Performance Analysis of Cyclostationary Spectrum Sensing Over Different Fading Channels

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ABSTRACT
In research area of wireless communication, cognitive radio gets more endearment in recent times. The main motive behind the use of cognitive radio is to sense the available spectrum, which is very limited, for the users who wish to use it for the transmission purpose. The users can be primary or secondary, based on, whether they are licensed or un-licensed. Different goals of cognitive radio include spectrum sensing, spectrum sharing, spectrum management, and spectrum mobility. Spectrum sensing plays vital role in the cognitive radio system since it is used to detect signal presence on the air. This paper signifies the role of Cyclostationary Spectrum Sensing technique to define a device capable of detecting OFDM signals in a noisy environment. The work has been done for the applications employed in high frequency, such as, Wi-Fi and WiMAX.

Keywords
Cognitive radio, spectrum sensing, Rayleigh fading, Rician fading, FFT accumulation

1. INTRODUCTION
The key idea behind CR is to develop smarter radios which are aware of, and can adapt to, their environment. There are two main subsystems in a cognitive radio; a cognitive unit that creates decisions built on various inputs and an elastic SDR unit whose functioning software delivers a range of conceivable operating modes. A cognitive radio is frequently referred to as a cognitive radio scheme or a cognitive network. Detecting the presence of signals in the frequency spectrum is called spectrum sensing. An empty spot in frequency will be a candidate to allocate a new communication link. Under the definition of a primary and secondary user, this last one has to be able to detect or may be informed of an incoming primary user and move on the fly to another vacant spot. This action requires some level of certainty on the process to find on empty spot as well as fast allocation of this. The challenge of the spectrum sensing is to perform the detection reliably and within a required time response. Of course some flexibility is also needed to scan the spectrum and digital processing takes place regardless of the used detection method [8]. The processing is usually performed out of band since transmission or reception cannot be interrupted.

2. OFDM IN COGNITIVE RADIO SYSTEMS
OFDM is a modulation scheme that uses multiple carriers to transmit data. Each of these carriers could be modulated using any variation from BPSK to N-QAM. Digital domain implies flexibility and it is known that cognitive radios lay over software defined radios, which in turn demands great grades of programmability. OFDM definition makes it easier to be adapted to different bands and different performance requirements by changing parameters on the implementation. These are some of the reasons why OFDM is the technology that best fit for cognitive radio systems.A cognitive radio system requires spectrum sensing capabilities that are usually implemented by means of the FFT. OFDM already has an FFT machine that in many cases could be shared for spectrum sensing algorithms. Definition of OFDM carriers takes place in the digital domain before the FFT. This allows the manipulation of individual carriers as a strategy to reduce the current bandwidth in case needed. This is where adaptability of OFDM resides, making possible to modify power on individual carriers, suppressing any of them, modulation order and even spectrum shaping [5].

3. FUNCTIONS OF COGNITIVE RADIO
There are different functions of the cognitive radio which are used in the spread spectrum. The functions are as follows:-

3.1 Spectrum Sensing
In the spectrum sensing the unlicensed or secondary users continuously monitors the activities [13] of the primary or licensed user band. If there having spectral holes then those spectral holes are used by the secondary user. The secondary users can use those spectrum holes without primary user interference.

3.2 Spectrum Sharing
When the licensed band is not used by the primary users so the property of providing those spectrum holes to the secondary users in the cognitive radio is called spectrum sharing.

3.3 Spectrum Management
The primary (licensed) user use the licensed band, but actually the whole licensed spectrum band is not used by the primary user. So there are spectrum holes or white spaces in the spectrum band. The property of founding and select the white spaces by the cognitive radio is called spectrum management.

3.4 Spectrum Mobility
Cognitive radio leaves channel when primary user comes. This property of cognitive radio is called as the spectrum mobility.

