THE UNIVERSITY OF TURKISH AERONAUTICAL ASSOCIATION
INSTITUE OF SCIENCE AND TECHNOLOGY

SPECTRUM SHARING IN COGNITIVE RADIO NETWORKS BASED ON REDUCTION BY DOMINANCE AND AVERAGE ALGORITHMS

MASTER THESIS

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DESEMBER 2017

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Ref. No: 10172311

IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE

DEGREE OF MASTER OF SCIENCE IN ELECTRICAL AND

ELECTRONIC ENGINEERING

Supervisor: Assist. Prof. Dr. Javad RAHEBI

Ahmed Sudad Namuq, having student number **1403630070** and enrolled in the Master Program at the Institute of Science and Technology at the University of Turkish Aeronautical Association, after meeting all of the required conditions contained in the related regulations, has successfully accomplished, in front of the jury, the presentation of the thesis prepared with the title of: **"SPECTRUM SHARING IN COGNITIVE RADIO NETWORKS BASED ON REDUCTION BY DOMINANCE AND AVERAGE ALGORITHMS".**

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Thesis Defense Date: 07.12.2017

THE UNIVERSITY OF TURKISH AERONAUTICAL ASSOCIATION
INSTITUTE OF SCIENCE AND TECHNOLOGY

I hereby declare that all the information in this study I presented as my Master's Thesis, called: SPECTRUM SHARING IN COGNITIVE RADIO NETWORKS BASED ON REDUCTION BY DOMINANCE AND AVERAGE ALGORITHMS, has been presented in accordance with the academic rules and ethical conduct. I also declare and certify with my honor that I have fully cited and referenced all the sources I made use of in this present study.

Ahmed Sudad Namuq
07.12.2017

ACKNOWLEDGEMENTS

Thanks to the most compassionate, gracious and merciful. May Allah's blessings and peace be upon our prophet Mohammed who protects us from the depths of darkness and leads us forth into light, and his household.

It is a pleasure to express my special thanks to my friends Humam Mahmood who helped me, Ahmed Sadeq and Yasir Ali who inspired me and my family and other friends for their valuable support.

I would like to express my sincere gratitude to Assist. Prof. Dr. Javad RAHEBI for his supervision, special guidance, suggestions, and encouragement through the development of this thesis.

DESEMBER 2017 **AHMED SUDAD NAMUQ**

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBRIVIATION

PSD : Power Spectral Density.
CR : Cognitive Radio.
BER : Bit Error Rate.
UWB : Ultra-Wide Band.
QoS : Quality of Service.
RF : Radio Frequency.
CSMA/CA : Carrier Sense Multiple Access/Collision Avoidance.
FCC : Federal Communications Commission.
DSSS : Dynamic Spectrum Sharing Scheme.
BS : Base Station.
PU : Primary User.
SU : Secondary User.
SSDR/AA : Spectrum Sharing using Dominance Reduction and Average Algorithms.
TM : Transmission.
MFS : Maximum Frequency Selection.
PFS : Probabilistic Frequency Selection.
CRNs : Cognitive Radio Networks.

ABSTRACT

SPECTRUM SHARING IN COGNITIVE RADIO NETWORKS BASED ON REDUCTION BY DOMINANCE AND AVERAGE ALGORITHMS

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December 2017, 61 pages

The Cognitive radio is a kind of two-way cognitive radio that automatically changes its transmission or reception parameter this alteration of parameters is based on the active monitoring of several factors in the external and internal radio environment, such as radio frequency spectrum, user behavior and network state the optimizes that use of available radio-frequency (RF) spectrum while minimizing interference to other users.

The idea of spectrum sharing for the participation of more than one operator uses one channel at the same, taking in consideration the different types of sharing techniques using (distributed sharing).

This thesis in the field of spectrum sharing represents a scheme in terms of spectrum sharing. This scheme allows scheduling of the sensed spectrum holes between cognitive radio users by deeming the alterations happen in the radio environment along with the activity of Primary User on existing in-use channels.

So, the major contributions of this project are implementation dominance and average algorithm much superior in terms of Increase the efficiency of spectrum usage. Finally, we are modeling our work with game theory (using reduction by dooming and average) by using Graphic User Interface in MATLAB program.

Keywords: Cognitive Radio, Primary User, Secondary User, Base Station, Radio Frequency, SSDR/AA.

ÖZET

ORTALAMA ALGORITMANIN VE DOMINANTLIGIN AZALMASINA DAYALI BILISSEL RADYO AĞILARINDA SPEKTRUM PAYLAŞIMI.

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Tez Danışmanı: Doç. Dr. Javad RAHEBI

Aralık 2017, 61 sayfa

Bilişsel radyo iletim veya alım parametresini otomatik olarak değiştiren bir çeşit iki yönlü bilişsel radyodur. Parametrelerin bu değişimi radyo frekans spektrumu, kullanıcı davranışı ve ağ durumu gibi iç ve dış radyo ortamındaki çeşitli faktörlerin aktif olarak izlenmesine bağlıdır ve diğer kullanıcılara müdahaleyi en aza indirirken, mevcut radyo-frekansı spektrumu kullanımını optimize eder.

