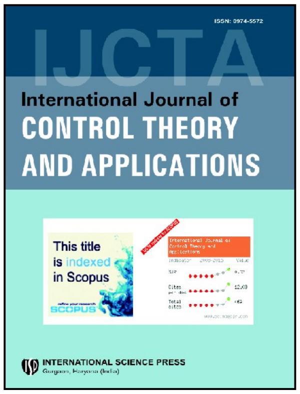

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Spectrum Prediction in Cognitive Radio Networks Using Neural Networks

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Abstract: In Cognitive Radio Networks, the secondary user, which opportunistically use the service needs to vacate the channel whenever primary user comes back. To know the re-entry of primary users, the secondary users has to sense the Spectrum Periodically which will become obstruction to the transmission or reception of secondary users. To overcome this problem, spectrum prediction is useful. Neural Network Based Spectrum Prediction is explored in this paper. This can improve the Spectrum Utilization of secondary users. By making use of the prediction information, the secondary user will have a fair idea of when the Spectrum would be available with less Occupancy. With the help of this Knowledge, it can use the spectrum without many discontinuities. The performance of Prediction is measured in terms of Mean Square Error and Regression with respect to number of training samples of data pertaining to Spectrum Occupancy of earlier days and months.

Keywords: Cognitive Radio, Spectrum Prediction, Neural Networks, Mean Square Error, Regression.

1. INTRODUCTION

Radio Frequency Spectrum is a valuable and limited resource. Any wireless device needs this frequency resource for its transmission or reception purposes. While some prime services like television broad casting, cellular phones, AM and FM radio etc. can afford for licensed spectrum, applications like Wi-Fi, Bluetooth, Zigbee etc. need to depend on unlicensed bands. Though most of the radio frequency spectrum is lend for licensed users, their utilization is very less [1] with respect to time, space and frequency. On the other hand so many small application users (Secondary Users) starve for spectrum due to overcrowding in unlicensed ISM (Industrial, Scientific and Medical) bands, which can be used freely. This situation arises not entirely due to limited nature of the spectrum but also due to its inefficient utilization. Cognitive Radio Technology [2] is a solution in this direction to enable the efficient usage of radio frequency spectrum, by allowing the non-licensed users also to use the licensed spectrum, when it is not in use by the licensed user. These opportunistic spectrum users are called secondary users while the authorised spectrum users are known as primary users.

The life cycle of cognitive Radio is shown in Figure-1 [3]. The first task to be performed by secondary user is to sense the spectrum periodically for identifying vacant channels. When it comes across such vacant channels, it can use it for its communication purposes. But it should continue the spectrum sensing mechanism while using it also, to know about the reappearance of primary user, so as to vacate the spectrum to make it interference-free channel to the primary user. Usually, after getting the vacant spectrum information from sensing mechanism, Spectrum analysis and decision block will analyze and decide which spectrum hole is suitable for which secondary user. The function of spectrum mobility is to vacate the occupied channel of primary user, who returns back. In cooperative usage scenario, the primary user will intentionally give the spectrum to secondary user for helping its communication or for some profit. In this case spectrum sensing is not required.