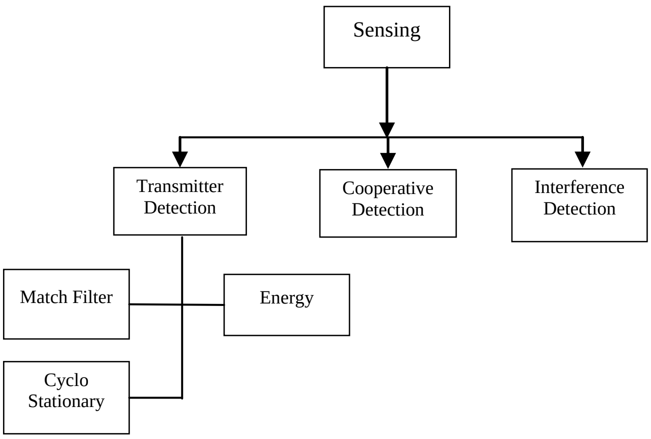

Fig.1: Functions of Cognitive Radio

4. SPECTRUM SENSING TECHNIQUES

There are mainly three methods to determine signal presence, all of them with some trade-off. They are energy detection, matched filtering and cyclostationary detection. It is important to note that the evaluation of these methods to use for spectrum sensing is heavily biased on the CR application requirements.

4.1 Energy Detection

Energy detection is the most common way of spectrum sensing due to the lower computation required and no need of any knowledge about the possible signal. The energy detected is compared with a threshold established over the noise floor. The detection could be done in time or frequency domain. Time domain implementation consists of averaging the square of the signal. Energy detector is not able to recognize between noise, signal or interference and these reasons rule out this method for many CR applications although it could be used to support more complex strategies. Although this is the less expensive and more generic method, it performs poor at low SNR levels and could lead to false detection.

4.2 Matched Filter

Matched filter approach gives the best SNR since it matches a specific signal. The approach requires demodulation of the signal which means having in advance deep knowledge of primary user signal.

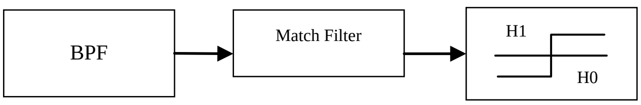

Fig. 2: Block diagram of Matched Filter

Coherent detection is required and it implies time and frequency synchronization, knowledge of modulation scheme, bandwidth, frame format, etc. It could be impractical to implement a CR which could hold capabilities for all signal types. Although this information could be saved in the spectrum sensing device as a catalog of possible signals, it would come costly in terms of processing and memory.

4.3 Cyclostationary Feature Detection

In general any modulated signal include some periodicity by definition and some others added for synchronization or signaling purposes such as preambles, pilots, cyclic prefix, etc. It means that autocorrelation of the signal exhibit an observable grade of periodicity. Instead of power spectral density, cyclic correlation function is used, and the algorithms are able to differentiate noise from signals, since noise is not correlated. The Cyclic Spectral Density (CSD) is formed after the spectrum and will output peaks when cyclic frequencies are present.

These algorithms are based on a statistic approach which means an average has to be performed and it requires time to give an output. Also the process involves more than one FFT calculation and correlation making it computationally pricy compared with some other methods. Cyclostationary detection deteriorate with the sampling frequency offset the reason is that the spectral correlation function is estimated based on the correlation of the FFT coefficients, that due to any variable offset, could cancel each other instead of adding up [9].

5. LITERATURE SURVEY

In 2004, Danijela Cabricetal described the Implementation Issues in Spectrum Sensing for Cognitive Radios. They described how to improve radio sensitivity of the sensing function through processing gain they investigated three digital signal processing techniques: matched filtering, energy detection, and cyclostationary feature detection. They shows through analysis is that cyclostationary feature detection has advantages due to its ability to differentiate modulated signals, interference and noise in low signal to noise ratios [2].

In 2006, Zhi Tian.et al explained the Wavelet Approach to Wideband Spectrum Sensing for Cognitive Radios. Wavelet transform is employed to detect and estimate the local spectral irregular structure, which carries important information on the frequency locations and power spectral densities of the sub bands. The wavelet approach offers evident advantages over the conventional use of multiple narrowband BPFs, in terms of both implementation costs and flexibility in adapting to dynamic PSD structures [4].

In 2008, Zhi Quan et al proposed strategy is efficient in improving the dynamic spectrum utilization and reducing interference to the primary users. The spectrum sensing problem is formulated as a class of optimization problems in interference limited cognitive radio networks. They proposed that spectrum sensing schemes can considerably improve the system performance [6].

In 2010, Mort Naraghi-Pour and Takeshi Ikuma evaluated the performance of the algorithm for both additive white Gaussian noise (AWGN) and Rayleigh-fading channels and study its sensitivity to carrier frequency offset. Simulation results are presented to verify the accuracy of the approximation assumptions in our analysis. The performance of the proposed algorithm is also compared with those from the energy detector, the covariance detector, and the cyclic-autocorrelation detector. They show results that algorithm outperforms the covariance detector and the cyclic autocorrelation detector [10].