Birden fazla operatörün katılımı için spektrum paylaşma fikri aynı anda bir kanal kullanırken farklı türdeki paylaşma tekniklerinin kullanımını dikkate alır (dağıtılmış paylaşım).

Spektrum paylaşımı alanındaki bu tez spektrum paylaşma bakımından bir düzen sunmaktadır. Bu düzen mevcut olarak kullanılmakta olan kanallardaki Birincil Kullanıcı aktivitesi ile radyo ortamında gerçekleşen değişiklikleri dikkate alarak bilişsel radyo kullanıcıları arasındaki algılanan spektrum boşluklarının programlanmasına olanak vermektedir.

Bu nedenle, bu projenin temel katkısı uygulama hâkimiyeti ve ortalama algoritmanın spektrum kullanımının etkililiğini arttırma bakımından oldukça üstün olmasıdır. Son olarak, matlab programındaki Grafik Kullanıcı Ara Yüzünü kullanarak oyun teorisi ile (belirleme ve ortalama ile indirgeme kullanılarak) çalışmamızı modelledik.

Anahtar Kelimeler: Bilişsel Radyo, Birincil Kullanıcı, İkincil Kullanıcı, Baz İstasyonu, Radyo Frekansı, SSDR/AA.

CHAPTER ONE

OVERVIEW

1.1 Introduction

Intelligent radios that have two characteristics, one is spectrum scanning and the other is parameter adjustment ability, are usually referred to as Cognitive Radio. Some of the authors have measured the Power Spectral Density (PSD) of the established 6 GHz broad indicator. Utilization of spectrum that will stipulate an innovative dimension in the era of technology to spectrum use has been indicated in figure 1.1.

However, figure 1.1 also represents PSD which is about to indicate the utilization behavior of the principal users in the field of radio [1].

The schemes that consent the CR users to utilize the best obtainable spectrum are known as the 'Dynamic Spectrum Access schemes'. Cognitive radios and their working or functioning is demonstrated with the help of cognitive cycle. The major modules on which the cognitive cycle is consisted are spectrum sagacity (which is about to find the spectrum holes), spectrum allotment (which is about to allocate logical spectrum), spectrum verdict (which characterized the spectrum holes), and in the last spectrum adjustability which is accountable to vacate channels for the principal users.

With the purpose to circumvent intervention with the licensed user, the ultimate stride is indispensable [2].

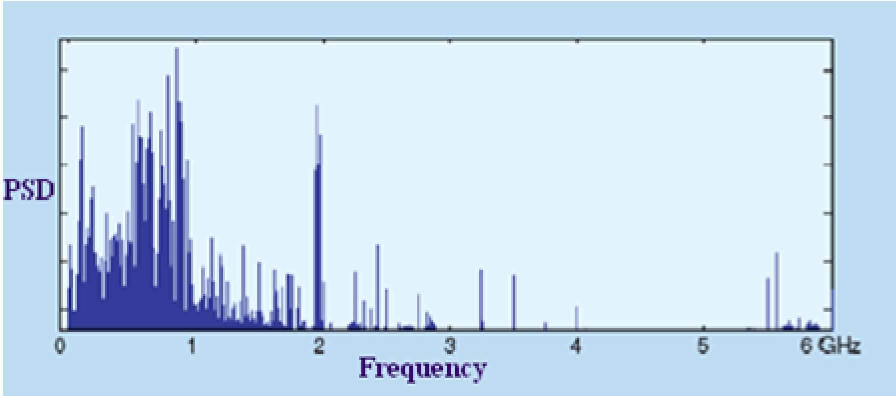


Figure1.1: Dimension of Spectrum Deployment

1.2 Wireless Network

The devices of licensed spectrum function surrounded by the segment of radio spectrum which are specifically assigned by the FCC; it has been viewed that these devices are operated to be reserved for the firms that have been granting the permits. All the license holders can operate without any intervention or the spectrum multitude as they have the exclusive rights for it. Within the same geographical location, the permissible fortification and execution has been given by the FCC with the intention to prevent other operators from broadcasting over the similar frequency. It has been found that there is a propensity to be narrowband in communications of the bands by utilizing a solitary frequency carter; in contrast, they do not have the energy constraints of ISM-band contrivances [3].

Accordingly, utilities have comprehensible and obvious benefits in excess of unlicensed spectrum in order to maintain a tremendous signal-to-noise well-built signal levels while operating on a fanatical frequency. These utilities have prospectively 10 to 100 times more authority than unlicensed utilities in the case of a primary aerial. They have also small sound levels which result from the spectrum's FCC protection; however, they also join to amplify the variety considerably and to make the performances of communications much stable. There is a fraction of mile among the endpoints but despite this fact, a wireless network can send out twenty miles among the endpoints equipped 100 times beyond the limit of an unlicensed spectrum. Devoid of transitional network equipment's to acquire, install, retain and restore, towers and endpoints can correspond unswervingly. As a negative aspect, the obtainable licensed spectrum is the inadequate resource having some difficulties and it is very expensive to attain. Particularly for the industrial, scientific or medical applications, unlicensed strategy on the elegant network maneuver in one of the bands set away by the FCC and for which accessible bandwidth might be a challenge. Spectrum devices are required to abide by the FCC regulations for the bands whereas they are free to access; the rules require that the devices send out 1 watt or less of power because of the harmful interventions while accepting any intervention received exclusive of causing undesired functions [4].

