SIMULATION OF COOPERATIVE SPECTRUM SENSING USING COGNITIVE RADIO

A

PROJECT REPORT

Submitted in partial fulfilment of the
requirement for the award of the degree
of

BACHELOR OF TECHNOLOGY

Under the guidance

of

Dr. T. P. Sharma

By

SHIVANGI ANEJA[11551]

DEPARTMENT OF COMPUTER SCIENCE AND ENGINEERING

NATIONAL INSTITUTE OF TECHNOLOGY

HAMIRPUR-177 005 (INDIA)

MAY, 2015

NATIONAL INSTITUTE OF TECHNOLOGY HAMIRPUR

CANDIDATES'S DECLARTION

We hereby certify that the work which is being presented in the project titled "**Simulation Of Cooperative Spectrum Sensing Using Cognitive Radio**" in partial fulfilment of the requirements for the award of the Degree of Bachelor of Technology and submitted in the Department of Computer Science & Engineering, National Institute of Technology, Hamirpur, is an authentic record of our own work carried out during a period of January, 2015 to May, 2015 under the supervision of **Dr. T.P. Sharma,** Associate Professor, Department of Computer Science & Engineering, National Institute of Technology, Hamirpur.

The matter presented in this project report has not been submitted by us for the award of any other degree of this or any other Institute/University.

(SHIVANGI ANEJA)

This is to certify that the above statement made by the candidates is correct to the best of my knowledge.

Date: (Dr.T.P Sharma)

Associate Professor

Signature of Supervisor Signature of Project Coordinator

ACKNOWLEDGEMENT

We take this opportunity to express our deepest gratitude and appreciation to all those who have helped us directly or indirectly towards the successful completion of this project.

First and foremost, we would like to express our sincere appreciation and gratitude to our esteemed guide Dr. T.P. Sharma, Associate Professor, Department of Computer Science & Engineering (CSED), National Institute of Technology, Hamirpur, for his insightful advice, encouragement, guidance, critics, and valuable suggestions throughout the course of our project work. Without his continued support and interest, this project would not have been the same as presented here.

We express our deep gratitude to Dr. T. P. Sharma, Associate Professor and Head, CSED, National Institute of Technology, Hamirpur, for his constant co-operation, support and for providing necessary facilities throughout the B.Tech program.

We would like to take this opportunity to express our thanks towards the teaching and non-teaching staff in the Department of Computer Science & Engineering, National Institute of Technology, Hamirpur, for their invaluable help and support in these four years of our study. We are also grateful to all our classmates for their help, encouragement and invaluable suggestions.

Our special thanks to our parents, supporting families and friends who continuously supported and encouraged us in every possible way for the successful completion of this project.

Last but not least, we thank God Almighty for his blessings without which the completion of this project work would not have been possible.

SHIVANGI ANEJA(11551)

ABSTRACT

The primary objective of IEEE 802.22 standard is to determine vacant spectrum bands available in Digital television channel (DTV) and to utilize them for wireless rural broad band connectivity. Cognitive Radio (CR) aims at maximizing the utilization of the limited radio bandwidth while accommodating the increasing number of services and applications in wireless networks. For cognitive radio networks to operate efficiently, secondary users (SU) should be able to exploit radio spectrum that is unused by the primary network. A critical component of cognitive radio is thus spectrum sensing. In this report, we propose simulation methodology for spectrum sensing technique to meet the requirements of IEEE 802.22 standard. This report describes several simulation scenarios that can be used to evaluate spectrum sensing by single unit (local sensing) and multiple SU's (collaboratively). The detection performance is described through extensive simulation using MATLAB simulation tool. In most of the existing work, the simulation scenario of CSS algorithm has been based on common theoretical assumptions rather than to meet the operational requirements of WRAN standard. Further, it can be found that spectrum sensing and sharing has been designed separately. It is necessary to consider these two parts jointly because spectrum sensing results declares the presence/absence of PU. However, it will not address the problem of how to share the spectrum holes among co-existing SU's through strategic interaction. This report discusses about the algorithm framework of local sensing using energy detection and cooperative sensing based on machine learning to meet the functional requirement of IEEE 802.22 WRAN standard. The simulation results of the proposed spectrum sensing algorithm leads to formulate effective coalition formation game in order to make effective strategic interaction among SU's.

