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Energy Efficient Spectrum Sensing Techniques for Cognitive Radio Based Wireless Networks

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Abstract

Cognitive Radio is an intelligent network technology which can sense unused channels over a wireless spectrum and modify parameters enabling more transmissions to improve radio operations. The spectrum is allocated by a regulatory organization and is not used all the time by licensed users which creates spectrum holes. Cognitive Radio allows secondary users to sense these spectrum holes and utilize them when the primary user is not active. It uses various techniques available to sense the unutilized spectrum. In this project we are going to analyze these available techniques and discuss their implementation in an energy efficient way.

Keywords: *Cognitive Radio, energy efficient, spectrum sensing, wireless networks.*

1. Introduction

Cognitive Radio is an intelligent network technology which can sense unused channels over a spectrum and modify parameters allowing more transmissions at the same time to improve radio operations. It can be modified to utilize the best channels to avoid user interference and congestion. Radio spectrums are used as primary form of wireless communication. Every country has an organisation that manages the use and allocation of radio frequencies. A formal request needs to be made for the use of radio frequencies. Since there are many users for radio frequencies, the spectrum is not sufficient. When the spectrum is allocated in a static way it does not allow the usage of the spectrum to its full potential.

Cognitive Radio technology is used to overcome this problem. A cognitive radio allows users to detect when a spectrum is not being used and then uses that radio spectrum for transmission. In this project we are going to implement energy efficient spectrum sensing techniques in cognitive radio based wireless networks with speed and accuracy.

2. Literature Survey

[1] The currently most popular spectrum sensing methods are: Matched filter Detection, Energy Detection, and Cyclostationary Feature. Matched filter detection is the preferred method when the structure of primary user waveform is known and it provides the best sensing outputs within the shortest time. Cyclostationary features and energy detection are preferred over matched filter detection when the structure of primary user is not known. In cases where noise uncertainties are unknown Cyclostationary feature detection works better than energy detection method. The energy detection method can be implemented in NI LabView in ISM band or industrial, scientific and medical radio band using bluetooth devices operating in the 2.4Ghz range to act as primary users.

[2] The capabilities of Cognitive Radio can be developed by using Reinforcement Learning. The experiments conducted on the white spaces present in radio frequency slot, using Universal Software Radio Peripheral (USRP), along with LabView can be used to generate environment simulation. Energy

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detection spectrum sensing with Q-learning is used to detect available signals and adjust the gain on the device by using software to control USRP. The process is based on trial and error to find the best possible state; giving positive feedback when using the good states and negative feedback when selecting the bad ones. The highest scoring pattern will be a balanced result of exploration and exploitation.

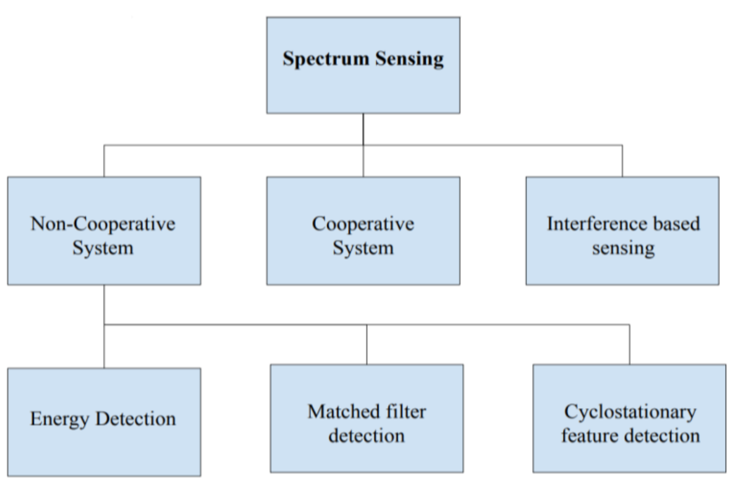
[3] A lot of different spectrum sensing algorithms are being studied with their advantages, disadvantages and challenges faced in implementing each algorithm. Special attention should be given to the implementation of subo-Nyquist techniques. This type of spectrum sensing allows us to find more spectrum holes over a frequency range and reach higher throughput in CR based wireless networks. Wideband spectrum sensing algorithms can be categorised based on how they are implemented using the latest available technologies. The issues in the designing and implementing these algorithms for cognitive radio networks can be addressed with further research in the field.