In 2011, Mahdi Orooji et al proposed a blind detection method, which assumes no prior knowledge of the signaling scheme used by the PU, the noise power, or the channel path coefficients. The cross correlation among the received signals is a result of the correlation among the channel path coefficients from the primary user (PU) transmitter to different antenna elements of the secondary receiver [12].

In 2014, Won Mee Jang et al proposed a blind spectrum sensing method using signal cyclostationary. Often, signal characteristics of the primary user (PU), such as carrier frequency, data rate, modulation and coding may not be known to cognitive users. This uncertainty introduced difficulties in searching for spectrum holes in cognitive radios. At a low signal-to-noise ratio, it had been understood that monitoring the presence of the PU's signal was hardly possible without knowing its cycle frequencies. The proposed sensing method makes it possible to detect the PU's signal without the relevant information of the signal attributes [13].

6. PROPOSED WORK

We proposed a new method to design a Cognitive Radio technology which is under development and research efforts are focused on improvement in modification of existing wireless networks, signal awareness and spectrum sensing techniques. Cognitive Radio techniques have already been applied to wireless standards like 802.22 and 802.11k. The optimum use of spectrum is an open area of research in the field of Cognitive Radios and efforts are going on for the optimum use of unused spectrum in spectrum sensing.

Foe very high speed applications, a spectrum sensing technique should require less computation time and should have less complexity. Also the performance of any spectrum sensing technique depends upon the type of application (data, voice, etc.) for which it is applied. So the developed or modified spectrum sensing technique must be evaluated for a specific application.

Implementation Steps:

- Cyclic Autocorrelation Function

Initially we define the autocorrelation function as cognitive sensing node. This idea originates from the instance of having a pulse modulation of single magnitude like $+/-1$ that after square hide any phantom line but the dc one. Then the transformation $y(t) = x(t).x(t-\tau)$ promises spectral lines for $m.f_0$ where m is an numeral. Defining $\alpha = mf_0$ we declare

$$M_y^\alpha = \langle y(t)e^{-j2\pi\alpha t} \rangle$$

$$= \langle x(t).x(t-\tau)e^{-j2\pi\alpha t} \rangle \neq 0$$

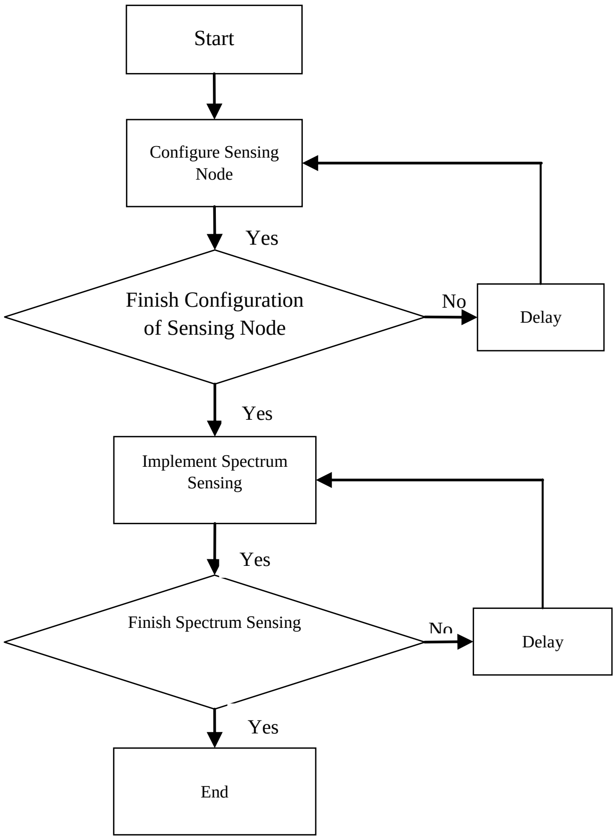

Fig. 3: Cognitive Radio in a spectrum sensing

- The spectral-correlation function

The Spectral Correlation purpose definition comes from the basic idea of discovery the middling power in the frequency domain as $R_x(0) = |\, x(t)|^2$. If the correlation in the frequency domain among the shifted forms $v(t)$ and $u(t)$ has to be found then the appearance becomes

$$R_x^0(\tau) = \langle u(t)v*(t) \rangle$$
$$= \langle |x(t)|^2 e^{-j2\pi\alpha t} \rangle$$

