SPECTRUM ALLOCATION AND SCHEDULING IN COGNITIVE RADIO FOR 4G LTE NETWORKS

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Abstract- Cognitive radio is a low-cost communication system, which can choose the available frequencies and waveforms automatically on the premise of avoiding interference of the licensed users. The spectrum sensing is the key enabling technology in cognitive radio networks. It is able to fill voids in the wireless spectrum and can dramatically increase spectral efficiency. In this thesis, we used matlab to simulate the received signals from the cognitive radio networks and an energy detector to detect whether the spectrum is being used. The report also compares the theoretical value and the simulated result and then describes the relationship between the signal to noise ratio (SNR) and the detections. At last, the method, energy detection with Matched Filter detection simulation and result are discussed which is considered as the guidelines for the future work. LTE, an initials’ of Long Term Evolution, marketed as 4G LTE, is a standard for wireless communication of high-speed data for mobile phones and data terminals. It is based on the GSM/EDGE and UMTS/HSPA network technologies, increasing the capacity and speed using a different radio interface together with core network improvements. The standard is developed by the 3GPP (3rd Generation Partnership Project) and is specified in its Release 8 document series, with minor enhancements described in Release 9. That is why I have chosen 4G LTE Network for Spectrum Allocation. It will be more advanced and beneficial for all wireless mobile communication.

Keywords— Cognitive Radio, Energy Detection, Matched Filter Detection, LTE networks

I. INTRODUCTION

In cognitive radio systems, the unlicensed (secondary) users can use the licensed spectrum as long as the licensed (primary) user is absent at some particular time slot and some specific geographic location. Cognitive radio (CR) is one of the most promising technologies to deal with such irrational frequency regulation policy and has received lots of attention. In 2004, the IEEE formed the 802.22 Working Group to develop a standard for wireless regional area networks (WRAN) based on cognitive radio technology. WRAN systems will operate on unused VHF/UHF bands that are originally allocated for TV broadcasting services and other services such as wireless microphone which are called primary users. In order to avoid interfering with the primary services, a WRAN system is required to periodically detect if there are active primary users around that region. As discussed above, spectrum sensing is a fundamental component in a cognitive radio. There are however several factors which make the sensing problem difficult to solve. First, the signal-to-noise ratio (SNR) of the primary users received at the secondary receivers may be very low. For example, in WRAN, the target detection SNR level at worst case is ~20dB. Secondly, fading and time dispersion of the wireless channel may complicate the sensing problem. In particular, fading will cause the received signal power fluctuating dramatically, while unknown time dispersed channel will cause coherent detection unreliable. Thirdly, the noise interference level changes with time which results in noise uncertainty. There are two types of noise uncertainty: receiver device noise uncertainty and environment noise uncertainty. The sources of receiver device noise uncertainty include (a) non-linearity of components; and (b) thermal noise in components, which is non-uniform and time-varying. The environment noise uncertainty may be caused by transmissions of other users, including near-by unintentional transmissions and far-away intentional transmissions. Because of the noise uncertainty, in practice, it is very difficult to obtain the accurate noise power. There are mainly four types of spectrum-sensing methods: 1) energy detection (ED), 2) matched filtering (coherent detection), 3) feature detection and 4) Eigenvalue-based detection. Among them, ED is optimal if the secondary user only knows the local noise power. The matched-filtering-based coherent detection is optimal for maximizing the detection probability, but it requires the explicit knowledge of the transmitted signal pattern (e.g., pilot, training sequence, etc.) of the primary user. The feature detection, which is often referred to as the cyclostationary detection, exploits the periodicity in the modulation scheme, which, however, is difficult to determine in certain scenarios. By constructing the decision variables based on the eigenvalues of the sampled covariance matrix to detect the presence of the primary user, the eigenvalue-based sensing methods presented in do not need to estimate the power of the noise and, hence, are cross-layer more practical in most CR networks.