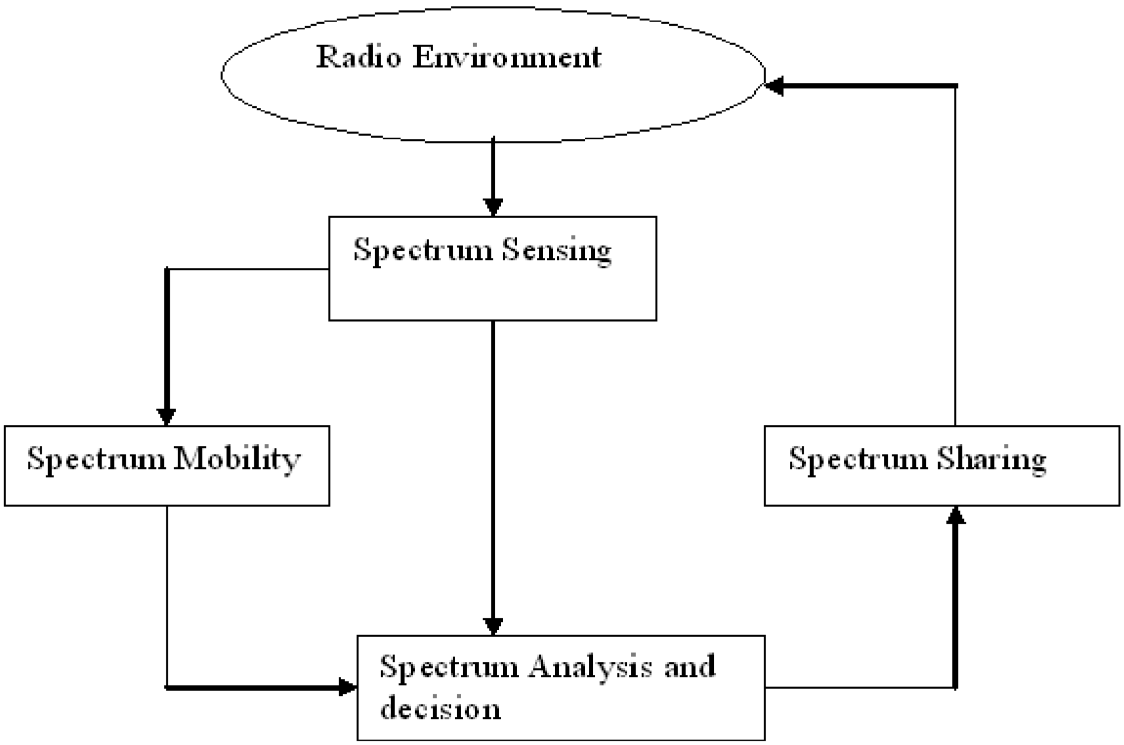

Figure 1: Life Cycle of Cognitive Radio

However, in opportunistic usage scenario, secondary users need to sense the spectrum continuously to find vacant channels. When the secondary user finds a spectrum hole it starts using it, but with a condition that it vacates the channel immediately after the primary user comes back. For this to happen, it needs to sense the channel periodically even after getting the channel, which will disturb its transmission or reception continuously. In addition to this, primary users will suffer from interference if the switching or termination speed of secondary user is less compared to response time of primary users. Spectrum prediction can help to reduce the above mentioned problems of primary and secondary users, by predicting the vacant spectrum at various times.

In this work, Neural Network based prediction is used to predict the vacant channels status in advance, so that the secondary user can plan to avail the channel when it is relatively free. It also enables the secondary user to vacate the channel quickly whenever Primary User comes back, which results in reduced or no interference to Primary Users. Through this, sensing time and energy of secondary users are saved, because it senses only when it is found that Primary User is coming back instead of all the time continuously. However, to support the unexpected re-entries of the primary user, some mechanisms like the message passing through control channels, will be needed.

The remaining part of this paper is organized as follows. Section 2 describes related work. Proposed work is explained in section 3 and Results are illustrated in section 4 Section 5 concludes the paper.

2. RELATED WORKS

To overcome the operational delays involved in sensing, sharing, analysis and decision making spectrum prediction is proposed to be used in cognitive radio networks. Various spectrum prediction techniques like Hidden Markov Model based prediction, Multi layer perceptron neural network based prediction, Bayesian Interference based prediction, Moving Average based prediction and static neighbor graph based prediction are proposed in literature [3]. Usually, secondary users need to sense the radio frequency spectrum and respond according to the available channels at that instant. But it may result in wrong decision, if the primary user corresponding to that channel is using it heavily, during that time, and a brief non-usage is sensed by the secondary user.

This may cause continuous channel hopping to secondary users that results in degraded QoS. In [4], arrival rates and holding times of primary users is predicted to overcome the problem of temporal connection loss for secondary users and interference to primary users. It also mentioned that, to avoid confliction problem, response time of primary users should be greater than the switching time of secondary users. As is known, spectrum sensing consumes significant energy and time of secondary users.