1.3 Cognitive broadcasting Network

A cognitive radio can be defined as a type of two-way radio which acts automatically in terms of changing the transmission or also the reception constraints wherever the intact wireless communication network corresponds resourcefully. This two-way radio also avoids any type of intervention with licensed or unlicensed non-liable users. All the constraints and their adjustment and modification is specifically based on the vigorous screening of various elements within the peripheral and in-house radio environment, for instance, the user actions, user networks, and radio frequency spectrum. Be certain on the set of constraints allowed in choosing on broadcasting and reception adjustments and also for the chronological causes, certain kinds of cognitive radio can be discriminated [5].

1.4 History of Cognitive Radio

Cognitive radios and the idea of these devices has been promoted in the Spectrum Policy Task force report of the FCC while considering this to be an insistent elucidation with the intention to enhance spectrum utilization. In the history, the clear and presentable definition of cognitive radio has not been constituted while some authors gave relatively conservative definitive of cognitive radios. According to those authors, the network of radios that exists with superior precedence principal users and by means of sensing their individual existence and enhancing their own attributes related to transmission in such scenario that they do not capitulate any of the detrimental interventions are known as the cognitive radios [6]. One of the unique attributes and confronts of the accomplishment of Cognitive Radios is the sensing function that has the capability to swiftly adapt the broadcasted waveform. In the cognitive radios, an inimitable practice is employed which is known as the

Dynamic Frequency Shifting which basically involves sensing. The involvement of sensing function is based on the presence of the radar signal and by avoiding the frequency channels that evade interferences [7].

There is a simplistic approach to abandon the influenced 802.11A frequency channels are far-flung from most favorable within the spectrum exploitation. However, it indicates that the controlling devices are disposed to recognize the spectrum that can be shared with the help of sensing and forestalling [8].

1.5 Thesis Motivation

In cognitive radio step all networks and other nodes are picked with some radios called cognitive radios that can scene and could be learn, besides react to changes in network circumstance. It can learn from the adaptation in addition to settle on future choices, all while considering end-to-end destinations. Nonetheless, this system is sort of two-way radio that consequently changes its transmission or gathering requirements ,so this modification of restrictions is constructed on the active observing of numerous factors in the exterior besides interior the situation of radio, such as radio frequency spectrum, user performances besides network contingent upon the arrangement of parameters considered in settling on transmission other than gathering adjustments, and for authentic reasons, we can recognize certain sorts of subjective radio.

1.6 Problem definition

The idea of spectrum sharing for the participation of more than one operator uses one channel at the same, taking in consideration the different types of sharing techniques using (distributed sharing).

1.7 Contributions of Thesis

The major contributions of this project are

1. Implementation dominance and average algorithm much superior in terms of Increase the efficiency of spectrum usage.
2. The proposed algorithm provides much better throughput as compared to similar algorithm used in spectrum sharing.

1.8 Thesis Novelty

The novelty of this project is implementation of dominance and average algorithm for the participation of more than one operator uses one channel at the same time.

1.9 The plan of the Thesis

The cognitive broadcasting is found to get the range with less time and less cost. However, the Spectrum sharing allows more than one secondary user using one spectrum in different times in order to implement this step a game theory has provided the best time to use the spectrum through the spectrum sensing and distributed among the users as the most appropriate. Algorithm of domination and average show us the possibility to delete some unstable spectrum, which has little time to get the maximum use of time and shared between users.

1.10 Literature Review

Many researchers have contributed in the same field by their thesis approach (Spectrum sensing and Spectrum Sharing In Cognitive Radio Network). Some of those researchers are:

Feizresan et al. demonstrated the idea of the restricted accessible range and the wastefulness in the range use which requires another correspondence worldview to misuse the current remote range sharply; this new systems administration worldview is alluded to as Cognitive Radio (CR) systems. In CR systems, one of the fundamental difficulties in open range use is the range sharing [9].

Cabric et al. (2006) showed the concept of a most important shift in radio design and it can be considered as just the initiation which attempts to allocate spectrum in a primarily new approach. It has been found by the research that these radios are dealing with the verity that the usage of spectrum is generally poor in several bands regardless of the augmenting requirement for the wireless connectivity [10].

Sharma et al. have introduced the game theory conceptions by proposing the new emerging ways about how game theory can be utilized to model several interfaces between cognitive radios in AHCRN. There are various layers which can be utilized for the game theory for instance the data link layer, higher layers, physical layers and also the network layers [11].