In this paper we discussed the problems in Spectrum sensing. Spectrum sensing is best addressed as design problem. Cognitive radio sensitivity can be improved by enhancing radio RF front-end sensitivity, exploiting digital signal processing gain for specific primary user signal, and network cooperation where
users share their spectrum sensing measurements. The various spectrum sensing techniques are: classical spectrum sensing, cooperative spectrum sensing, multiple antenna sensing and MIMO spectrum sensing that we will discussed in this paper in details The paper is organized as follows; Section II defines Spectrum Sensing. Section III explains the Classical Techniques of Spectrum Sensing, In section IV we have proposed the Implementation Of Energy Detector with Matched Filter. In section V we carried out Spectrum Allocation using 64 QAM in 4G LTE Networks. Simulation Results are presented in Section VII and finally Conclusion are drawn in section VII

II. SPECTRUM-SENSING

A cognitive radio is a radio frequency transmitter/receiver that is designed to intelligently detect whether a particular segment of the radio spectrum is currently in use, and to jump into the temporarily-unused spectrum very rapidly, without interfering with the transmissions of other authorized users. Main functions of cognitive radio are: Spectrum sensing, spectrum management, spectrum mobility and spectrum sharing. Spectrum sensing detects the unused spectrum and shares it without harmful interference with other licensed users. Spectrum Management is the task of selecting the best available spectrum to get user communication requirements. Spectrum Mobility is defined as the process when a cognitive radio user exchanges its frequency of operation. Spectrum Sharing decides which secondary user can use the spectrum hole at some particular time. One of the major challenges in open spectrum usage is the spectrum sharing, which is also known as Dynamic Spectrum Sharing problem.

Figure 1. Measurement of 0-6 GHz spectrum utilization at BWRC. Figure 1 shows the power spectral density (PSD) of the received 6 GHz wide signal collected for a span of 50% sampled at 20 GS/s. This view is supported by recent studies of the FCC’s Spectrum Policy Task Force who reported vast temporal and geographic variations in the usage of allocated spectrum with utilization ranging from 15% to 85%. A number of spectrum sensing methods have been proposed in literature. There are several factors that make spectrum sensing practically challenging. First, the required SNR for detection may be very low.[6] Second, multipath fading and time dispersion of wireless channels complicate the spectrum sensing problem. Thirdly, the noise level may change with time and location which yields the noise power uncertainty issue for detection. To overcome these challenging factors there is a boom in spectrum sensing methods and a wide scope of research in this area. We can classify these spectrum sensing methods in following three ways: Classical spectrum sensing, cooperative spectrum sensing and Antenna based spectrum sensing (Multiple antenna spectrum sensing and MIMO spectrum sensing). Most of these spectrum sensing methods are briefly reviewed in this paper.

III. CLASSICAL SPECTRUM-SENSING METHODS

These techniques provide basic concept of spectrum sensing which is further used in various emerging spectrum sensing techniques.

Matched Filter Detection

Matched filtering is known as optimal method for detection of primary users when the transmitted signal is known. It is a linear filter designed to maximize the output signal to noise ratio for given input signal. It is obtained by correlating a known signal, with an unknown signal to detect the presence of the known signal in the unknown signal. A matched filter compares two signals and outputs a function describing the places at which the two signals are most like one another. This is carried out by taking Fast Fourier Transform (FFT) of two signals, then multiplying their coefficients and after that taking Inverse Fast Fourier Transform (IFFT) of the result, the output can be find out the main advantage of matched filter is that due to coherency it requires less time to achieve high processing gain since only O(1/SNR) samples are needed to meet a given probability of detection constraint. However, a significant drawback of a matched filter is that a cognitive radio would need a dedicated receiver for every primary user class and this makes the spectrum sensing more difficult in Matched Filtering.[8]

2. Conventional Energy Detection Method

Energy detection is a non coherent detection technique in which no prior knowledge of pilot data is required. Following issues in spectrum sensing based on energy detection: 1. Required sensing time needed to achieve the desired probability of detection and false alarm. 2. Limitations or energy detector performance due to presence of noise uncertainty and background interference. 3. Performance improvements offered by network cooperation.
Depending on the application, the signal to be detected can be either unknown or known.