The authors of [5] employed neural network based prediction using multi layer perceptron and Hidden Markov model to predict spectrum holes. The advantage of neural network based prediction is that, it doesn't require any prior knowledge of primary user's modulation schemes, usage frequency etc like coherent detection. Spectrum hole prediction based on historical data is carried out in [6]. They arranged the predicted idle channels in the order of their decreasing probability of being idle, so that whenever the secondary user needs to vacate the channel, it can automatically occupy the most probable idle channel.

Due to hardware limitations, the sensing results of secondary users may not be reliable and the sensing is related to only a limited region. To overcome this problem and to save time and energy of secondary users, prediction is introduced in [7]. The secondary users are supposed to switch its operational frequency adaptively, otherwise their quality will be degraded abruptly. In [8] Multi Layer Perceptron based prediction is used to overcome this problem by predicting the idle channels list in advance. Genetic algorithm is used to optimize the weights of neural networks to have accurate and reliable prediction in [9].

3. PROPOSED WORK NEURAL-NETWORK BASED SPECTRUM

Prediction is carried out in this work. Basically a neural network contains an input layer, some number of hidden layers and an output layer. The number of neurons present in input layer is representing number of input parameters that decide the outputs. The number of output variables reflect the number of output neurons. Each input parameter has its own weight. From each input neuron to each hidden neuron connection is made and each connection has its own weight. Similarly from each hidden neuron to each output neuron, connections are made with own weights as shown in Figure 2.

The prediction of spectrum using neural network contains three phases. They are training phase, validation phase and test phase. During training phase, the weights are being modified to give correct prediction. Validation phase is used to generalize the weights and testing will be taking place in test phase.

In this model one hidden layer is considered with a delay of two seconds. Levenberg marquardt algorithm is used for training. The training samples are taken from uniform random distribution. The performance of prediction is measured in terms of regression and Mean Square Error.

4. RESULTS AND DISCUSSION

By changing the percentage of training samples, error is computed, which indicates the difference between target and output. How error is varying with respect to time for 90% training samples is shown in Figure 3. Figure 4 illustrates the same information for 70% training samples. It can be observed from Figures 3 and 4 that error is half fold for just 20% increment of training samples.

