Spectrum Sensing for Cognitive Radio based on RVM

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Abstract

In a complex geographical environment, communication quality of communication equipment is being seriously challenged. Secondary Users(SUs) must make the best possible use the idle spectrums that Primary Users(PUs) do not use and change spectrum frequently. Using the relevance vector machine(RVM) to establish a signal noise Ratio(SNR) Model for interference information and bit error rate(BER). Through the model and real-time interference information, the minimum channel SNR meeting the BER requirements of communication equipment can be predicted, and we can also calculate the minimum transmitted power. According to the simulation results, this method has better performance for selecting available channel and restraining interference.

1. Introduction

Due to more than 20 years, radio communication technology has developed rapidly and radio spectrum is becoming more and more scarce. To solve the problem of spectrum scarcity, cognitive radio(CR) is being developed.

CR is a radio that can be programmed and configured dynamically to use the best wireless channels in its vicinity to avoid user interference and congestion. As an emerging technology, CR is getting more and more attention. And selecting channels with high availability is an another good method to increase spectrum utilization. Through building mapping model among interference information, BER and SNR based on RVR can select available channel and restrain interference.

2. Related Work

The cognitive ability of Cognitive Radio (CR) is the real reason for moving it from concept to practical application. With enough artificial intelligence, it is possible to respond to real-world situations in real time by drawing on past experience, including past knowledge of dead zones, interference, and usage patterns. Thus, it is possible for the CR to give the radio the function of determining which frequency band to use based on the band availability, location and past experience. With the development of many CR-related research, there are many different understandings of CR technology. The most typical one is around Dr. Mitola.

In response to various descriptions in CR research, the US FCC proposed a rather simplified version of CR. They suggested in FCC-03322 that any radio with adaptive spectrum awareness should be called cognitive radio CR. The FCC more precisely defines CR as a radio that dynamically changes its transmitter parameters based on interaction with the operating environment, with the functionality of context sensing and self-modification of transmission parameters. CR is a new type of radio that reliably senses the spectrum environment over a wide frequency band, detects the presence of legitimate authorized users (primary users), and can adaptively occupy locally available locals.

3. SNR model

Signal-to-noise ratio (SNR or S/N), the power of the amplifier's output signal, is often expressed in decibels as the ratio of the output noise power to the output noise power at the same time. Through SNR model, we can easily see whether the channel quality is good or bad.

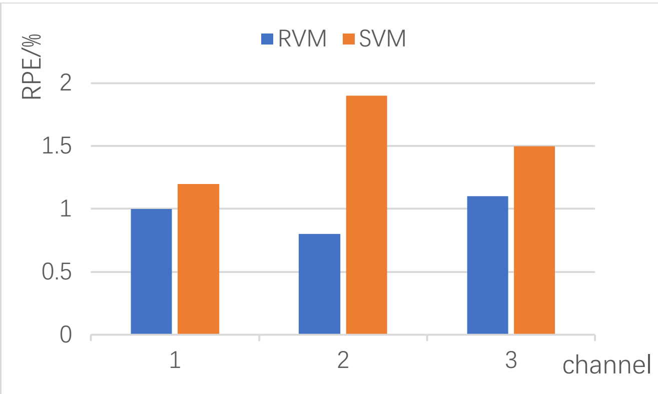
Establishing SNR model is to establish regression relation between interference information, BER and SNR. Generally, there are three ways to establish regression relation. neural network, relevance vector machine (RVM) and support vector machine (SVM).

Neural network is not applicable to few samples. Compared with SVM, the greatest advantage of RVM is reducing the computational complexity of the kernel function When dealing with non-linear problems so RVM is more time-saving. And the kernel function of RVM does not need to satisfy Mercer condition.

The RVM is a sparse probability model that similar to SVM and is a new supervised learning method. RVM is widely used in pattern recognition, data classification and regression prediction.

To further compare RVM and SVM through a simple simulation experiment. Set up three channels, channel 1 has no interference source, channel 2 has 2 interference source and channel 3 has 1 interference source. And use Relative Percentage Error(PRE) as the evaluation criterion. Usually, within 10% of PRE, the model can be considered more accurate.

Experimental result is shown on Fig. 1.



(Fig.1) RPE value of BER for channels

According to the experimental results, we can see that PRE of RVM and SVM are both less than 10%. And RVM has less error than SVP, so we decided to use RVM to build the SNR model.