The main contribution of this study is as follows:

- The Simulation scenario of spectrum sensing algorithm has been formulated to meet the requirements of IEEE 802.22 WRAN standard.
- Local sensing phase carried out using energy detection to scan the complete available channel set from 54MHz- 682MHz with channel bandwidth of 8MHz. Similarly, cooperative spectrum sensing (CSS) phase is based on Machine learning technique.

- The performance of our proposed algorithm is evaluated using detection probability and target false alarm rate. The secondary users are considered as non-stationary during simulation run

.

Table of Contents

List of Figures

CHAPTER 1

COGNITIVE RADIO

1.1 Definition

A cognitive radio is an intelligent radio that can be programmed and configured dynamically. Its transceiver is designed to use the best wireless channels in its vicinity. Such a radio automatically detects available channels in wireless spectrum, then accordingly changes its transmission or reception parameters to allow more concurrent wireless communications in a given spectrum band at one location. This process is a form of dynamic spectrum management.

In response to the operator's commands, the cognitive engine is capable of configuring radio-system parameters. These parameters include "waveform, protocol, operating frequency, and networking". This functions as an autonomous unit in the communications environment, exchanging information about the environment with the networks it accesses and other cognitive radios (CRs). A CR "monitors its own performance continuously", in addition to "reading the radio's outputs"; it then uses this information to "determine the RF environment, channel conditions, link performance, etc.", and adjusts the "radio's settings to deliver the required quality of service subject to an appropriate combination of user requirements, operational limitations, and regulatory constraints".

.

1.2 History

The concept of cognitive radio was proposed by Joseph Mitola III in a seminar at KTH (the Royal Institute of Technology in Stockholm) in 1998 and published in an article by Mitolas and Gerald Q. Maguire, Jr. in 1999.

It was a novel approach in wireless communications, which Mitola later described as:

The point in which wireless personal digital assistants (PDAs) and the related networks are sufficiently computationally intelligent about radio resources and related computer-to-computer communications to detect user communications needs as a function of use context.

Cognitive radio is considered as a goal towards which a software-defined radio platform should evolve: a fully reconfigurable wireless transceiver which automatically adapts its communication parameters to network and user demands.

Traditional regulatory structures have been built for an analog model and are not optimized for cognitive radio. Regulatory bodies in the as well as different independent measurement campaigns found that most radio frequency spectrum was inefficiently utilized. Cellular network bands are overloaded in most parts of the world, but other frequency bands (such as military, amateur radio and paging frequencies) are insufficiently utilized. Independent studies performed in some countries confirmed that observation, and concluded the semis

Fixed spectrum allocation prevents rarely used frequencies from being used. Regulatory bodies in the world have been considering whether to allow unlicensed users in licensed bands if they would not cause any interference to licensed users. These initiatives have focused cognitive-radio research on dynamic spectrum access.

Recent Successes

ZSL's (Zoological Society of London):

London Zoo is working with UK regulator Ofcom to test TV White Space (TVWS) technology. TVWS uses gaps in the spectrum assigned for television transmissions. Videos of the markets are being streamed to YouTube 24 hours a day.

TVWS uses sections of spectrum either left intentionally blank to act as a buffer between TV signals or space left behind when services went digital. Footage of the animals is wirelessly transmitted to YouTube using Google's spectrum database to ensure no interference with existing channels. Further research is going on in this area.

1.3 Working of the Cognitive Radio

Primary Users are the users that have t right to use the part of the spectrum. Secondary users can occupy the free band of primary users. These unused parts of the spectrum of primary users are known as spectrum holes.

The major functions of the cognitive radio are broadly described below

[1] Spectrum sensing

[2] Decision regarding spectrum holes

[3] Spectrum sharing

One of the most important components of the cognitive radio concept is the ability to measure, sense, learn, and be aware of the parameters related to the radio channel, availability of spectrum and power, radio's operating environment, user requirements and applications, local policies and other operating restrictions.

In our project, we simulated the spectrum sensing and spectrum hole decision making part. They are described in detail below.

1.3.1 Spectrum sensing

Spectrum sensing is the first stage in cognitive radio in which the radio scans a section of the frequency spectrum for any active signal

Spectrum sensing an essential component of the Cognitive Radio technology which involves,

1. Identifying spectrum holes
2. Detecting the interference to primary user transmission and quickly vacating the frequency.

