Methods of Signal Detection and Recognition in Cognitive Radio Networks

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Abstract. The paper employs techniques of signal detection and recognition to perform spectrum sensing in cognitive radio networks. The main focus is on extensive use of signal recognition techniques, which is not the case yet in the context of cognitive radio networks. In particular, the use of unconventional methods of signal recognition allows us to not only divide received signals into classes of those which belong to primary or secondary users but, additionally, register appearance of new, uncategorized, sources of radiation. As a consequence, all considered in the paper procedures may be employed by the local frequency control authorities to monitor radio frequency resource utilization. Performance analysis of presented in the paper algorithms for signal selection and recognition is performed by the method of Monte-Carlo.

Keywords: Cognitive radio networks · Spectrum sensing · Signal · Detection · Recognition

1 Introduction

Nowadays, wireless radio technologies are widely implemented. At the same time, the demand increases rapidly and the frequency resource gets to be quite overfilled. Nevertheless a thorough analysis indicates poor efficiency of frequency band utilization [17]. For example, a large frequency band has been allocated for TV and radio broadcasting services. There are rarely used subbands which may be provided for organizing communication with the aim of collecting data from various sensors of public utilities and security systems, personnel warning systems in hospitals, etc.

The IEEE 802.22 standard has become one of the possible solutions to the problem. It specifies radio systems operation in the 54–698 MHz frequency range. The standard was developed with the concept of cognitive radio (CR) [4,8,11,16,20] in mind. In this case, the system searches for "spectral holes", that is, subbands of the frequency range that are not used at the moment by primary (licensed) users, and provides secondary users with them. In other words, the main task of the CR system [10] is to monitor the dynamics of changes in the broadcast environment of a given frequency range. There are two ways of acquiring information on frequency resource utilization [16], namely

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(i) from the database of the cognitive radio system;
(ii) by direct sensing a given frequency range.

Main methods of processing collected sensing information include:

(i) detection of radio emissions of the primary user transmitter (non-cooperative method);
(ii) detection of radio emissions of the heterodyne of the receiving device of the primary user (cooperative method);
(iii) interference detection method.

To identify unoccupied frequency channels, an analysis of the signal/noise environment in the frequency channels should be carried out first. As a result, a decision is made on the presence in the analyzed subband of either a signal and noise mixture, or noise only. That is, we actually deal with the problem of detecting a signal mixed with noise. It should be noted that signals and noise in frequency channels are normally random. Thus, we usually face the problem of detecting random signals mixed with random noise. And as a consequence there emerges a priori uncertainty with regard to probabilistic characteristics of signals and noise. A literature survey [4,14,16,20,21] yields the following list of the most frequently used methods to detect primary user radio emissions:

(i) energy method;
(ii) method of matched filtering;
(iii) search for cyclostationarity.

The second and third detection methods are based on employing certain information about the signal, while the energy method does not. The energy detector is the most used, due to its low computational complexity and ease of implementation. The main peculiarity of such the method is low detection accuracy at low SNRs, as well as the difficulty of determining the required operation threshold, taking into account the constantly changing signal and noise environment in frequency channels.

The advantage of the matched filtering method is the short observation time to obtain the required values of false alarm or missed detection probabilities. The disadvantages include the need to use a certain type of receiving device to retrieve signals of each class of primary users. This makes the method impractical for widespread use in CR networks.

The method based on discovering cyclostationarity features, makes use of the initial redundancy inherent in the signal. The advantage of the method is that it is capable of discriminating the signal from noise quite well. This is possible even when the wanted signal is below the noise level. The disadvantages of the method include high computational complexity and significant observation time.

Though, there is another option we have in order to perform spectrum sensing with the aim to find free subbands in CR. Namely, we may employ methods of statistical theory of signal detection [6,9,12]. However they require proper learning samples of signals to be provided, which is hardly implementable as we are unable of acquiring learning samples for every radio emission type.