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Study on Spectrum Sensing Techniques

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Abstract

Cognitive radio is a recent emerging technology for effective use of spectrum. To provide newer opportunities in advanced wireless communication system. Spectrum sensing and security are the key issues of Cognitive Radio (CR). The main aim of Cognitive Radio (CR) is to detect unused or idle frequencies of cellular spectrum, not used by Primary User (PU's). Practically PU's frequencies can be idle or busy. The goal is to investigate spectrum sensing predictive methods. These methods find idle or busy states of frequencies at discrete interval of time periods. The decision is made to assign these free frequencies to Secondary Users (SU's). For this we use Machine Learning (ML) techniques to improve its performance, usability and efficiency. A machine learning system includes pre-processing, feature extraction and decision making classifier.

This paper lists recent research activities and co-operative spectrum sensing. Identification of CR terminals is done by predictive spectrum sensing methods. Machine learning algorithm are used for classification.

Keywords

Cognitive Radio (CR), Primary User (PU's), Secondary Users (SU's), Machine Learning (ML), Software Defined Radio (SDR), Low Noise Amplifier (LNA).

Introduction

Now a day's requirement of bandwidth has increased a lot. This forced research community to find new better techniques for radio spectrum utilization. To achieve this goal the dynamic usage of cellular spectrum is required. Spectrum sharing capability results to higher spectral efficiency. Cognitive Radio recognizes spectrum white spaces which are idle & can be reused by secondary users (SU's).

A main role of a CR is to detect white spaces and based on priority allocate to SUs. This increases the spectral efficiency and the channel capacity. The '**Shannon Channel Capacity**' is given by $C = B\log(1 + SNR)$. Where C is channel capacity, B is Bandwidth and SNR is signal to noise ratio. To fulfill the user requirement spectrum needs to be managed effectively. This adaptive spectral efficiency of 4G network is reaching to Shannon limit. Thus Cognitive radio enables next generation networks to utilize the spectrum more efficiently.

A nut shell CR gathers information regarding transmission frequency, BW, power, modulation of the serving area. Using this information SU's can identify the idle or unused spectrum. To achieve the optimal performance SDR re-configurable device can be used to meet the CR requirements. Dynamic channel allocation between PU's & SU's are to be done in seamless manner.

Figure 1 shows basic concept of sensing CR spectrum of cellular systems. It consists of three basic task; (1) Radio Environment: In the available cellular spectrum SU's need to identify unused frequencies dynamically among PU's. (2) Adaptive spectrum management: Spectrum Sharing, Decision & Allocation all together is referred as adaptive spectrum management. CR selects the best available bands for other cellular service (viz white TV, Wireless LAN, Wireless sensor network etc.) and (3) Spectrum Mobility: Reconfigurable device like SDR (SU's) can adaptively change its transmission parameters (carrier frequency, power level, channels BW etc.).

Sensing

It is a continuous process where in information about cellular network behavior is gathered for allocation SU's for real time application. Many research community has discussed different sensing techniques such as radio identification based sensing, cyclo-stationary feature detection, energy detection and cooperative spectrum sensing, matched filter detection, waveform based sensing.

Radio-Scene Analysis

The process of radio environment is to identify unused or idle frequencies & allocate it to SU's dynamically

Decision

The probabilistic models are used for cooperative decision in allocating SU's by soft & hard process.

Action

Statistical models are used to predict the radio environment parameters for mutual allocation among many SU's.

Learning

Stochastic information for geographically based activity are monitored by ML algorithms for real time CR implementation.

Radio Environment

Reconfigurable Transmitter & Receiver cellular unit.

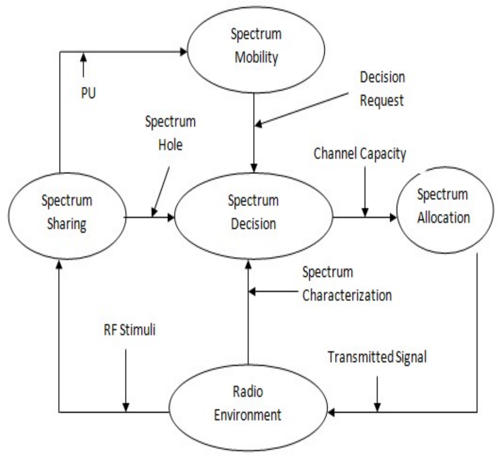

Figure 1: Cognitive Radio Cycle

Materials and Methods

Spectrum Sensing Setup

The figure 2 shows the experimental setup that is to be used for our research. The antenna is used to receive particular wideband spectrum & it is followed by Low Noise amplifier (LNA). The Fast Fourier Transformer (FFT) analyzer is used to measure frequency components at discrete intervals of time. The real time data is collected from different cellular network at different time interval & geographical location. This helps us to analyze the spectrum usage of PU's on hourly, daily basis at different geographical locations. Furthermore, detail experimental analysis can be carried out for cooperative, non-cooperative predictive statistical models. ML approach may help us to allocate SU's to access unused or idle frequency slots.