Kulkarni and Chaudhari represented their model in terms of cognitive radio by utilizing non-cooperative game theory [12]. It has been described by the researchers that cognitive radio accesses the resources of principal users due to the fact that it can be modeled as a game among the principal users as well as the secondary users. Utility function has been proposed in the study for power allotment specifically for secondary users; however, the study also depicts the improvisation in number of active secondary users. Execution is contrasted and the super-secluded amusement. Proposed non-helpful diversion demonstrate outflanks super-particular amusement in expanding the limit of psychological system and in the execution of BER. It is watched that at Bit Energy to Noise proportion of 15 dB, BER of proposed non-agreeable diversion demonstrate is 10-4 when contrasted with 10-3 that is accomplished for super-secluded amusement

1.11 Thesis Layout

The organization of this project is as follows:

Chapter One: Introduction of Cognitive Radio, explanation of the types of wireless network, history of Cognitive Radio and the aim of the project.

Chapter Two: Discusses how Cognitive Radio work by use functions of spectrum management then explanation of the model, techniques of spectrum sharing, techniques of spectrum sensing and game theory.

Chapter Three: Implementations of the work using game theory.

Chapter Four: Presents the future works and conclusions.

CHAPTER TWO

THEORETICAL FUNDAMENTAL

2.1 Introduction

Psychological Radio (CR) is a shrewd remote correspondence framework that knows about its encompassing condition, gains from the earth and adjusts its inner states to factual varieties in the approaching RF jolts rolling out comparing improvements in certain working parameters progressively the primary destinations of the intellectual radio are to give exceptionally solid interchanges at whatever point and wherever required and to use the radio range proficiently. The key issues in the intellectual radio are mindfulness, knowledge, learning, versatile, unwavering quality, and productivity [14].

Transmission methods for psychological radio frameworks incorporate overlay underlay and interlace Underlay or impedance shirking model permits simultaneous transmission of primary and secondary users in Ultra-Wide Band (UWB) design where the primary users are ensured by authorizing ghostly veils on the optional flags so that the produced obstruction is underneath the clamor floor for the primary user in any case, underlay permits just short-go correspondence because of the power limitations. Overlay or known obstruction demonstrate additionally permits simultaneous transmission of primary and secondary users. The secondary users utilize some portion of their transmission control for transferring the information of primary users and part of the power for their own particular auxiliary transmission. In the interlace display the intellectual radio screens the radio range occasionally and deftly imparts over the range gaps [14].

2.2 Cognitive Radio Techniques

The techniques related to the cognitive radio are categorized keen on spectrum management that has the capability to capture the best accessible way that could collect spectrum which would be beneficial for the needs of the user communication while having less excessive intervention into other primary users. For the better outcomes, cognitive radios have to select best spectrum band to meet up the requirements of QoS within the obtainable spectrum bands. This is the reason that these spectrum management functions are needed for cognitive radios; on the other hand, these functions can be sorted in spectrum verdict, spectrum allotment, spectrum sagacity and spectrum adjustability which have been shown in figure 2.1 below [15].

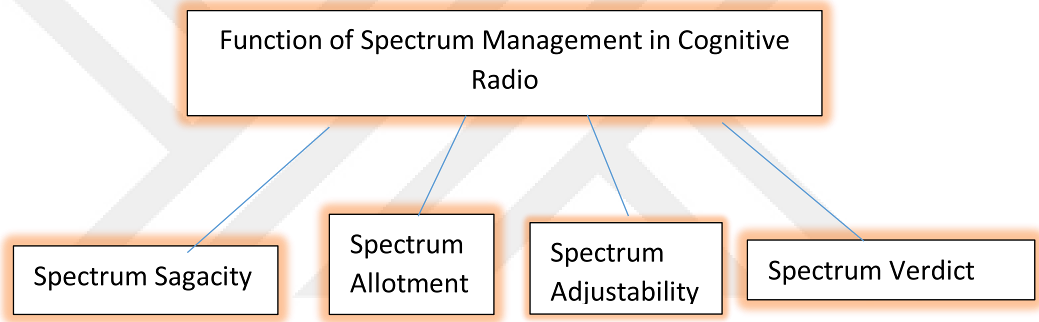


Figure 2.1: Function of spectrum management

2.2.1 Spectrum Sensing

Is considered one of the techniques of the CR which feels packages unused and is trying to use an opportunistic manner to be to prevent interference with the primary user (PU from the requirements of improved user's presidents (PU) and the discovery of empty space has a special type called control sensing) can the secondary (SU) to find a group spectra are available and how the user feels s spectrum frequently that have more practices [16].

For having the capability to sense extremely low pointers or signals, there is a need to have better sensitivity in cognitive radios as compared to the conventional radios in a significant manner. This is because of a high demand of the requirements of Radio Frequency (RF) and Analog-to-Digital Converter. It is extremely tough to meet needs as the advanced practices within cognitive radios are required to make them practicable. Generally, range sense techniques can be classified into match filter detection, energy exposure, and feature exposure and wave late detection. In adding up, sensing techniques can be utilized both by supportive and non-cooperative style subsequent to consistent treatment and sampling of a wideband signal. The practices utilized for the digital signal processing participate in augmenting the sensitivity of radio. Recent researches are primarily about to focus on principal transmitter detection specifically derived from confined surveillances of the secondary users [17].