This involves detecting reliably, quickly and robustly, possibly weak, primary user signals

1.3.2 Spectrum Sensing Techniques

In practice Spectrum Sensing becomes a challenging task because the channel from the primary transmitter to the secondary user can be bad because of *shadowing and time varying multipath fading*. As a result, detecting the primary user based on the observation of a single secondary user may not be enough, especially under low SNR conditions.

Spectrum sensing can be done using the following methods

1) Transmitter detection
2) Cooperative detection
3) Interference temperature detection under the transmitter detection
4) Matched filter detection: Matched filter detection means applying the matching filter to the signal to get the high processing gain and better detection performance.
5) ***Energy detection:*** Decision static follows chi-square distribution by false alarm and detection probability.
6) Cyclostationary detection methods: Modulating the signals and coupling with the sine wave carriers, hopping sequences and cyclic prefixes.

1.3.3 Spectrum Sensing Methods

Standalone Sensing: In standalone sensing, individual node senses the Power Spectral Density (in Energy Detection Technique) and decides upon the availability of spectrum for secondary user transmission.

Cooperative Sensing: In cooperative sensing, a cognitive radio network is formed. They individually make a decision about the availability of spectrum and share their knowledge with each other. With the information from all the nodes, a central node then decides upon the availability of spectrum. In this report, we simulated a cooperative spectrum sensing scenario.

Advantages of Cooperative Sensing

1. The hidden node problem can be addressed
2. Problem of worsening signal to noise ratios can be dealt with

3. Time required for the detection of the primary signal can be reduced
4. Reliability of sensing information is increased.

1.4 Simulation of Cognitive Radio Networks

At present, modelling and simulation is the only paradigm which allows the simulation of complex behaviour in the environments cognitive radio networks.

Network simulators like OPNET, MATLAB, Net Sim and NS2 can be used to simulate a Cognitive radio network. Areas of research using Network simulators include

a) Spectrum Sensing
b) Spectrum Allocation
c) Measurement and modelling of Spectrum usage

In our project, we simulated the cognitive radio network spectrum sensing using MATLAB. We used "Cooperative spectrum sensing" technique where individual nodes use "Energy Detection" to come to a local decision about the presence of Primary User (PU).

Based on the local decisions, the Fusion centre comes to a final decision about the presence of the primary user. The "Energy Detection" is explained in detail in the next section.

CHAPTER 2

ENERGY DETECTION

2.1 Introduction

Energy detection is a spectrum sensing method that detects the presence/absence of a signal just by measuring the received signal power. This signal detection approach is quite easy and convenient for practical implementation. Energy detector is the most widely used technique in radiometry.

The energy detector detects the received signals' energy to compare with the threshold and then deduce the status of the primary signals. The disadvantage is that a threshold we used will be easily influenced by unknown or changing nose levels, so the energy detector will be confused by the presence of any in-band interference.

Another disadvantage of the energy detector is that perfect noise variance information is required. When there is noise uncertainty, there is an SNR threshold below which the energy detector cannot reliably detect any transmitted signal.

This disadvantage can be overcome by estimating the noise variance as accurately as possible. Different algorithms exist that can be used to estimate the noise variance, which when combined with input signal information can give the signal strength at that point. The noise is generally estimated to be "Additive White Gaussian Noise" or AWGN. Three main algorithms are required for this job. They are, Periodogram, threshold detection, and channel availability detection.

$$s(\omega) = \frac{1}{N} \left| \sum_{n=1}^{N} x(t) e^{-j\omega t} \right|^2$$

2.2 Periodogram

The Fast Fourier Transform (FFT) is an efficient method for transforming signal from

time domain to the frequency domain. The Periodogram is based on the Fourier transform – and most often the Fast Fourier Transform (FFT), which is an efficient way of calculating the Discrete Fourier Transform. The difference between the two is that the Periodogram takes the FFT of evenly spaced segments of the data rather than the entire data at once. The equation for a Periodogram is given as the following:

$$s(\omega) = \frac{1}{N} \left| \sum_{n=1}^{N} x(t) e^{-j\omega t} \right|^2$$

In this, the processing gain is proportional to FFT size N and the averaging time (t). Increase in the size of FFT improves the frequency resolution which is helpful in detecting narrowband signals. Also if we reduce the averaging time it improves the SNR by reducing the noise power. In the application of spectrum sensing, the Periodogram method is superior because it provides a better variance for the set of input data. Periodogram will generally produce a smoother graph and enables the system to detect and display signals in the presence of noise.