[4] Spectrum sensing is a very important element of CR based system designs. Spectrum sensing is a crucial feature of Cognitive Radio which allows . Conventional spectrum estimation techniques which are based on Short Time Fourier Transform face problems such as low frequency resolution, high variance of estimated power spectrum and high side leakages. Methods such as Multi Taper Spectrum Estimation successfully alleviate these infarctions but increase the overall complexity of the process. Considering all the records apparently the filter bank range estimation detailed by F. Boroujeny and wavelet based range estimates are the most encouraging methodologies for CR applications.

[5] There are various difficulties and issues that are faced in implementation of CR based wireless networks. The improvement in cognitive radio networks requires association and collaboration of many progressed networking techniques, including interference management, distributed spectrum detection, CR reconfiguration management and cooperative communications. So as to completely understand the potential of cognitive radio systems in wireless communications for effective usage of limited radio frequency spectrum, the strategies that are utilized in detecting the interference and spectrum detection should be reliable so that the original user will not suffer from the cognitive radio systems and use their licensed frequencies without any disturbance.

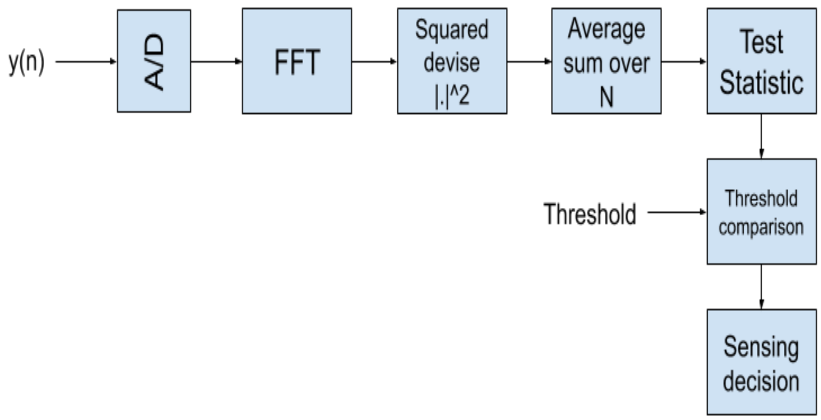
3. Types of Spectrum Sensing Techniques

Spectrum sensing techniques are classified into three types: Non-cooperative sensing, Cooperative sensing and Inference based sensing. Non-cooperative sensing also known as transmitter detection technique is further divided into matched filter detection, energy detection and cyclostationary feature detection.



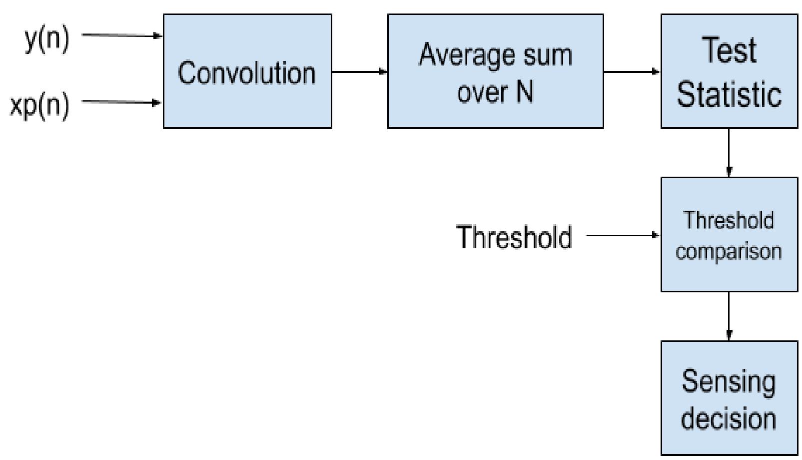
A. Energy Detection

In this method, the incoming signal is sensed based on the energy present in the spectrum. It is the most popular technique as it is much simpler to use and does not require prior knowledge of the user signal. In this technique, the signal is made to pass via a band pass filter of a specified bandwidth and then analyzed over a time interval. The integrated result is then matched to a predefined limit to detect the absence of the primary user.