The practices of spectrum sensing can be categorized into:

1. **Match filter detection**

Match filter detection is basic information about the Cognitive Radio and it is quick to explore taifumchris referring to the kind of PU, which increases the price of applications and implementations [18].

2. **Feature detection**

Reveal periodical internal and needs a long time to sense the spectrum that can distinguish signals from different networks independently and asynchronously [18].

3. **Energy detection**

Be slower in the spectrum sensing means suffering a long time to reveal the spectrum as well as influenced by the noise and the lake when there is no basic information about the cognitive Radio [18].

4. **Wave-late detection**

The Wavelet change is a method for deteriorating a flag of enthusiasm For to an arrangement of premise waveforms, called wavelets, which in this way give an approach to dissect the flag by looking at the coefficients of wavelets. In a large portion of the applications, the energy of the change originates from the way that the primary elements of the change are limited in time and recurrence [16].

2.2.2 Spectrum Sharing

The capacity to keep up the Quality of Service (QoS) of Cognitive Radio users without making impedance the PU by planning the numerous entrance of users and in addition assigning correspondence assets adaptively to the hangs of radio condition Performed amidst transmission session and inside the range band.

The asset assignment depends on neighborhood perception, CR user need to perform channel choice and power portion while picking the best channel obliged by obstruction to another CR and PU.

In power allocation, the CR user needs to adjust its transmission power by considering co-channel interference. There is an access of spectrum as there may be several CR users who try to attain the spectrum. It can be said that this admittance can be protected by the coordination in order to prevent the smashing of the multiple users in the overlapping sections of the spectrum [19].

2.2.2.1 Spectrum Sharing Techniques

That can classify the Spectrum techniques into for step design/Decision, centralized control and distributed control we view each of them as follow:

1. Design/Decision Processes

The accompanying subsections break down the extensive number of conceivable plan and choice procedures into a reasonable arrangement of orders of methods which have been proposed to configuration/choose psychological radio operational parameters to encourage concurrence with different users. Instead of review these as discrete fundamentally unrelated classifications, we trust that fluctuating blends of the accompanying strategies will be used in many frameworks [20].

2. Centralized Control

Centralized entity is one of the solutions that manages the allotment of spectrum and attain these procedures by aiding them. In general, the procedure of distributing sensing is intended by insuring that every entity within the CR network forwards their measurements to the central entity about the allotment of spectrum. In this way, each entity in the CR network builds a map of spectrum allotment [20].

3. Distributed Control

In a conveyed conspire, conjunction is overseen by various elements who for the most part (however not generally) have clashing needs and work with various data sets. Cases of dispersed control for conjunction incorporate the CSMA/CA calculation, between cell control impacts (e.g., cell breathing), diagram shading calculations, and calculations established in diversion hypothesis [20].

2.2.2.2 Models for Spectrum Sharing

That can classify the models for spectrum sharing into for sharing Among Equal Primary devices step, sharing between Primary and Secondary, Sharing among equal Secondary devices, we view each of them as follow models for Spectrum Sharing are classified into [21]:

1. Sharing Among Equal Primary Devices

Many heated debates in the way of spectrum are looking to create the new spectrum that is known as “commons.” In this policy all spectrums are shared and no one holds the priority. This policy can describe devices and other tools that will cooperate. It could also describe some devices that could only exist. There is a condition where all possibilities are summed up together under the policy of “commons.” (Unfortunately, this tragedy has created plentiful of the policy about spectrum that lies pointless where all supporters and adversaries having their influences on mismatched basis. This “coexisting” method is defined in many countries but not all countries use this because this is costly [21].

2. Sharing Between Primary and Secondary

Primary auxiliary sharing is presumably most valuable when the primary framework has been given elite rights through permitting, as there are by and large circumstances or potentially areas where different gadgets could transmit in this range without causing unsafe impedance. At the end of the day, sharing can take one of two structures participation or concurrence when sharing depends on conjunction; optional users are basically undetectable to the primary. Along these lines, the greater part of the many-sided quality of sharing is borne by the optional. No progressions to the primary framework are required, which is particularly useful for heritage frameworks that are hard to change. Prior to any optional users can be conveyed, rules must be set up to secure the primary. Auxiliary users can either be permitted to transmit at such low power that they never make hurtful obstruction the primary, as with ultra wide band, or they can be permitted to transmit shrewdly when and just when they discover that transmissions won't cause unsafe impedance [21].

Shrewd get to be presumably deficient for applications that require ensured nature of administration, and consequently ensured provoke access to range. Be that as it may, numerous applications can profit by pioneering access. The difficulties of entrepreneurial get to be appropriate to subjective radio consolidated with range sensors. On the other hand, it is conceivable to guarantee that an auxiliary transmitter is adequately a long way from primary beneficiaries utilizing an area innovation. Secondary method also wants that method that could that could retrieve the changes in database. Transmission must be stopped when database is out of date. Database should extend its functions to full radio maps, which would be beneficial in the spectrum, services and also in paths. Advocates of opportunistic must overcome some blunder changes. At first, the primary system must be protected. This combat is always clashed over resourceful access to "white space." The Federal Communications Commission (FCC) has lined in this type of sharing after the transmission of digital television but there is still time to bring change in the course. Mainly two types of prototypes are submitted to FCC for evaluation [22].