2.3 Process of Energy Detection

The process of energy detection can be briefly described as follows:

- The frequency range over which the secondary user is to transmit are decided (r1-r2)
- The spectrum is scanned to find any holes in the given range
- Energy detection is done at every frequency in the range by using a Periodogram as described below
- Decision metric is calculated from the received signal.
- The decision metric is compared with a calculated threshold based on probabilities of detection and false alarm, to come to a decision whether the PU is present or not

The decision of the energy detector is based on the statistical inference of a hypothesis regarding a signal's presence. The below equation represents the hypotheses described above.The received signal- 'RS' can be either only noise w(n) or signal together with noise (s(n)+w(n)).

$$RS(n) = \begin{cases} w(n) \\ w(n) + s(n) \end{cases}$$

After the signal (RS) is received at the secondary user, each secondary user calculates the decision metric (M) based on which the presence of primary user is decided. The equation for finding the decision metric is as given below.

$$M = \sum_{n=0}^{N} |RS(n)|^2$$

'N' is the observation vector

The performance of energy detector can be evaluated by using two probabilities: Probability of detection P_d and Probability of false alarm P_f. The probability of detection is to decide the presence of primary user when it is truly present. In contrary, the P_f is to decide the presence of PU when it is actually not present. It can be formulated as,

$$P_d=(M>\lambda/H_1)$$

$$P_f=(M>\lambda/H_0)$$

'λ' is decision threshold which can be selected for finding the optimum balance P_d and P_f. H_0 is the hypothesis that signal is not present. H_1 is the hypothesis that signal is present.

By setting a desired probability of false alarm and calculating the variance of a data set, the system sets a threshold to indicate signals above the noise level. However, it requires the knowledge of noise and received signal power. Since it is difficult to estimate the received signal power as it changes based on the transmission characteristics and the distance between the cognitive radio and primary user. Hence, the knowledge of noise power estimation is sufficient for selection of a threshold. Each SU processes its received energy and compares with local threshold. The received signal strength of each SU varies based on its distance from Primary transmitter.

CHAPTER 3

COOPERATIVE SPECTRUM SENSING

3.1 Introduction

As expressed earlier there has been a rapid growth in wireless communication technologies and thus there has been increased pressure in both the licensed and unlicensed frequency spectra. Since the fixed spectrum assignment will fail to cater to the needs of media, utilising the existing spectrum for holes as transmission media seems a viable alternative. As mentioned above, every secondary user has a mechanism devised to estimate the frequency bands that are not occupied. However, there is a huge challenge when the number of secondary users is very high. Every secondary user will detect the presence of white space at different frequencies owing to the different energy levels that they receive from the primary user. In such a case, the accuracy of an individual secondary user is questionable and we need a central station which can decide as to which of the frequency bandwidths are actually available for detection. This role is performed by the fusion centre, which based upon a predefined algorithm utilizes the results from the individual secondary users and determines the available frequency bands. Also, cooperative spectrum sensing in essence refers to the understanding between the different secondary users to utilise a particular frequency. Once the fusion centre has detected a white space and communicates that to the secondary users, not all can utilise the frequency for data transmission at one instant. There needs to be cooperation among the secondary users to utilise the available bandwidths at different instances and allow the other secondary users to use while it itself is idle. Thus cooperation is essential in any spectrum sensing module.

3.2 Cooperative Spectrum Classification

The process of cooperative sensing starts with spectrum sensing performed individually at each CR user called local sensing. To facilitate the analysis of cooperative sensing, cooperative spectrum sensing into classified into three categories based on how cooperating CR users share the sensing data in the network: centralized, distributed, and relay-assisted.

In centralized cooperative sensing, a central identity called fusion centre (FC)2 controls the three-step process of cooperative sensing. First, the FC selects a channel of a frequency band of interest for sensing and instructs all cooperating CR users to individually perform local sensing. Second, all cooperating CR users report their sensing results via the control channel. Then the FC combines the received local sensing information, determines the presence of PUs, and diffuses the decision back to cooperating CR users. Unlike centralized cooperative sensing, distributed cooperative sensing does not rely on a FC for making the cooperative decision. In this case, CR users communicate among themselves and converge to a unified decision on the presence or absence of PUs by iterations. Based on a distributed algorithm, each CR user sends its own sensing data to other users, combines its data with the received sensing data, and decides whether or not the PU is present by using a local criterion. If the criterion is not satisfied, CR users send their combined results to other users again and repeat this process until the algorithm is converged and a decision is reached.