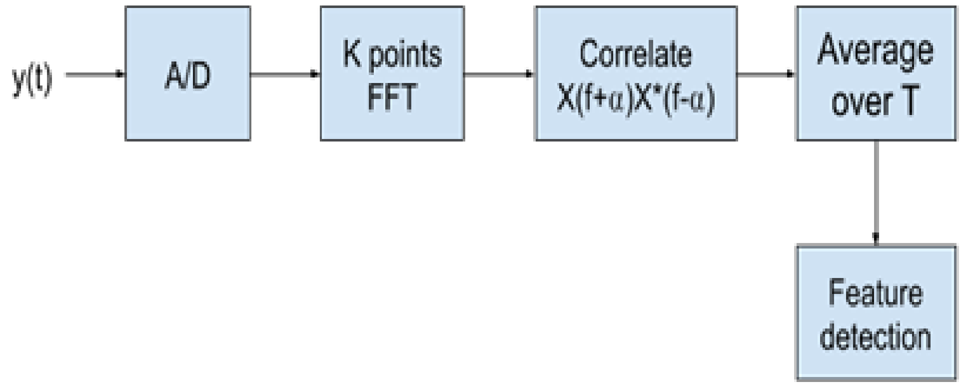
B. Matched Filter Detection

In this method, a matched filter is used to boost the output signal to noise ratio of incoming signal. It is preferred when the primary user waveform structure is known. It has a very short sensing time as it only needs a calculated number of results to reach probability of detection constraint. It is the optimal and preferred method when the licensed user signal is familiar to the secondary user.



C. Cyclostationary Feature Detection

In this method, the inherent cyclostationary properties of the signal are used which have periodic statistics. These periodic statistics are exploited to sense the existence of licensed user. Due to its noise rejection capability, it performs better than other known techniques like energy detection. For this method the non-licensed user needs to have knowledge of licensed user signal characteristics. This method is highly complex leading to long sensing times.



4. Energy Efficient Techniques for Spectrum Sensing

Spectrum sensing techniques need to be implemented in an energy efficient manner to reduce power consumption. Few of the energy efficient implementation of spectrum sensing techniques are discussed below.

A. Sleeping

In this technique, the cognitive radio device turns off its sensing device randomly based on the probability *m*. This probability is called the sleeping rate of the device. This technique is also known as on/off sensing. Cognitive radios do not consume energy when they are not transmitting or sensing. This technique makes the cognitive radio consume energy only when the radio is sensing during the on-stage and if a spectrum is available then energy is consumed when transmitting data in the available spectrum. At other times the device is in off-state based on the probability and no sensing and transmitting operations take place during this time.

B. Reinforcement Learning

In this technique, we use a machine learning approach of trial-and-error, in which the sensing decision making device will observe the state of the environment and then decide the outcome that is the most rewarding. Higher rewards are given for desirable decisions, which enforce these actions, leading the device more likely to make desirable decisions in the future. Energy efficiency is achieved by only using the sensing device when the conditions are most rewarding.

C. Adaptive Spectrum Probing

In this technique, the total energy consumption is minimized by using the most optimum energy sensing interval. Initially the secondary user sets the spectrum sensing interval. Later the spectrum sensing interval is determined based on the results of the last spectrum sensing results. In this technique the spectrum sensing time interval is not fixed and keeps on changing based on the previous spectrum sensing results.

5. Conclusion

Spectrum sensing is a key aspect of cognitive radio based wireless networks. In this paper, we have discussed several techniques that can be utilized to implement spectrum sensing techniques in an efficient way which reduces the power consumption greatly. These techniques can be used for both cooperative and non-cooperative spectrum sensing.

These methods can be implemented and used in combination with each other to form more efficient spectrum sensing devices. These techniques improve the efficiency of the Cognitive Radio greatly making it feasible to implement. Such devices however, will need more complex hardware and more research to be implemented at a commercial level.

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