The Power Spectral Density PSD could be imagined as passing the signal $x(t)$ by a narrowband pass filter and scheming the average power, where the filter is simulated all over the band. In the limit where the bandwidths (B) of the filter methods zero [1]:

$$S_x(f) = \lim_{B\to 0} \frac{1}{B} \langle |h_B(t) \otimes x(t)|^2 \rangle^n$$

$S(f) = \int_{-\propto}^{\propto} R_x(\tau)\, e^{-j2\pi f t}\, d\tau$ Fourier Transform of autocorrelation

$S_x^\alpha(f) = \int_{-\propto}^{\propto} R_x^\alpha(\tau)\, e^{-j2\pi f t}\, d\tau$ Fourier Transform of cyclic autocorrelation

- Cyclic Spectrum Estimation

The Strip Spectral Correlation Analyzer (SSCA) and FFT accumulation (FAM) are both under the time-smoothing organization. The SCD function of $x[n]$ is definite as $S_x(f) = \sum_{k=\propto}^{-\propto} R_x^\alpha(k)\, e^{-j2\pi f k}$ by means of the discrete Fourier transform, where

$$R_x^\alpha(k) = \lim_{n\to\infty} \frac{1}{2N+1} \sum_{n=-N}^{N} [x(n+k)e^{-j2\pi\alpha(n+k)}]\,[x(n)e^{-j2\pi\alpha n}]$$

This way:

$$S\_x\^\alpha\,(n,f)\_\Delta t = 1/T\,\langle x\_T\,(n,f+\alpha/2)\; x\_T\^*\,(n,f-\alpha/2)\rangle$$

Where $x_T\left(n, f \pm \frac{\alpha}{2}\right)$ are the multifaceted demodulators that by meanings are band pass signals shifted to DC.
The band pass filter is applied as a data narrowing window in the time domain of a length.

- FAM Implementation

FAM is one of the approaches under time-smoothing organization which has good efficiency, calculation wise. There are parameters complicated that are used to trade-off determination, reliability and of course computation decrease.

FAM contains of capturing in a time length Δ_t a piece of the received signal $x[n]$ which is the outcome of $x(t)$ sampled at f_s . Approximation of $S_x^\alpha(n,f)_{\Delta t}$ is achieved over this time length. This calculation is achieved iteratively over consecutive smithereens in the time domain until satisfactory results for a summation of several $S_x^\alpha(n,f)_{\Delta t}$ satisfies the request in terms of time of calculation and objective to meet.

- FAM Performance Analysis

FAM presentation could be examined by essential a spectrum sensing expedient capable of outputting a value that designates the attendance of a particular signal like 802.11. The production has to be a ratio metric defined since wireless indications does not promise fixed signal energy levels. A good excellent for the expedient output could be the summary of the peaks where introductions should seem and also comprise the pilot's peaks.

7. SIMULATION RESULTS

The demand for broadband services is growing exponentially. WiMAX enables wireless broadband access anywhere, anytime, and on virtually any device and has generated unparalleled interest within the wireless networking community. WiMAX offers numerous advantages, such as improved performance and robustness, end-to-end IP-based network, secure mobility, and broadband speeds for voice, data, and video [11].

Wi-Fi is based on the IEEE 802.11 family of standards and is primarily a local area networking (LAN) technology designed to provide in-building broadband coverage.