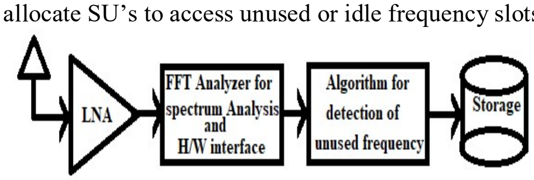

Figure 2: Spectrum Measurement Experimental Setup

The main challenge in CR is spectrum sensing. Fig 3 shows spectrum sensing techniques that are used to dynamically sense & allocate cellular channel.

Transmitter Detection

Different detection methods are used to identify PU's based on signal parameters.

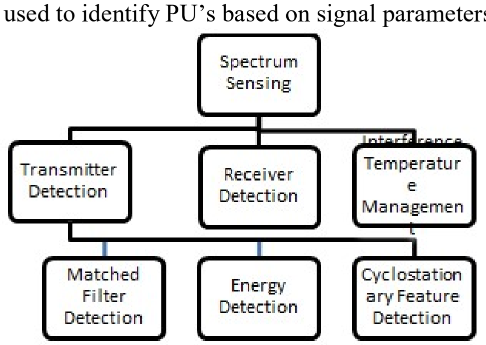

Figure 3: Spectrum Sensing Techniques

Matched Filter

Matched filter is an optimum filter widely used for gathering spectrum information of PU's. It also detects presence and absence of PU's. Advantage of matched filter is, it requires less time for high processing gain. Disadvantage is CR needs a dedicated receiver for every PU's. [1-4]. Refer figure-4

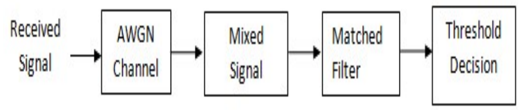

Figure 4: Matched Filter

Energy Detection

For fading environment matched filter is not an optimal choice to sense CR. To measure random received signal strength squaring method is used to detect PU's. Furthermore, probability of detection (Pd) and probability of false (Pf) alarm are used in detection of PU's. A low value of Pd indicates an absence of PU's thereby CR can use that spectrum with higher chance. A high value of Pf indicates lesser use of spectrum [5-7]. Refer fig-5 for energy detection

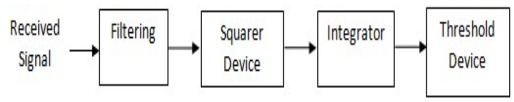

Figure 5: Energy Detection

Cyclo-stationary Feature Detection

Auto correlation method is used to extract the signal information of PU's such as mean, autocorrelation and periodicity. These parameters help to identify type of modulation scheme, symbol order and presence of signal interference. The correlation coefficient is used to decide the presence and absence of PU's in CR network. To find these parameter computational time is more this degrades the performance of CR [8-9]. Refer figure 6

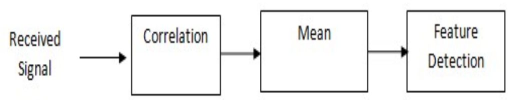

Figure 6: Cyclo-stationary Feature Detection

Cooperative Based Detection

Artificial intelligence is used learn the spectrum activity. However many challenges are faced while applying ML techniques [10-22].

The taxonomy of ML techniques is shown in figure 7.

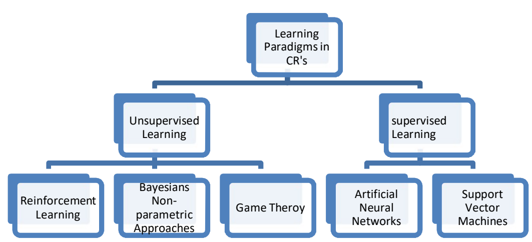

Figure 7: Typical Problems in CR and Corresponding Learning Algorithm [21]

Supervised Learning

It's guided by a teacher. It needs to be trained. It is task driven. This algorithm builds a mathematical model of a set of data that contains both input & target. Here we first train the model with the lots of training data (input & target). Using new data we get the output we predict. Exact output may not be obtained but it will be very close to it. Variation in output depends upon the training data & algorithm. Classification & regression algorithms are used in supervised learning.

