Wideband Spectrum Sensing in Cognitive Radio using Uniform and Non-Uniform Filter Banks

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by

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ABSTRACT

Rapid growth in wireless communication services has increased the demand for spectrum resources. A recent report by Federal Communications Commission (FCC) reveals the fact that major part of the spectrum is underutilized. The existing static frequency allocation schemes are not able to accommodate the requirements of increasing data rate and wireless services. Such scenarios demand innovative techniques to exploit the available spectrum. Cognitive Radio (CR) techniques have proven to be a solution to alleviate the spectrum scarcity using spectrum sensing techniques.

In this thesis, we focus on wideband spectrum sensing using filter bank techniques. Even though narrowband spectrum sensing makes a binary decision on the whole spectrum, it is unable to identify spectral holes and spectral opportunities within a wideband spectrum. On the other hand, in wideband spectrum sensing, the available bandwidth is divided into multiple subbands or subchannels for spectrum sensing. A solution to this would be filter bank spectrum sensing.

Filter banks can be derived using modulation of a single prototype filter having high stopband attenuation, narrow transition width, and small passband ripple. Architectures based on filter banks allow sensing multiple subbands simultaneously with low spectrum leakage from adjacent channels when properly designed subband filters are used. We have designed a variable step prototype filter iteratively for the filter banks satisfying Near Perfect Reconstruction (NPR) condition. Cosine Modulated Filter Bank (CMFB) was used for spectrum sensing using the designed prototype filter as they provide higher bandwidth efficiency and lower sidelobes desirable for spectrum sensing. The sensing performance depends on the granularity of filter banks. Finer granularity band improves the probability of detection at the cost of increase in computational complexity. In order to reduce computational complexity, a coarser to finer multistage CMFB was proposed to detect narrowband users in a wideband spectrum. In such cases, only the bandwidth of interest is sensed with finer resolution instead of the entire bandwidth. Since polyphase filter banks are computationally efficient compared to CMFB, the later work was done with polyphase filter banks.

Since the spectrum bands are predefined for commercial communication scenarios, CR system requires to check whether a spectrum band is free or occupied. Then the detected spectral band can be utilized opportunistically. However, in multi-channel military wireless communication, there exists a requirement to identify the center frequency and the spectral edges of the primary users for fractional utilization of the available bandwidth. In order to address this problem, a novel *centroid* based low complexity polyphase filter bank multistage approach was proposed. The sensing was performed from coarser to finer spectral resolution using filter banks. Depending on the energy distribution at each stage, narrowband users were detected in wideband channels. Using our approach, the primary users can be detected in the first stage itself in cases they appear between two subbands. As the first stage has coarser subbands (number of subbands are less), the complexity in computation as well as hardware is drastically reduced. However, if the primary user appears exclusively within a single subband, the detection process can be completed in the second stage without ambiguity. We have considered IEEE 802.22 Wireless Regional Area Network (WRAN) standard as an application for validating our algorithm using multistage polyphase filter banks to detect Wireless Microphones (WM) in Television (TV) channels. The proposed scheme was analyzed and validated through extensive simulations for the detection of WM.

A novel *center of mass* approach was proposed for the detection of multiple users in wideband spectrum. Further, mathematical relation for the estimation of center frequency and spectral boundaries/edges were also established. To reduce the complexity, the detection is carried from a coarser to finer spectral resolution depending on the energy distribution at each stage. The subbands whose energy lies within the predefined thresholds are further sensed with finer resolution in the subsequent stages. For simulations, the signal having three different communication standards such as Bluetooth, Zigbee, and Wideband Code Division Multiple Access were considered.

Applications such as digital channelizers in Software Defined Radios (SDR), digital audio industry, biomedical signal processing, subband adaptive filtering, and communication requires non-uniform frequency partitioning to better exploit the signal characteristics. In such applications, implementation of non-uniform filter banks has elicited enormous interest in multirate signal processing. Non-uniform filter banks were implemented with channel combiner using single and multi-prototype approaches. The non-uniform bands are generated by directly combining the adjacent subbands of uniform filter bank. The prototype filter is optimized in such a way that they are combined at 3 dB cut-off frequency and, thereby satisfies the NPR condition. Single prototype approach had the limitation of more distortion in case of large number of combiners while generating wideband from a narrowband prototype this was overcome by multi-prototype approach. The multi-prototype based method is found to have less complexity and distortions when compared to the single prototype channel combiner based approach.

In order to efficiently use the detected spectral holes, a rate request sequenced bit loading secondary user reallocation algorithm for Discrete Multi Tone (DMT) systems in CR was also proposed. Our algorithm is applicable to DMT systems for secondary user reallocation. DMT systems support different modulation techniques on different subchannels according to the Signal to Noise Ratio (SNR). The maximum bits and power that can be allocated to each subband is determined depending on the Channel State Information (CSI) and secondary user modulation scheme. The spectral holes or free subbands are allocated to secondary users depending on the user rate request as well as subchannel capacity. A comparison is done between random rate request and sequenced rate request of secondary user for subchannel allocation. Through simulations, it is concluded that with sequenced rate request, higher spectral efficiency is achieved.