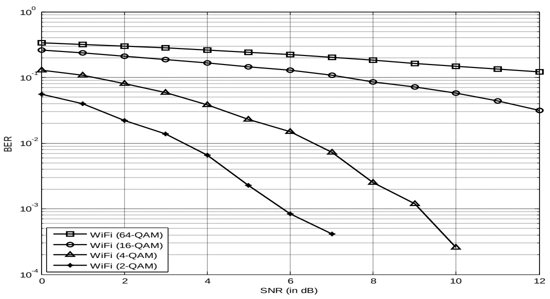

Fig. 4: SNR vs. BER for Wi-Fi signal using Rayleigh channel

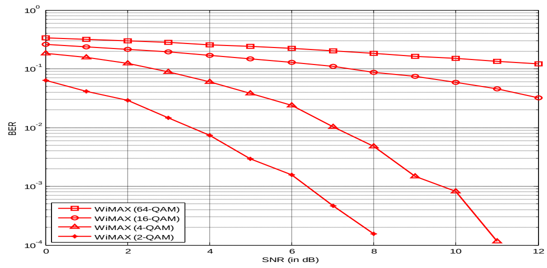

Fig. 5: SNR vs. BER for WiMAX signal using Rayleigh channel

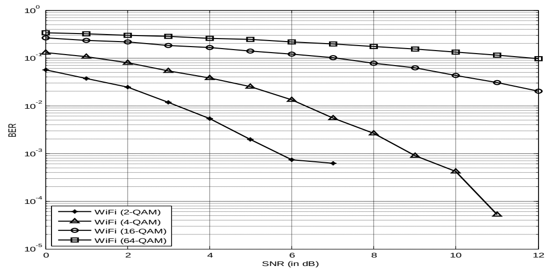

Fig. 6: SNR vs. BER for Wi-Fi signal using Rician channel with K factor = 5

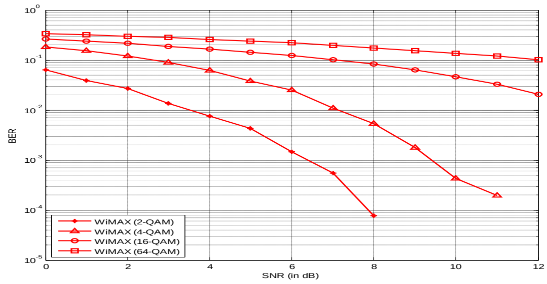

Fig. 7: SNR vs. BER for WiMAX signal using Rician channel with K factor = 5

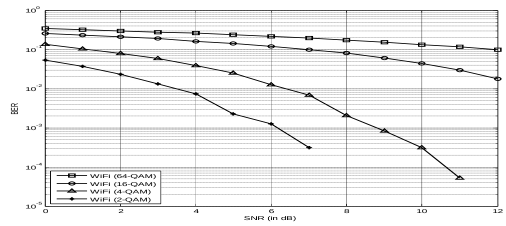

Fig. 8: SNR vs. BER for Wi-Fi signal using Rician channel with K factor = 10

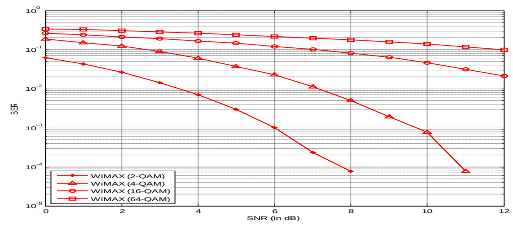

Fig. 9: SNR vs. BER for WiMAX signal using Rician channel with K factor = 10

For different formats of QAM, both Wi-Fi and WiMAX systems are almost identical in terms of BER performance. A minor difference is observed between the Wi-Fi and

WiMAX systems, thereby making the WiMAX more efficient than Wi-Fi as the range of WiMAX is greater than Wi-Fi system for same SNR. Of all the modulations discussed above, spectral efficiency of 64-QAM is best and thus it is more desirable. Spectral efficiency of 64-QAM is 6 bits/sec/Hz, i.e., it transmits 6 bits per second using 1 Hertz of bandwidth.

8. CONCLUSION

Simulation results prove that we can use Cognitive radio systems for Spectrum Sensing and that too with less complexity than previous systems. A Cyclostationary Spectrum Sensing technique is devised to detect OFDM signals in a noisy (AWGN) environment. The proposed system was compared with existing spectrum sensing techniques in terms of bit error rate performance.

The validity of the proposed spectrum sensing technique was done using Wi-Fi and WiMAX systems. As seen from the simulation results, there was a minor increase in the BER of a WiMAX system when compared to a Wi-Fi system at same SNR. This difference or increase in BER of the WiMAX system is tolerable as the communication range of a WiMAX system is far better than that of a Wi-Fi system at same SNR. Also, WiMAX being a wideband system can handle more users than Wi-Fi which is a narrow band system. The proposed system can be implemented on hardware and tested on some real-time applications like high speed modem for data transfer, voice over IP, and many more.

9. REFERENCES

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