3. Sharing Among Equal Secondary Devices

It is once in a while expected that secondary users must be unlicensed really like primary users of range; secondary users can be authorized or unlicensed. Both authorized and unlicensed optional are precluded from making unsafe obstruction the primary. One contrast is that an authorized optional framework requires not stress over impedance from another auxiliary. In this manner, nature of administration can be ensured for the auxiliary when (and just when) exercises of the primary don't act as a burden. In addition, on the grounds that there is just single substance making impedance the primary, it might be less demanding to guarantee that obstruction never achieves a level that would be unsafe. This may likewise make it conceivable to securely utilize substantially higher-control auxiliary users. Then again, if get to is unlicensed, numerous more frameworks may make utilization of the range. This approach talk about is right now most pertinent to the TV void area [21].

The FCC has cautiously settled that devices can work in the white space, but major issue is whether their devices are certified or non-certified. Should white space be certified commercially in cellular companies? A carrier must cover all regions or it should be unlicensed such as models that Philips and Microsoft have exposed. Decision depends on which products are in highest mandate by the public. These views will change from one country to another. If several systems are used to handle as secondary users, they must cooperate with each other. Coexistence is theoretically more simple in many ways. Many accomplishments such as of using cognitive radio to circumvent meddling with a primary system that always come from devices that control whether it is safe to transmit. Of course, that does not solve the problem of shared meddling among secondary devices [23].

2.2.2.3 Features of Spectrum-Sharing

Sharing plan can be well considered and branded by two important features. The first feature is whether sharing is founded on assistance or existence. The division has reflective suggestions for both policy and technology in a prototype that is completely based on cooperation; as well as the devices that are under different directorial control should communicate and cooperate with each other to evade common meddling. Amongst other things, this means that there should be a common protocol must be defined, that could be supported by all systems in the band. with a existence model, devices try to avoid meddling without explicit signaling at most, devices can sense each other's presence as meddling as can be seen throughout this special issue, cognitive radio is a powerful tool for sharing that is totally based on coexistence; the ability to reattach a device based on the sensed interference levels from neighbors is beneficial when avoiding mutual interference. Using a cooperative model, devices may react to what they are exactly told, and this ability to self-reliantly sense that whether environment may or may not be important, depending on the scheme all methods try follow their place where devices can exchange information. We would assume these devices to make more effectual use of spectrum to perform better strategies to evading common interference However, cooperation has its disadvantages, thanks to concealed stations and other realistic anxieties, communications may not always be probable [24].

There must be something that could watch the transaction cost, complexity of different devices, and communication that would be overhead that offset the benefits of cooperation. Another important point is that need of common protocol in cooperation must share a degree of similarities among different devices that could prevent innovations. This is problem when we try to share the spectrum with the help of legacy tools. This is because these tools are not designed with new sharing equipment's. Obliging systems with untrustworthy relationship is important to cooperate also presents postures of complex security challenges. Such adjustments will be further deceptive in the next section, when we discuss about specific sharing models. Further research will show whether existence is preferable and when cooperation is preferable.

In several situations, widespread use of one within a given band makes the other unusable, if possible. The necessity for collaboration can also attach operation costs, as well as device complexity, delay, and communications above, maybe even to the degree that such costs balance the aids of cooperation, the necessity for a mutual protocol in cooperative sharing forces a degree of similarity amongst devices that can hinder invention. This is also problematic when trying to share the function of spectrum with legacy apparatus, which were not intended or applied with new sharing measures. Cognitive Radio is most often discussed as an elementary tool for primary-secondary sharing, but if intended in agreement with an suitable policy, cognitive radios might be useful for sharing amongst equals as well. Probably the greatest frequently used expressive feature for a class of wireless [25].

Devices which are used in the function are not known whether they are licensed or unlicensed. The point is to be noticed that the set of system is that in which the spectrum could share arrangements and not the agreement itself. Both primary and secondary devices can be licensed or unlicensed, there must be licensed system will be used by permission for the regulator to operate within a given frequency band.

The licensing is the process in which there is an opportunity for the regulator to ensure high-class access to a path as it wishes which is the strong protection to secure from the problem of interferences [25].