4. Relevance Vector Machine Method

The Model expression of RVM is:

$$t_i = y(x_i + \mathrm{w}) + \ \varepsilon_i$$

x_i is input vector
t_i is input vector
ε_i is gaussian noise that mean value is 0 and variance is σ^2

So the output model of RVM is:

$$y(x,w) = \ \Sigma_{i=1}^{N} \ w_i \ K(x,x_i) + \ w_0$$

$K(x,x_i)$ is kernel function.

The different from SVM is that hyper parameter (a) is introduced in RVM. RVR is a machine learning based on Bayesian framework that can get more sparse results than SVM. Hyper parameter affects the sparsity of the model.

Prior distribution function is :

$$P(w,a) = \ \Pi_{i=0}^{N} \ N(w_i \ | \ 0, a^{-1} \ )$$

Posterior distribution function is :

$$P(w|t,a,\sigma^2) = \frac{P(t|w,a^2)P(w|a)}{P(t|a,\sigma^2)}$$

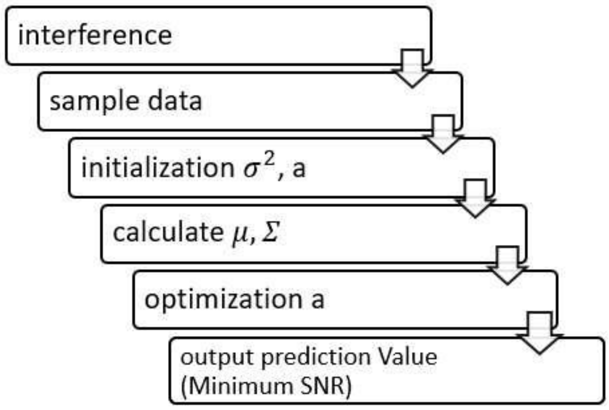
Optimizing parameters by iteration formula :

$$a_i^{new} \ = \frac{1 - a_i \Sigma_{ii}}{\mu_i^2}$$

$$(\sigma^2)^{new} \ = \frac{||t - \Phi_\mu \ ||}{N - \sum_i \ (1 - a_i \sum_{ii} \ )}$$

μ is posterior mean value

RVM training process is shown on Fig. 2.



(Fig.2) RVM training process

5. Simulation

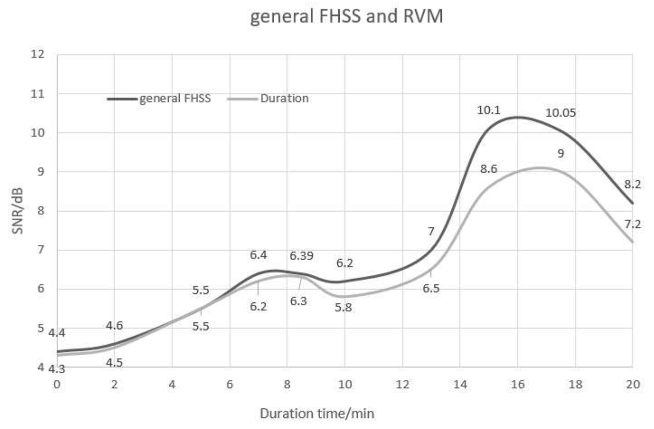
There are Primary Users(PUs) and secondary Users(PUs) in a cognitive radio network. SUs can use the spectrum when PUs are not in. Once PUs appears, SU must give up the spectrum and find the other available spectrums.

Through RVM model, we can predict the minimum SNR and select the available channels that satisfy the minimum SNR.

Let one SU use the spectrum and check whether the next spectrum meets the standard. Once PUs appear, the SU quickly changes to other available spectrum that detected before and check whether the next spectrum meets the standard again.

Make PUs active for 20 minutes and increase the occurrence frequency of PUs and interference Over time to conduct simulation experiments

Experimental result is shown on Fig. 3.



(Fig.3) General FHSS and RVM

6. Conclusion

This paper is based on RVM model, proposed A new idea of spectrum sensing.

According to the experimental results, the RVM need less SNR than can achieve the same bit error rate as general Frequency-Hopping Spread Spectrum(FHSS), especially when interference increases.

In addition, using Principal Components Analysis(PCA) can realize dimension reduction but also can reduce model accuracy which deserves further study

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