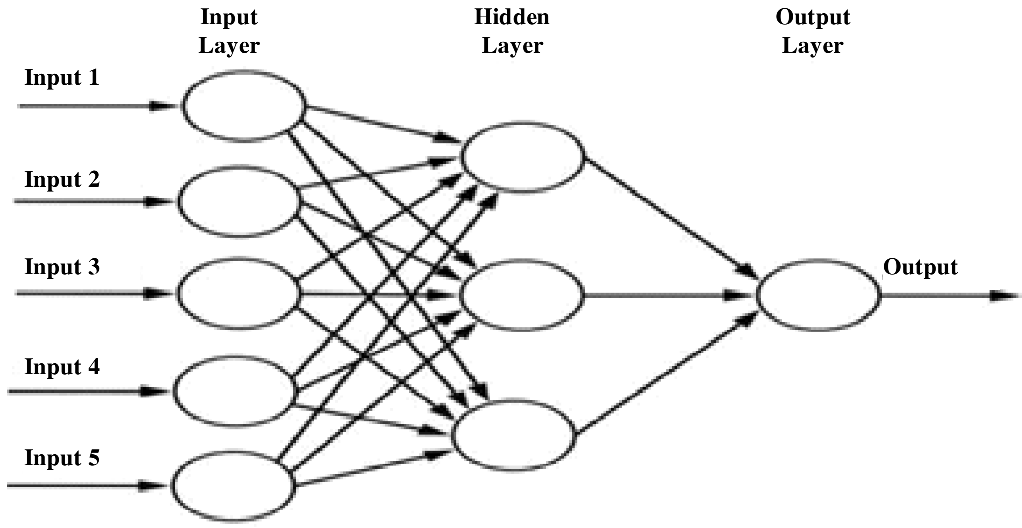

Figure 2: Basic Model of Neural Network

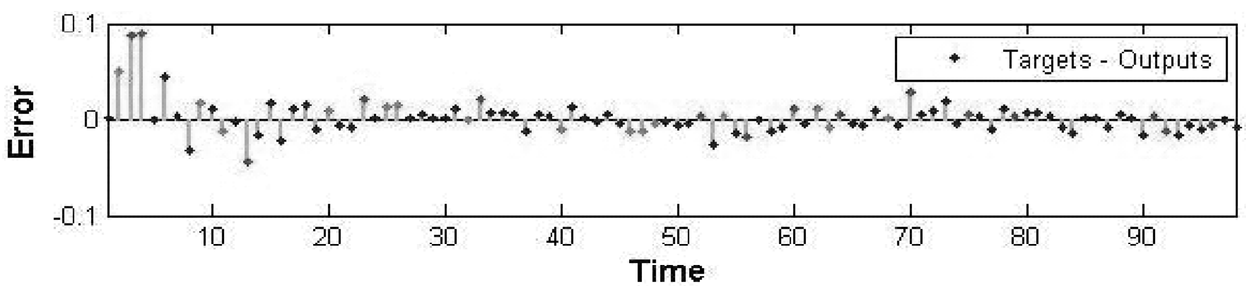

Figure 3: Error for 90% Training Samples

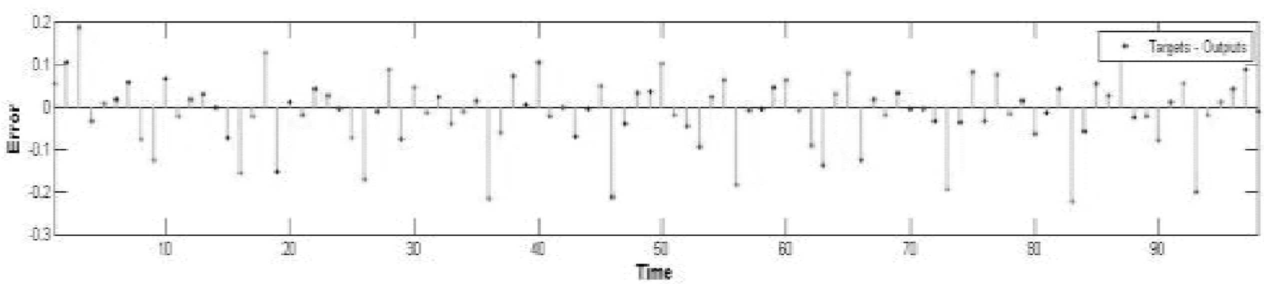

Figure 4: Error for 70% Training Samples

By varying the percentage of training samples, Regression and Mean Square Error are observed. Figure 5 shows how regression is varying with respect to percentage of training samples. It is observed that regression is increasing with increase in number of training samples. Regression relates the mean value of original data with mean value of predicted data. The highest value of regression is one indicating the complete correlation.

The variation of Mean Square Error is shown in Figure 6. It is observed that Mean Square Error is decreasing with increase in percentage of training samples. About 33% Mean Square Error is reduced with increase of training samples by sixty percent. The ideal value of mean square error is zero, that indicates zero prediction error.