We can summarize the spectrum sharing as we show in figure 2.2

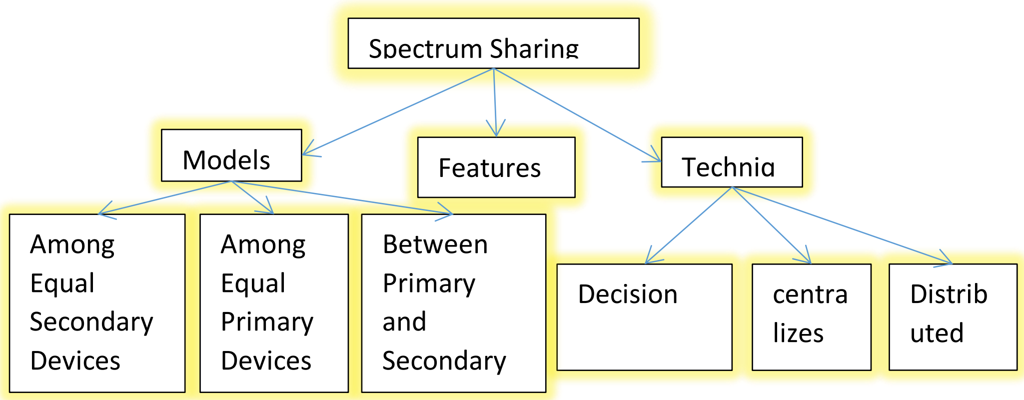


Figure 2.2: Summarize Spectrum Sharing

2.2.3 Spectrum decision

The objective of range choice is to choose the best accessible channel. range choice system is proposed to decide an arrangement of range groups by considering the application prerequisites and additionally the dynamic idea of range groups to this end, to begin with, every range is described by mutually considering primary user movement and range detecting operations in light of this, a base fluctuation based range choice is proposed for ongoing applications, which limits the limit change of the chose range groups subject to the limit limitations for best-exertion applications, a most extreme limit based range choice is proposed where range groups are chosen to amplify the aggregate system limit. Besides, a dynamic asset administration conspire is produced to arrange the discussions choice adaptively subject to the time-shifting cognitive radio network limit [26].

2.2.4 Spectrum mobility

We can define the spectrum as the procedure when an intellectual radio user trades its recurrence of operation Cognitive radio systems focus to utilize the range in a dynamic way by enabling the radio terminals to work in the best accessible recurrence band, keeping up consistent correspondence necessities amid the progress to better spectrum [27].

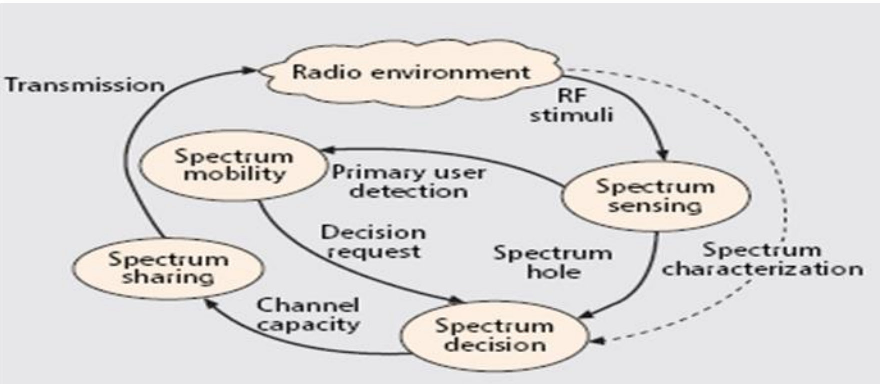


Figure 2.3: Process of Cognitive Radio

2.3 Spectrum Sharing and Flexible Spectrum Access

The difference among the primary and secondary users of spectrum has been considered in this white space and it has been found that secondary users comply with the principal users in using the spectrum. Despite the consequences of the regulatory model, elasticity and competence are needed to be reproduced in spectrum attainment. In this manner, spectrum sharing plays a significant part to modify or increase the utilization of spectrum specifically in the perspective of open spectrum. It has been viewed that the practices or techniques that sense and adjust to the environment of radio are principally needed, such as in the unlicensed bands while enabling the secondary access to the spectrum [22].

2.3.1 Spectrum Sharing (overlay and underlay)

Radio spectrum and its open access is sanctioned by the regulation bodies of radio specifically for the radio systems, despite the licensed spectrum for a dedicated technology, with the negligible broadcasting powers in an ostensible underlay sharing practice or technique. An instantaneous and clumsy usage of the spectrum in the domain of time and frequency has been realized by the underlay sharing practice. By this means, practices or techniques in order to extend the secreted signal over a large band of spectrum are utilized [23].

Just a little part of the radio range is accessible as open recurrence band for unlicensed operation. All things considered, these groups have fortified a tremendous financial accomplishment of remote innovations like the famous WLAN IEEE 802.11. Then again, the genuine accessibility of new range is an apparently obstinate issue. Psychological radios utilize adaptable range get to procedures for distinguishing under-used range and to stay away from unsafe obstruction to different radios utilizing a similar range. Such a deft range access to under-used range, regardless of whether the recurrence is doled out to authorized secondary administrations, is alluded as overlay range sharing [24].

Overlay sharing requires new conventions and calculations for range sharing. Also, range direction is affected, particularly in the event of vertical range sharing as presented underneath: The operation of authorized radios frameworks may not be meddling while distinguishing range openings and amid auxiliary operation in authorized range [25].

2.3.2 Practical Usage of the Spectrum

Practical usage of the spectrum can be discussed in the context of the under-utilized spectrum which is referred to as the spectrum opportunity or spectrum prospect. There are two terms which can be utilized on an equal basis which are the terms ‘white spectrum’ and ‘spectrum hole’. In order to utilize the prospects of the spectrum by way of overlay sharing, the transmission schemes are adopted by the cognitive radios. In this manner, cognitive radios fit into notorious usage patterns of the spectrum and it has been exemplified in figure 2.4. As a consequence, all the prospects related to the spectrum have to be classified in an unswerving manner.