In addition to centralized and distributed cooperative sensing, the third scheme is relay-assisted cooperative sensing. Since both sensing channel and report channel are not perfect, a CR user observing a weak sensing channel and a strong report channel and a CR user with a strong sensing channel and a weak report channel, for example, can complement and cooperate with each other to improve the performance of cooperative sensing. In fact, when the sensing results need to be forwarded by multiple hops to reach the intended receive node, all the intermediate hops are relays. Thus, if both centralized and distributed structures are one-hop cooperative sensing, the relay-assisted structure can be considered as multi-hop cooperative sensing

3.3 Cooperative Spectrum Sensing Framework & Elements

The framework of cooperative sensing consists of the PUs, cooperating CR users including a FC, all the elements of cooperative sensing, the RF environment including licensed channels and control channels, and an optional remote database. There are other fundamental components that are crucial to cooperative sensing which are essential to the process of cooperative sensing. These include:

1. ***Cooperation models*** consider the modelling of how CR users cooperate to perform sensing. We consider the most popular parallel fusion network models and recently developed game theoretical models.

2. ***Sensing techniques*** are used to sense the RF environment, taking observation samples, and employing signal processing techniques for detecting the PU signal or the available spectrum. The choice of the sensing technique has the effect on how CR users cooperate with each other.

3. ***Hypothesis testing*** is a statistical test to determine the presence or absence of a PU. This test can be performed individually by each cooperating user for local decisions or performed by the fusion centre for cooperative decision.

4. ***Control channel*** and reporting concerns about how the sensing results obtained by cooperating CR users can be efficiently and reliably reported to the fusion center or shared with other CR users via the bandwidth-limited and fading-susceptible control channel.

5. ***Data fusion*** is the process of combining the reported or shared sensing results for making the cooperative decision. Based on their data type, the sensing results can be combined by signal combining techniques or decision fusion rules.

6. ***User selection*** deals with how to optimally select the cooperating CR users and determine the proper cooperation footprint/range to maximize the cooperative gain and minimize the cooperation overhead.

7. ***Knowledge base*** stores the information and facilitate the cooperative sensing process to improve the detection performance. The information in the knowledge base is either a priori knowledge or the knowledge accumulated through the experience.