Unsupervised Learning

It is self-sufficient in learning. It is data driven. Here training data is not structured. This algorithm builds a mathematical model of a set of data which contains only input & no desired output. The training data doesn't include the target. Here we don't tell the system where to go. The system has to understand itself from the data we give. Hence called an unsupervised learning. Clustering & anomaly detection are used for unsupervised learning. As its bit difficult to implement it's not widely used as supervised.

Comparison between supervised & unsupervised learning methods are listed in table-I & between few algorithm are listed in table-II

Supervised Learning	Unsupervised Learning
Output data is known	Output data is unknown
Very complex computational complexity	Less complex computational complexity
Does off-line analysis of data	Does real time analysis of data
Results are more accurate & reliable	Results are moderate accurate & reliable
Needs a teacher to train	Self-sufficient in learning
Task driven	Data driven
Model consists of both input & target	Model consists of only input & no desired output
Training data is structured	Training data is not structured

Table 1: Comparison between Supervised & Unsupervised Learning.

	Techniques	Advantages	Disadvantages
Unsupervised learning techniques [24]	Reinforcement learning (RL)	1. Gives optimal solution for MDP's 2. Groups on off-policy & on-policy	1. for discrete number of states is more
	Non-parametric Learning	1.Deals with random variables having probability distributions 2.Provides solid decision theoretical framework	1. Selection of priory information is difficult , this may leads error in generating results. 2. Computational time is more for large number of variables
	Game theory	1. Uses scientific quantitative technique to arrive at an optimal strategy for multi-players. 2. Develops a framework for analyzing decision making	1. Not able to analyse all the competitive problems. 2. Requires knowledge of parameters which is not possible all the time.
Supervised learning techniques [24]	Artificial Neural Network (ANN) [23]	1. Ability to produce approximated results for incomplete information 2. This has memory, hence training is easy and produces accurate result 3. It has entire network information	1. Can be over trained 2. If not trained properly, it can lead to wrong class label 3.More computational time 4. Hardware dependant 5. No specific rule for structure of ANN
	Support Vector Machine (SVM) [24]	1.Computation time is less High chance of precision for unstructured data (text, images and trees) 2.It has memory 3. Avoids over fitting 4. Uses kernel hence useful in solving complex problems	1. Cost of increased memory and computing resources 2. Selection of good kernel is not easy 3. Training time is more for larger data set

Table 2: Comparison of Algorithms

Characteristics of Efficient ML [21]:

1. Learning methods to observe CR networks .
2. Cooperative method in distributed CR network.
3. Adaptive learning in unknown radio network.

Spectrum Sensing Challenges [21-22]:

1. Channel Uncertainty: Cellular system network have lot of uncertainty. This is due to channel fading. At most care will be taken while allocating SU's under such channels.
2. Noise uncertainty: CR should detect minimum SNR of PU's so that SU's can be allocated for unused frequency of PU's.
3. Aggregate uncertainty: Cooperative spectrum sensing techniques are required to avoid wrong selection of PU's. This is due to increase in SU's; this creates more interference among them.
4. Sense interference limit: The prime epitome of sensing spectrum is to identify unused frequency bands effectively in a cellular band.
5. Hardware requirements: For real time dynamic spectrum sensing the experimental setup requires high dynamic range and higher sampling rate Analog to Digital convertor. Low noise amplifier with high speed processor for recording spectrum activity.
6. Detection capability: In multi user CR network PU's are to be identified in minimum time to serve more number of SU's
7. Security: Due to non-cooperative operation of SU's may improper usages of PU's spectrum.
8. Spread spectrum primary user detection: In wide band network it is difficult to detect PU's as power is distributed over wide frequency range.

Expected Outcome of the Proposed Project

1. Creation of different cellular spectrum data base for different geo-locations
2. Novel model to identify and to classify PU activities
3. Result validation of system
4. Contribution to the society as a new technology

Conclusion

In cognitive radio network spectrum sensing is key process. We have studied different technique and challenge to sense the spectrum and details are discussed in this paper.