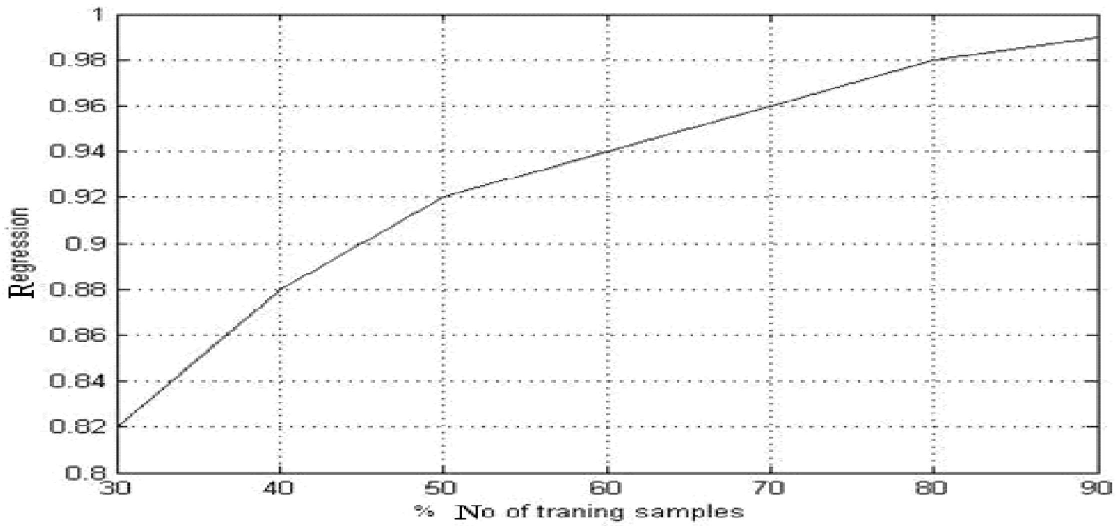

Figure 5: Regressions no of Training samples

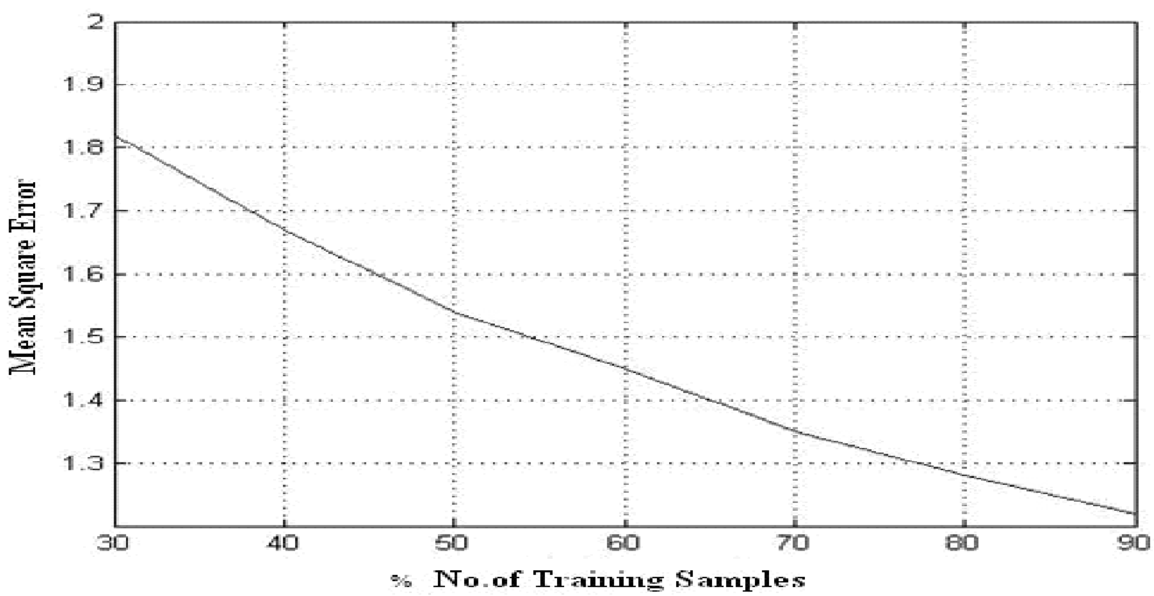

Figure 6: Mean Square Error Vs No Of Training Samples

5. CONCLUSION

Spectrum prediction using neural network based approach is carried out in this work. Advantages like reduced primary user interference and saving of energy and time for sensing by secondary devices, can be achieved, with the help of this prediction. It also results in effective utilization of bandwidth. From the results it is observed that higher levels of training offers accurate prediction of about 90 percent.

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