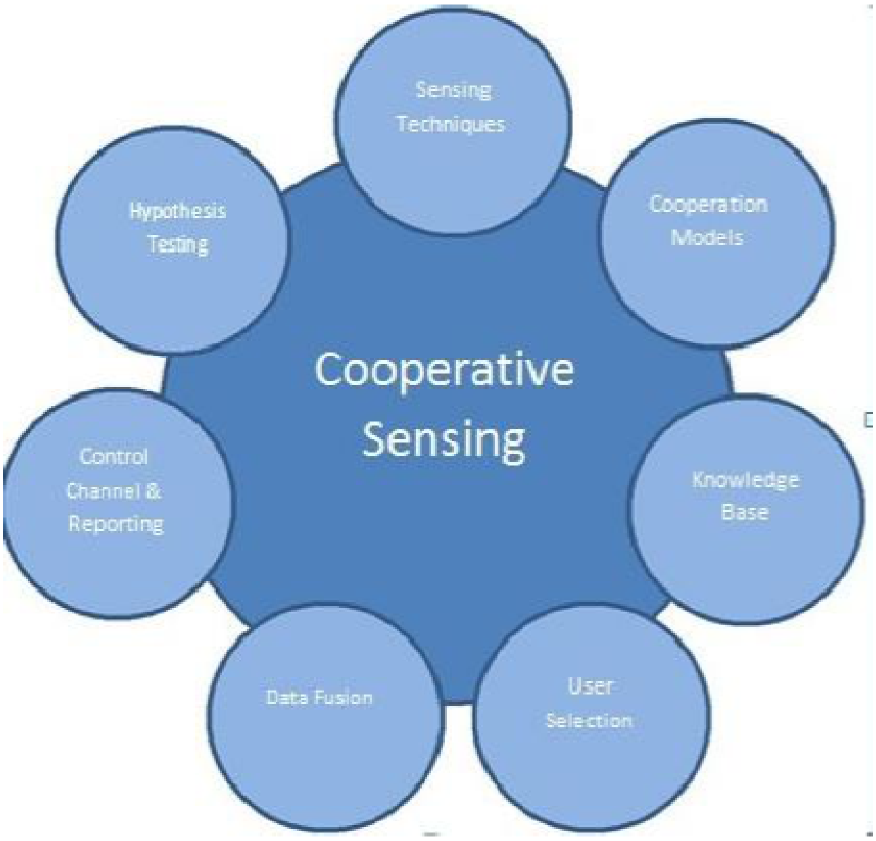

Figure 3.1:Cooperative Sensing

3.4 Popular Cooperative Sensing Algorithms

In our research methodology we have followed the centralized fusion approach where the fusion centre combines the local decision of the secondary users by an appropriate algorithm. Over the years many different algorithms and approaches have been used for the purpose of white hole detection. While earlier there used to be hard computed methodology, it slowly gave rise to advanced machine learning and game theoretical models because the whole point of cognitive radio is that it should have the ability to learn. Below listed are a few of the popular techniques:

Hard Computing Based Methods: These methods employed the most basic combination techniques. These primitive models used the local decisions of the secondary users and combined them using an 'AND', 'OR' or majority rule. This technique heavily relied on the local decisions of the secondary users such that in the OR rule, even if one of the secondary users detects a presence of a hole, the FC concludes the presence of a white space.

Weighted Decision: Not all secondary users receive even energy levels from the primary user for their local detection to be perfect. The closer the SU to the PU, the higher the energy levels detected and the higher the probability of its decision being correct. On the contrary, a SU far away may receive distorted energy signals due to noise making it less ideal choice for the detection. Thus every secondary user is assigned a weight based on which its local decision is considered. Generally weights are assigned in proportion to the signal levels received however these weights can be changed from time to time.

Game Theoretical Model: In game theoretical models, cooperative sensing is modelled as a game with a set of players, which are the cooperating CR users. Depending on the nature of the game, the behaviours of cooperating CR users are modelled differently. For example, in a coalitional game, CR users cooperate in the form of groups, called coalitions while in an evolutionary game, CR users are selfish users who may choose to cooperate or not cooperate depending on their own benefits. Thus the cooperation of the SUs is based on a game theory approach. To improve the detection performance and respond to PU activity and topology change, CR users merge or split the coalitions if the utility of the merged or split coalitions is larger than the original coalition partitions.

Machine Learning: These form the most popular widely used algorithms for cooperative radio sensing. Machine learning techniques essentially complete the working of a cognitive radio because it involves the learning that is essential for cognitive radio.

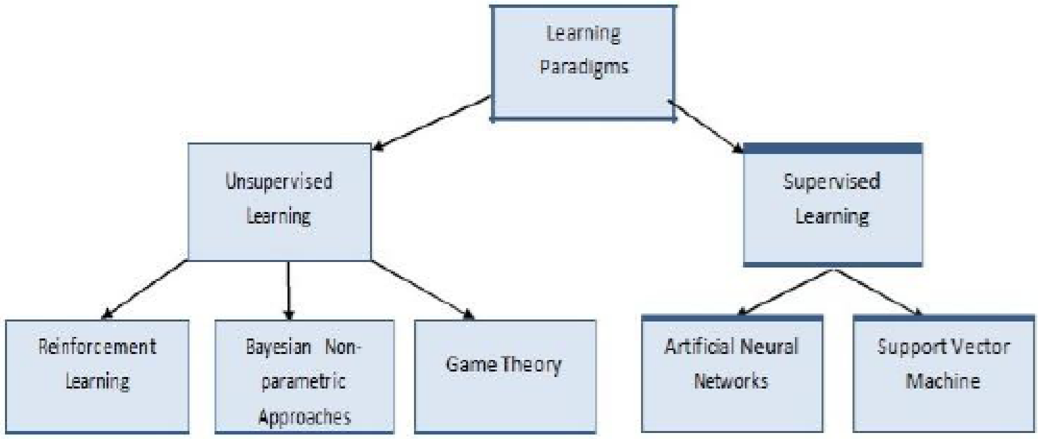

Figure 3.2:Learning Paradigms

Learning can be either supervised or unsupervised, as depicted in the figure. Unsupervised learning may particularly be suitable for CRs operating in alien RF environments. However, if the CR has prior information about the environment, it might exploit this knowledge by using supervised learning techniques. A third learning regime is defined as the learning by imitation in which an agent learns by observing the actions of similar agents. Machine learning can help solve the two main problem in CR: Decision Making and Feature Classification. Supervised algorithms require training with labelled data. Reinforcement learning is a technique that permits an agent to modify its behaviour by interacting with its environment. In this case, the only source of knowledge is the feedback an agent receives from its environment after executing an action. Two main features characterize the RL: trial-and-error and delayed reward.

