probability that the Primary User(PU) if present in the wideband signal is detected correctly.
Let us denote it as Pd
Then the probability of missed detection may be defined as the condition when the licensed user present in the wideband is not detected properly. Let us denote it as Pmd
Therefore, Pmd=1-pd
Probability of False Alarm can be defined as the probability that the primary user is detected to be present when it is actually not present in the wideband spectrum.
Let us denote Probability of False Alarm as Pf

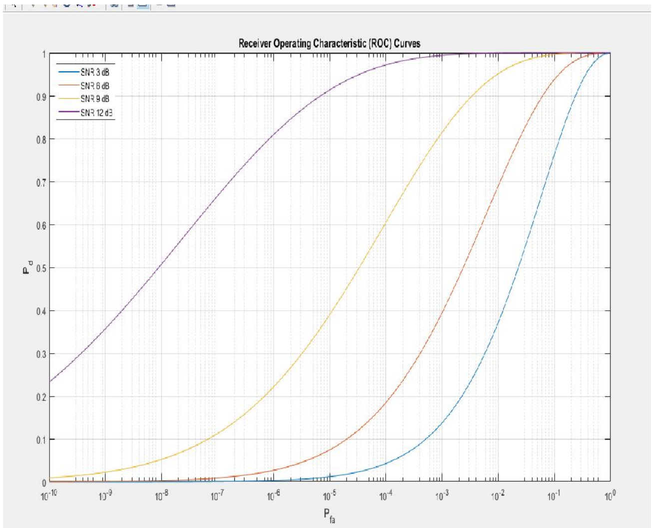

Figure showing Pd vs Pf for fixed SNR

SNR can be defined as the signal to noise ratio in a particular signal. Each signal is accompanied by some noise, Mainly AWGN(Additive White Gaussian Noise)

$$\text{SNR} = \frac{\text{POWER OF SIGNAL}}{\text{POWER OF NOISE IN THE SIGNAL}}$$

Here we have fixed certain SNR values and plotted Pd vs Pf for those constant SNR values.

SNR value is taken in dB

a=sqrt(2*SNR)
b=sqrt(t)

Marcumq function is used to find the Probability of detection Pd
Pd = marcumq(a,b,u)

The gammainc function is used to find the Probability of False Alarm Pf
Pf = gammainc((t/2),u,'upper')

This function can also be used to find Pd and P fa
[Pd,Pfa] = rocsnr(SNRdB,'SignalType','NonfluctuatingCoherent')

SI no.	SNR	Probability of detection	Probability of False Alarm	False Alarm Rate	Probability of missed detection
1	3 dB	0.75	10^(-1)	1 false Alarm in every 10 samples.	0.25
2	6 dB	0.70	10^(-2)	1 false Alarm in 100 samples.	0.30
3	9 dB	0.23	10^(-6)	1 false alarm every 1000000 samples.	0.77
4	12 dB	0.24	10^(-10)	1 false alarm every 10000000000 samples.	0.76

Figure: Table showing the analysis of the graph

In this way we can find out the Pd vs Pf for fixed SNR.

4.4 ROC CURVE FOR SNR vs PROBABILITY OF DETECTION

In this case the Probability of False Alarm Pf is taken to be constant and it is Pf=0.20

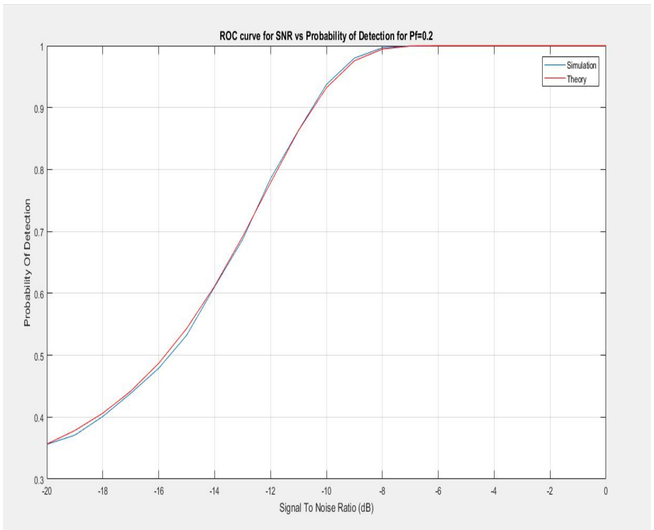

Figure showing SNR vs Pd for fixed Pf = 0.20

The graph is also plotted for an theoretical value of Pd which is determined as:Pd_the(i) = qfunc (((Threshold - (snr(i) + 1)).*sqrt(L))./(sqrt(2).*(snr(i) + 1)))

Where L=1000
And snr = 10^ (SNR(db)/10)
And pd_the(i)= Probability of Detection for a theoretical value
With help of these equations the graph is plotted and the following table is derived:

Probability of false alarm= 0.20

SI no.	SNR in Decibels	Probability of Detection Pd	Probability of Missed Detection
1	-4	1	0
2	-8	0.99	0.01
3	-12	0.78	0.22
4	-16	0.48	0.52

Figure: Table showing the analysis of the graph

In this way we can calculate the probability of detection Pd , the probability of false alarm Pf, probability of missed detection Pm=1-Pd. With all these, we can compute if the given wideband signal is occupied by the Primary User.

5. CONCLUSION

Based on a MWC framework for SNSS, a pre-decision detector known as Pairwise Channel Energy Ratio Detector is used to determine the presence or the absence of PU signals prior to signal support recovery. The PCER detector utilizes the ratio of pairwise energy from different channels to detect the presence or absence of Primary Users. The decision threshold and the probability of detection under the Neyman Pearson criterion are provided, which show that the decision threshold is unrelated to the noise power.The simulations are performed and the results are plotted correlating the Pd,Pf and SNR.

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