Chapter 8

Spectral Sensing Performance for Feature-Based Signal Detection with Imperfect Training

Quang Thai
Macquarie University, Australia

Sam Reisenfeld
Macquarie University, Australia

ABSTRACT

In this chapter, the effect of imperfect training data on feature-based signal detection is explored, as it relates to both training time and detection performance in a cognitive radio system. The improved performance of feature-based detection comes at the cost of either having to know in advance the signal features present in primary user transmissions (an unrealistic assumption) or learning them whilst operating “in the field.” Such learning, however, necessarily takes place with signal sets which do not perfectly represent the features of the primary users’ modulated signals. Using a two-stage detector performing both feature training and sensing functions, it is shown in this chapter that reducing the learning time generally results in poorer detection performance and vice-versa. A suitable trade-off between these two outcomes is obtained by optimizing a cost function that takes both factors into consideration. Cyclostationarity detection is specifically considered.

INTRODUCTION

The flexible and on-demand nature of wireless communications has seen it become increasingly ubiquitous in recent years, and it has become the focus of research and development activities that seek out new ways in which it can improve and enrich quality of life. The proliferation of wireless applications has also required a rethink of how the radio environment is used and how radio spectrum is planned and managed. In order to support both increased demand for existing wireless applications as well as new ones yet to be foreseen, either new exploitable radio spectrum must be found, or the existing spectrum

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must be used more efficiently. It has been proposed that the latter measure be met in the near future by equipping wireless devices with cognitive radio capabilities. Such devices would be able to recognize and exploit radio channels that were unutilized or under-utilized by existing primary networks for their own communication needs via a secondary network, effectively allowing channels to be multiplexed amongst these networks.

To be able to recognize such channels, cognitive radios must be able to perform spectral sensing (or spectrum sensing) - the process of determining whether or not a spectrally defined channel is in use at a particular time. A cognitive radio, as a secondary user, must perform spectral sensing for a number of spectrally separated channels to determine which of the channels are being used by primary users and which channels are available for exploitation. The reliable detection of the absence of primary user transmission on a channel establishes an opportunity for secondary user transmission on that channel. Correspondingly, the reliable detection of the presence of primary user transmission on the channel identifies the secondary user requirement to stop transmission on that channel and change to another channel for subsequent transmissions. This use of spectral sensing by the secondary user is referred to as “detect and avoid” (Reisenfeld, 2009).

Many spectral sensing algorithms have been considered for implementation in cognitive radio (Yucek & Arslan, 2009). Good detection performance has been obtained from detectors which use known patterns, or features, of the primary user modulated signal. However, cognitive radio transmission is over dynamic, fading channels with rapidly changing characteristics. It would not be reasonable to expect that a spectral sensing algorithm could be pre-programmed with all the known patterns or features of the modulated signals for all classes of primary users. Furthermore, the patterns may be modified by the specific channel characteristics which may be encountered. Therefore, it is extremely advantageous for feature-based detectors to train themselves to recognize the signal features of primary user transmissions using channel output observations.

A feature-based approach is used in cyclostationarity detection (Yucek & Arslan, 2009). A cyclostationarity detector has been described where the detector was trained to recognize features for the recognition of various classes of modulated signals (Thai & Reisenfeld, 2011). The training set consisted of signal observations where the primary user is known to be transmitting, and this was used to obtain the required features. This training set was ‘perfect’ because it was known that all observations contain primary user features. In an operational environment, this perfect training set is unavailable. The same operational environment must then be used to conduct training for spectral sensing. Supervised learning is achieved with an ‘imperfect’ training set - so-called because it may contain observations where the primary user signal is, in fact, absent.

In the remainder of this chapter, a general approach for training feature-based detectors in the field will be described. This approach is applicable to any algorithm which relies on a training set. The degradation in performance due uncertainty in the imperfect training set will be described.

**BACKGROUND: A MODEL FOR TRAINING USING FIELD CHARACTERISTICS**

In supervised learning, learning algorithms require a training set to determine the specific features which may be used for discrimination and classification. In cognitive radio applications, as mentioned previously, it may be required to obtain the training set from field observations. In previous work, training