Artificial Neural Network*:* The ANN has been motivated by the recognition that human brain computes in an entirely different way compared to the conventional digital computers. The benefit of using MFNNs is that they provide a general-purpose black-box modelling of the performance as a function of the measurements collected by the CR; furthermore, this characterization can be obtained and updated by a CR at run-time, thus effectively achieving a certain level of learning capability.

We chose to apply a learning model on a simulated cognitive radio network.

CHAPTER 4

EXPERIMENTS AND RRESULTS

4.1 Simulation of Energy Detection

The pseudo code for the energy detection algorithm described above is given below. There are three main functions Energy Detection, change in Velocities, and change in Distances which form the core of the energy detection algorithm. They are described in detail below:

```
FunctionEnergy detection ( ) {
Begin
  For user = 1 to No_of_Nodes
      Signal_at_node = Primary_User_Signal + AWGN;
      L= size(Primary_User_Signal);
      Threshold = qfuncinv(Pf(user) )/sqrt(L)+1;
      Periodogram_at_node=periodogram (Signal_at_node);
      Occupied[length(Periodogram_at_node)]=0;
      While i < length(Periodogram_at_node) do
         If Periodogram_at_node(i) > threshold then
            occupied(i)=1;
         Endif
          i=i+1;
      Endwhile
      Channel_width= 7 Mhz
       For every channel width in "Occupied"
       Energy =0;
       Sum=0;
       For every frequency in the channel width
            If occupied=1 at that frequency then
                 Sum=sum+1;
                 Energy= Energy+periodogram_at_node(freq);
            Endif
            If sum>width/2
                 Channel_available=1;
```

```
                Else
                    Channel_available=0;
                Endif
          Endfor
       Endfor //outer for loop
   Endfor//End of users loop
End   //End of Function
Function changeVelocities(velocityi,velocityj,x)
 Begin
   If mod(x,4)==0 then
       Reverse the velocityi
       If mod(x,2)==0 then
          Reverse the velocity
       Endif
    Else If mod(x,4)==1 then
          Reverse the velocityj
          If mod(x,2)==1 then
             Reverse velocityi
          Endif
    Endif
 End
 Function changeDistances(velocityi,velocityj,X,Y)
 Begin
       X=X+velocityi
       Y=Y+velocity;
       If (X,Y)>(100,100) then
           (X,Y)=(X,Y)-2*(velocity,velocity);
       Endif
       If (X,Y)<(0,0) then
           (X,Y)=(X,Y)+2*(velocity,velocity);
       Endif
 End
```

4.1.1 Energy Detection Function

The function “Energy Detection” takes the primary user signal and adds noise based on the distance between the secondary user and primary user. A probability of false alarm value is chosen at random at every secondary user and threshold is calculated at every node, based on the formula given in the code. Period gram of the noise added signal is also calculated over the frequency range 54-698 MHz

The frequency at which the Periodogram value exceeds threshold is noted. The frequency range is then separated into about 92 channels each of 7MHz width. The final decision of the secondary user is a binary array showing the availability of a channel in binary (1-channel available 0-channel unavailable). The Periodogram resolution is such that every five values correspond to a channel. Hence by majority rule, the channel availability is calculated.

4.1.2 Node Mobility

Every secondary user also has a certain initial velocity. The function “change Velocities” changes the velocities periodically. This can be changed as the user wishes. The function changeDistances changes the distances of all the nodes continuously. These two functions together generate random mobility to the nodes. This in turn affects the decisions made by the nodes.

4.1.3 Simulation

One Primary User and 10 secondary users are taken for our simulation. The primary user transmits a signal at unknown frequencies in the range 54-698 MHz .The secondary users individually detect this signal which is corrupted with noise and perform energy detection locally to come to local decisions. Then they perform cooperative sensing to come to a global decision.

The grid taken in the simulation was a 120*120 kilometre grid. All the nodes are initially assigned random positions and velocities. First periodograms, thresholds are calculated at every node and decisions regarding availability of channels are made based on the thresholds. These decisions are sent to the fusion centre which makes the final decision (will be explained later).