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References

1. T. Yucek and H. Arslan, “A survey of spectrum sensing algorithms for cognitive radio applications,” IEEE Communications Surveys and Tutorials, vol. 11, no. 1, pp. 116–130, 2009.
2. Y. Zeng, Y.-C. Liang, A. T. Hoang, and R. Zhang, “A review on spectrum sensing for cognitive radio: challenges and solutions,” EURASIP Journal on Advances in Signal Processing, pp. 1–16, 2010.
3. A. Sahai and D. Cabric, “Spectrum sensing: fundamental limits and practical challenges,” in Proc. IEEE International Symposium on New Frontiers in Dynamic Spectrum Access Networks (DySPAN), 2005.
4. D. Cabric, A. Tkachenko, and R. Brodersen, “Spectrum sensing measurements of pilot, energy, and collaborative detection,” in Proc. IEEE Military Communications Conference, pp. 1–7, 2006.
5. H. Urkowitz, “Energy detection of unkown deterministic signals,” Proc. IEEE, vol. 55, no. 4, pp. 523–531, 1967.
6. D. Cabric, A. Tkachenko, and R. W. Brodersen, “Experimental study of spectrum sensing based on energy detection and network cooperation,” in Proc. ACM 1st International Workshop on Technology and Policy for Accessing Spectrum (TAPAS), 2006.
7. H. Urkowitz, “Energy detection of unknown deterministic signals,” Proc. IEEE, vol. 55, pp. 523–531, Apr. 1967.
8. W. A. Gardner, “Exploitation of spectral redundancy in cyclostationary signals,” IEEE Signal Processing Magazine, no. 2, pp. 14–36, 1991.
9. S. Enserink and D. Cochran, “A cyclostationary feature detector,” in Proc. 28th Asilomar Conference on Signals, Systems, and Computers, pp. 806–810, 1994.
10. L. Chen, J. Wang, and S. Li, “An adaptive cooperative spectrum sensing scheme based on the optimal data fusion rule,” in Proc. IEEE International Symposium on Wireless Communication Systems (ISWCS), pp. 582–586, Oct. 2007.
11. Xiaoshuang Xing; Tao Jing; Wei Cheng; Yan Huo; Xiuzhen Cheng, "Spectrum prediction in cognitive radio networks," Wireless Communications, IEEE , vol.20, no.2, pp.90,96, April 2013
12. He and et al. “A survey of artificial intelligence for cognitive radios”, IEEE Transactions on Vehicular Technology, 59:1578{1592, May 2010.
13. D. Duna, L. Yang. And J. princep, “Cooperative diversity of spectrum sensing for cognitive radio systems,” IEEE Transaction on signal processing, vol. 58, No. 6, PP. 3218-3227, June 2010.

14. J. Unnikrishnan and V. Veeravalli, “Cooperative Sensing for Primary Detection in Cognitive Radio”, IEEE Journal of Selected Topics in Signal Processing, vol. 2, No. 1, Feberuary 2008.
15. T. Yücek and H. Arslan, “A survey of spectrum sensing algorithms for cognitive radio applications,” IEEE Communications Surveys and Tutorials, Vol. 11, No. 1, pp. 116–130, March 2009.
16. B. Wang "Advances in Cognitive Radio Network: A survey" IEEE Journal, Select Topics in Signal Processing, vol. 5, No.1, pp. 5-23, February 2011.
17. J. Wang, “Emerging Cognitive Radio application: A survey,” IEEE Communication Magazine, vol. 49, No. 3, pp. 74–81, March 2011
18. S. Haykin, “Cognitive radio: brain-empowered wireless communications,” IEEE Journal on Selected Areas in Communications, vol. 23, no. 2, pp. 201–220, Feb. 2005
19. J. Meng, W. Yin, H. Li, E. Hossain and Z. Han, “Collaborative Spectrum Sensing from Sparse Observation in Cognitive Radio Networks, ”IEEE JOURNAL on selected areas in communications, vol. 29, No. 2, pp. 327-337, February 2011.
20. Telfik Yucek and Huseyin Arslan “A Survey of spectrum sensing algorithms for cognitive Radio applications” First Quarter 2009 IEEE communication Surveys & tutorials,Vol.11.No.
21. Mario Bkassiny, Yang Li , and Sudharman K. Jayaweera,, A Survey on Machine-Learning Techniques in Cognitive Radios, IEEE COMMUNICATIONS SURVEYS & TUTORIALS, VOL. 15, NO. 3, THIRD QUARTER 2013.
22. Arpita Mandal and Sabyasachi Chatterjee , “A comprehensive Study on Spectrum Sensing and Resource Allocation for Cognitive Cellular Network” , IEEE, 2017 Devices for Integrated Circuit (DevIC), 23-24 March, 2017, Kalyani, India.
23. Ms. Vijaylaxmi.P.Jain, et.al. “Sleep Stages Classification Using WaveletTransform & Neural Network“, Proceedings of the IEEE-EMBS International Conference on Biomedical and Health Informatics (BHI 2012) Hong Kong and Shenzhen, China, 2-7 Jan 2012.
24. S. N. Sivanandam, S. N Deepa, “Introduction to Neural Networks Using Matlab 6.0”, Tata McGraw-Hill Education.