Figure 2: Implementation Of Conventional Energy Detector

The input signal goes into the A/D converter selected by the band pass filter first and we will get the threshold there. After we get the output from the integrator, which is compared with threshold, we will determine the presence of the primary users. The FFT size $N$ and the observation time $T$ will influence the processing gain, if $N$ is increased, it will improve the frequency resolution which is proper to narrowband signal detection. In the other hand, if $T$ is increased the noise power will decreased, thus the SNR will increased.

There are several drawbacks of energy detectors that might diminish their simplicity in implementation. First, a threshold used for primary user detection is highly susceptible to unknown or changing noise levels. Even if the threshold would be set adaptively, presence of any in-band interference would confuse the energy detector sequence and frequency hopping signals, for which more sophisticated signal processing algorithms need to be devised. As the energy detector is prone to the false detection triggered by the unintended signals, this method used to help improve the accuracy of the energy detector. In general, we could increase detector robustness by looking into a primary signal footprint such as modulation type, data rate, or other signal feature. To overcome these drawbacks we have implemented the new method which is described in section IV.

IV. IMPLEMENTATION OF ENERGY DETECTOR WITH MATCHED FILTER

Introducing this new technique of spectrum sensing can provide a better way to sense the vacant bands.

Figure 3: Implementation Of Energy Detector with Matched Filter

The input signal goes into the A/D converter selected by the band pass filter first and we will get the threshold there. It will be squared and integrated. After we get the output from the integrator it will be converted from serial to parallel form. The resulted data is modulated using 64QAM. This modulated data is subjected to Inverse fast Fourier Transform operation. This data is transmitted through awgn channel. Let $\text{sig}(t)$ be the transmitted signal, $w(t)$ is the channel noise, $\text{sig}(t) + w(t)$ be the received signal, which is given as the input to the matched filter and $\text{sig}(0)(t) + w(0)(t)$ be the output of the filter. Let the matched filter’s impulse response be $h(t)$, which is the mirror image of the desired message signal $\text{sig}(t)$. The signal component at output of the filter, at the observing instant $t_m$ is given by

$$\text{sig}(0)(tm) = 1/2\pi (s(ω)) 2$$

$$\text{sig}(0)(tm) = E$$  \hspace{1cm} (1)

Hence the output signal component has maximum amplitude of magnitude $E$, which is nothing but energy of the signal $\text{sig}(t)$. The maximum amplitude is independent of the waveform $\text{sig}(t)$ and depends only upon its energy. This Matched filter’s output will be considered as final output for detection of holes. This signal is simulated in Matlab R2010a and we are getting the number of holes that means status of primary users. And we can ensure that the spectrum is idle for secondary users for allocation.

V. SPECTRUM ALLOCATION USING 64 QAM IN 4G LTE NETWORKS

In this process following steps incorporated. 1. LTE basic terms 2. Relation between Bandwidth and Resource Blocks 3. Modulation Schemes and constellation 4. Data rate calculation 5. Allocation of secondary users to specific data rate using MATLAB. LTE basic terms are explained below.

i) Resource Element: Resource element is the smallest unit of transmission in LTE. ii) Subcarrier spacing: It is the space between the individual subcarriers, In LTE it is 15 KHz. iii) Cyclic Prefix: A set of samples which are duplicated from the end of a transmitted symbol and appended cyclically to the beginning of the symbol. CP = 5usec (standard case) iv) Time slot: 0.5 ms (i.e 1 Sub-frame = 1 ms), 1 Time-slot = 7 Modulation Symbols (when normal CP length is used) v) Resource Block: A unit of transmission resource consisting of 12 subcarriers in the frequency domain and 1 time slot (0.5ms) in the time domain. So 12 subcarriers x 7 symbols = 84 Resource Elements with normal CP. The Bandwidth of a RB is 180KHz. vi) LTE Sub frame: two slots i.e. 1ms in time

2. Relation between Bandwidth and Resource Blocks: Bandwidth directly affects the data rate. Different bandwidths have different number of RBs.

