Abstract

Wireless communication survives on the electromagnetic radio frequency (RF) spectrum. The scarcity of such vital resource, the RF spectrum, places a fundamental limit on the proliferation of wireless communication technologies. A report by the FCC Spectrum Policy Task Force in November 2002 has stated that the spectrum scarcity problem is mostly due to the insufficient utilization of the RF spectrum rather than the lack of unoccupied frequency bands. In other words, many of the legacy-controlled frequency bands are being underutilized, while the access of potential spectrum users to these underutilized bands is limited due to legacy command-and-control regulation. Cognitive Radio (CR) proposes a solution to spectrum scarcity problem by making the underutilized frequency bands available to use by secondary (non-legacy) users, hence improving the overall utilization of the RF spectrum.

Spectrum sensing, the first task of CR, is the task of locating and identifying spectrum opportunities available, i.e., spectrum holes. Spectrum sensing is therefore conducted over a considerably wide RF spectrum with more than one transmission technology involved. Moreover, in contrast to conventional radio networks, CR networks have dynamic spectrum allocation. This implies that, in addition to the power spectral density (PSD) levels of channels, the number of channels composing the sensed RF spectrum along with their center frequencies and bandwidths are all unknown. In this case, the task of finding these unknowns is called wideband spectrum sensing.

The first step of spectrum sensing is to identify the frequency location of each channel in the RF spectrum. In any given channel, the PSD is expected to exhibit sharp variation points (singularities) near the boundaries of the frequency band. Detecting and characterizing theses singularities would provide important information on the frequency locations of channels. This can be treated as an edge detection problem. The wavelet transform (WT) is a powerful mathematical tool for the identification and analysis of edges in image processing applications. Thus, the WT is employed in the frequency domain to detect the local spectral edges which are directly related to the frequency locations of channels. The second step of spectrum sensing is to classify the identified frequency channels as occupied or vacant according to the PSD level of each channel. The PSD level is estimated by energy detection.

This thesis presents a survey of the existing wideband spectrum sensing techniques using wavelet-based edge detection: the wavelet transform multiscale modulus maxima (WTMM), the wavelet transform multiscale product (WTMP), the wavelet transform multiscale sum (WTMS), and the Hilbert transform preceded by Gaussian smoothing algorithms. We search for the advantages, as well as the shortcomings, of each of these techniques. In addition, we offer modifications, such as changing the wavelet basis and adding a decision threshold, to the WTMS algorithm to improve its performance. Then, three improved sensing techniques are proposed; the first technique is based on a multiscale Hilbert transform, while the second technique is based on denoising the received PSD using wavelet thresholding whereas the third proposed technique is based on the characterization of singularities in the PSD from their WT multiscale information. In addition, new performance metrics are developed to evaluate and compare the performance of the proposed techniques against the existing counterparts. The proposed techniques outperform the existing edge-detection-based techniques. Moreover, we shall investigate the performance of several wavelet basis functions in order to select the best wavelet basis for this kind of wideband spectrum sensing. Finally, we shall propose two modified energy detection schemes, the broadened energy detection (BED) and the weighted energy detection (WED) techniques, to improve the performance of wideband spectrum sensing.

Improving the performance of the spectrum sensing stage would boost the performance of CR networks as accurate and efficient spectrum sensing is essential for successful CR operation. Simulations are provided for verification.