Chapter 2

Literature Review

In this work, multiple terms are used and discussed, such as Sensing Techniques, Spectrum Handover and Sensing task assignment.

This chapter aims to give an introduction about these terms and discuss the related work in literature concerning them.

2.1 Sensing Techniques

For the dynamic spectrum access process to be successful, a cognitive node (the node performing spectrum access) must be able to sense the surrounding environment and use the information that result from the sensing process to modify the access parameters and enhance the transmission.

In literature, multiple sensing techniques exist. They are classified mainly to three categories [8]:

- **Matched Filter:**
  One of the techniques in the field of signal processing for pointing a known pattern from a received signal is matched filter detection. In the presence of additive noise, the matched filter works as an optimal linear filter for maximizing the Signal to Noise Ratio (SNR). In this technique, the received signal is convolved with a time-reversed version of the prior known signal. Finally, the convolved output is compared with a predetermined threshold factor to decide whether the primary user is present on the

sensed spectrum.

The intuition behind the matched filter relies on the prior knowledge of the primary user waveform such as modulation type, order, the pulse shape and the packet format. To meet such a stringent condition, cognitive radios need to have cache all the information in their memory but achieving synchronization is the most cumbersome part for demodulation. However, it is still realizable because most of primary users have pilots, preambles, synchronization words or spreading codes that can be used for coherent detection.

- **Energy Detector:**
  For a scenario where it is tough for the cognitive node to have information about the primary user waveform, matched filter detection is not a most favorable choice. However, energy detection is a healthier alternative. The elementary approach behind the energy detector is estimation of power of the received signal. To compute the power of the received signal, a band pass filter is applied to the signal, then the output of the band pass filter of is squared and integrated. Finally, the integrated value is compared with a threshold to decide whether the primary user is present or not.

  One of the major shortcomings of energy detector is that the performance is subjected to uncertainty in noise power. It cannot discriminate between signal and noise power and so it exhibit high probability of false alarm under low SNR.

- **Cyclostationary Detection:**
  Researchers suggest cyclostationary feature detection to be the more suitable choice than matched filter and energy detector techniques. As discussed earlier, the matched filter as a coherent detector requires prior knowledge about primary signal and the energy detector as non-coherent detection does not require any sort of prior knowledge about primary signal. Although energy detector is easy to implement, it is highly susceptible to in-band interference and changing the noise levels and it cannot differentiate between signal power and noise power.

Commonly the primary modulated waveforms are coupled with patterns also characterized as cyclostationary features like sine wave carriers, pulse trains, repeating, spreading, hoping sequences or cyclic prefixes inducing periodicity. A cognitive radio can detect a random signal with a specific modulation type in the presence of random stochastic noise by exploiting the periodic statistics like mean and autocorrelation of the primary waveform. Features like autocorrelation and mean are estimated by analyzing spectral correlation functions. Detected features are the number of signals, their modulation types, symbol rates and presence of interferers.

2.2 Spectrum Handover

A cognitive node seeks to underlay, overlay or interweave its signals with those of the licensed users, without impacting their transmission. The underlay paradigm allows cognitive nodes to operate if the interference they cause to primary users is below a given threshold or meets a given bound on primary user performance degradation. In overlay systems the secondary users overhear the transmissions of the primary users, then use this information along with signal processing and coding techniques to maintain or improve the performance of licensed users, while also obtaining some additional bandwidth for their own communication. In interweave systems the secondary users detect the absence of licensed signals in space, time, or frequency, and opportunistically communicate during these absences [9].

In this work, the underlay paradigm is adopted. That is, concurrent transmission of licensed users and cognitive nodes may occur only if the interference caused by cognitive nodes on licensed users' signals is maintained below some acceptable bound. If, as a result of spectrum sensing, a licensed signal is detected and if the cognitive node is causing harmful interference to it or the Quality of Service (QoS) of the cognitive node is not satisfying, the frequency channel has to be quickly vacated and the cognitive user needs to apply spectrum handover process.

In [3] a fuzzy logic-based approach is presented that can be used for the handover decision making process. In this thesis, we adopt an approach close to that one with some modifications.

2.3 Sensing Task Assignment

In the third part of this thesis, assigning the channel sensing task to cognitive nodes is of interest. It is required to distribute the sensing task among nodes such that each node is assigned only a portion of the whole spectrum under consideration. A little work was performed in the area of distributing the sensing task across cognitive nodes in CRNs. In [10], a heuristic scheme is proposed to allocate channels to each cognitive node for sensing. Authors in [11] present a distributed cooperative multi-channel spectrum sensing scheme for a non-infrastructure based cognitive radio system. This distribution depends on the sensing error of each node over all channels. Moreover, the idea of forcing some nodes to sleep (not perform sensing) was also covered in related work as in [12], [13] and [14]. This idea was used for energy efficient spectrum sensing. Additionally, it was found to enhance the performance of the cognitive radio network (CRN) and reduce the sensing probability of error over the full channel assignment with hard decision transmission.