<table>
<thead>
<tr>
<th>Bandwidth (KHz)</th>
<th>1</th>
<th>2</th>
<th>5</th>
<th>10</th>
<th>15</th>
<th>20</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of RBs</td>
<td>6</td>
<td>12</td>
<td>25</td>
<td>50</td>
<td>75</td>
<td>100</td>
</tr>
<tr>
<td>Number of Resource Blocks</td>
<td>72</td>
<td>144</td>
<td>298</td>
<td>597</td>
<td>924</td>
<td>1456</td>
</tr>
<tr>
<td>Number of occupied subcarriers</td>
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<td>14</td>
<td>28</td>
<td>57</td>
<td>90</td>
<td>148</td>
</tr>
<tr>
<td>EFFT/FFT Size</td>
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<td>512</td>
<td>1024</td>
<td>2048</td>
<td>3072</td>
<td>5120</td>
</tr>
<tr>
<td>Subcarrier Spacing (Hz)</td>
<td>15</td>
<td>25</td>
<td>37</td>
<td>56</td>
<td>84</td>
<td>156</td>
</tr>
</tbody>
</table>

Table 1: Calculation of Resource Blocks
3. Modulation Schemes and Constellation: LTE supports modulations like QPSK, 16QAM, 64QAM. Each of modulation has its carrying capacity per symbol. One QPSK symbol can carry 2 bits. One 16 QAM symbol can carry 4 bits. One 64 QAM symbol can carry 6 bits.

4. Data Rate Calculation:
Resource Block (RB) = 12 Sub-carriers, For 20 MHz channel bandwidth (100 RBs), normal CP. Therefore, number of bits in a sub-frame. Data rate= 100RBs x 12 sub-carriers x 2 slots x 7 modulation symbols x 6 bits = 100800 bits
Hence, data rate = 100800 bits / 1 ms = 100.8 Mbps

5. Allocation Process:
Consider first three holes in the spectrum having data rates 50 Mbps, 75 Mbps, 100 Mbps. Secondary users demanding 75 Mbps, 100 Mbps, 50 Mbps. As are using MATLAB (R2010a) this data should be defined in Matrices which are given below as User matrix and hole matrix. By performing some MATLAB operations we can assign respective data rate to respective user. MATLAB functionality used to sort the users with required data rate with respect to holes and their availability of data rate.

VI. SIMULATION RESULTS
This paper presents the cognitive radio network using MATLAB (R2010a) 7.10.0.499. We have used the digital implementation of energy detector using FFT. It is assumed that there are 5 primary users in the spectrum. [1] The cognitive radio network continuously looks for the spectrum hole where primary user is not present which is determined by the energy detection method and as soon as it finds out the spectrum hole, it allots it immediately to the secondary user and whenever primary user wants to occupy the slot, secondary user immediately vacates it.
In above graph it is shown that secondary users are allocated to spectrum for their desired data rates. On X axis there are number of users and on Y axis there are number of holes which are allocated. This is simulated in Matlab R2010a. In this way the Spectrum allocation and scheduling is done in 4G LTE networks using 64 QAM modulation scheme If 4x4 MIMO is used, then the peak data rate would be 4 x 100.8 Mbps = 403 Mbps. If 3/4 coding is used to protect the data, we still get 0.75 x 403 Mbps = 302 Mbps as data rate

CONCLUSION

In this thesis, we succeeding simulate the output signals, and we distinguish whether there are primary users or not, we get how the SNR influences the detections. We also get the suitable SNR for the energy detector with Matched Filter detection. So we almost get the final result of the spectrum sensing for cognitive radio based on Energy Detection as we expected. By comparing the theoretical value and the simulated value we can get that the result we get is reasonable and scientific. By using 64QAM I got the higher data rates which are required by my secondary users for 4G LTE networks in wireless mobile communication. I have successfully allocated the secondary users using MATLAB R2010a which is user friendly. Considering the disadvantages and limitations of the method as mentioned in discussion part, we can do further works: a) Set the range of the errors between the threshold and the detected energy to distinguish the result within the acceptable errors.

b) Try to implement the energy detection in C code to sense the spectrum in CR networks within the Linux system.

REFERENCES


