Chapter 13
Improved Spectrum Sensing Based on Polar Codes for Cognitive Radio Networks

Idriss Chana
Moulay Ismail University, Morocco

Reda Benkhouya
Ibn Tofail University, Morocco

Abdallah Rhattoy
Moulay Ismail University, Morocco

Youssef Hadi
Ibn Tofail University, Morocco

ABSTRACT

One challenge of a sensing technique is reducing sensing time while ensuring good effective data rate. In fact, once compressive sensing based on sub-Nyquist sampling is adopted, sensing time can be reduced by saving number of samples. This increases the probability of missed detection which causes collisions with primary service and worsens channel imperfections. In such case erasures occur in addition to errors. In this chapter, the authors propose a new technique to correct erasures while keeping sensing time at a desired level. Based on polar code and low complexity decoding algorithm, the proposed technique exhibits for high code rates better performance in terms of bit error rate (BER) compared to two existing techniques based on other codes, namely low-density parity check (LDPC) and BCH.

INTRODUCTION

Electromagnetic spectrum is a scarce natural resource that needs to be managed. Cognitive radio (CR) is believed to ease congestion and overcome underutilization of the usually called spectrum. However, designing CR networks faces some challenging issues, such as spectrum sensing (SS). SS is a process of identifying the spectrum status for self-usage. The critical function of SS is required to identify spectrum

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status and to determine if the spectrum allocation satisfies the quality of service (QoS) requirements of all users.

Generally, detection performance is characterized by false alarm and missed detection probabilities. False alarm occurs when the SS inaccurately detects primary users. Missed detection occurs when spectrum holes are detected. Moreover, in case of missed detection, this may cause collision between the primary and the secondary transmission.

SS techniques are indeed not perfect. When SS fails, it not only causes collisions, but also increases the error rate. Such imperfections can be handled either by using channel coding techniques, or increasing the sensing time. Both of the methods result in the reduction of effective data rate for secondary users. One can say that increasing sensing time enhances detection, whereas time resource is limited and shared by SS and data transmission. Since the sensing time determines network responsiveness and performance, thus it is necessary to reduce it as minimum as possible. However, reducing sensing time increases collision probability, which causes erasures and data loss along the secondary user bit stream. Thus, to counter such effects, the secondary receiver can employ channel coding technique while maintaining a desired sensing time.

To optimize the performance of the secondary user (SU) without incurring undesirable collisions, one may use P_m as the constraint for ensuring protection of primary users (PU) while setting P_f as the optimization target to ensure maximization of spectrum reuse by secondary users (Lin, Liu, & Hsieh, 2013). Such problem can be formulated as follows:

Minimize Pf, conditional on the constraint of $P_m \leq \varepsilon$ (1)

where ε is the desired threshold for PU protection.

In this chapter, the compressive sensing (CS) is used for detecting the presence of the PU. Authors consider the use of a CS thanks to its applicability to a wideband spectrum, and mathematical amenity. The models in literature have not considered both number of samples and sensing time in CS. These factors are the primary constraints in this chapter. A priori, the sample number M is determined as:

$$M = \tau f_s \tag{2}$$

where f_s is a sampling frequency and τ is sensing time. Obviously from the Equation 2, increasing parameter M increases sensing time, which affects network responsiveness and performance. Nevertheless, decreasing M worsens sensing imperfections.

At given SNR, authors showed in (Benkhouya, Chana, & Hadi, 2016) that there is an appropriate M_e such that no more samples M are required to verify the Equation 1 above. If M_0 is denoted the value of M for which $P_m = 0$, then $\Delta M = M_0 - M_e$ is the number of saved samples. Authors proved that for the CS deployed, there is a time reduction corresponding to $\Delta\tau = \Delta M / f_s$. Since the sensing time is now reduced, this causes erasures and channel coding techniques should be adopted to tackle these defects.

The adoption of channel coding has been studied by Haddadi et al. (2013) using rate-compatible (RC) LDPC codes. And obtained results have proven the effectiveness of the solution. Authors in (Benkhouya,