Moreover, the usage of the spectrum needs harmonization particularly in the disseminated backgrounds. Several elements are considered to define the opportunities and prospects of the spectrum for instance the time, location, frequency and the broadcasting power. Radio resources are not utilized by the licensed devices of radio as they are utilized with the conventional patterns for instance the inoperative intervals which can be predicted and detected consistently [26].

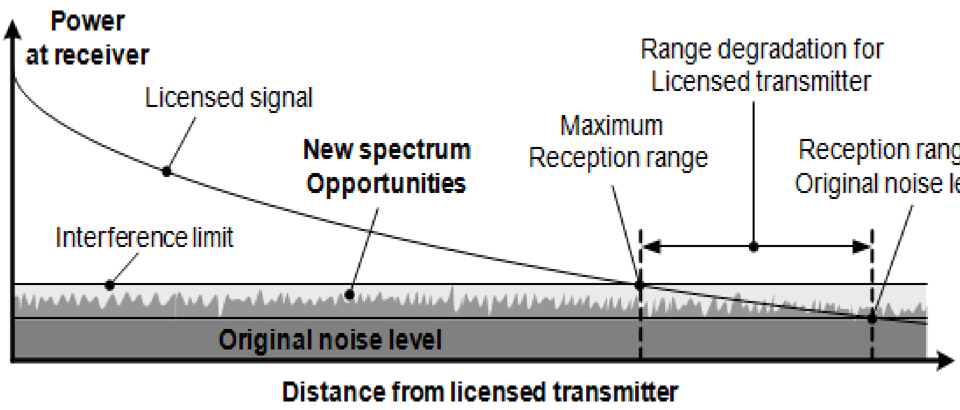


Figure 2.4: Underlay Spectrum Sharing in Proportion to the Obstruction Temperature Conception of the FCC

It has been found that the precise recognition of the prospects or opportunities of the spectrum is considered as confront due to its dependable nature specifically on the certainty and dynamics of the spectrum usage. The inevitability and frequency of the spectrum usage by the principal radio devices is influential for the accomplishment of the prospect recognition and the effectiveness of its usage by with the help of cognitive radios [20].

2.4 Synchronization or Coordination, Coexistence and Assistance or cooperation

Different terms have been utilized in the literature in regards to the coexistence, synchronization and assistance while several authors used these terms in different manners in their studies. The definitions of these terms have extreme significance therefore these are defined below; in spite of this, these terms have an importance in the QoS support [25].

Concurrence implies an objective at mediation avoidance inside a dispersed correspondence climate. Subsequently, no correspondence between coinciding gadgets is required and likely. In the event of a less utilized shared range, concurrence abilities are adequate to encourage a predictable correspondence. In the current years, conjunction has been extremely flourishing however casualty of its own prosperity is presently. A number of the successive different radio frameworks are existing together in the unlicensed recurrence groups like Wi-Fi and Bluetooth. Because of the steady threat for achieving the aggregate range, no QoS bolster is potential as a result of missing coordination or synchronization. The current executed practices to conjunction have confined mediation and prevention and their range use is exceptionally inefficient as concurrence involves just little temptation to safeguard range [19].

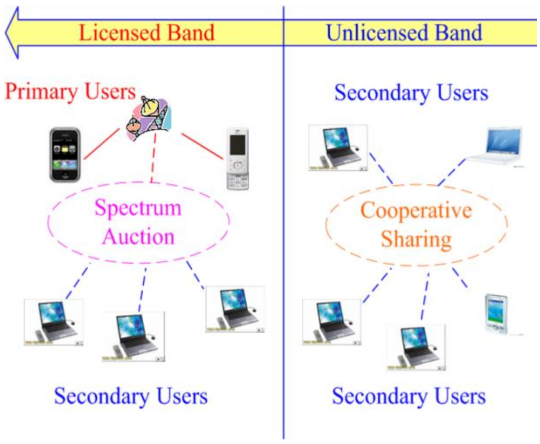
Reciprocated coordination or synchronization, either central or decentralized, is needed in spectrum sharing to facilitate the assistance of QoS. QoS assistance submits in this circumstance to the restricted utilization of spectrum to a conventional point of time for definite period [25].

Mutual cooperation or collaboration is about the philanthropic devices which delimitate their spectrum utilization and transmit each other’s traffic in the hope for benefiting from a possible collaboration when all radios contribute. Collaboration or cooperation comes along with the risk of being utilized by self-centered, prejudiced radios that result into a drawback for the collaborating radios. Collaboration is needed in establishing one self-configuring network of reciprocally collaborated radios in a disseminated communication setting. The utilization of deterministic outlines while assigning spectrum can also regarded as collaboration. These deterministic patterns help to amplify accurateness for other radios for recognition of spectrum prospects and allow a disseminated synchronization on the basis of surveillance [24].

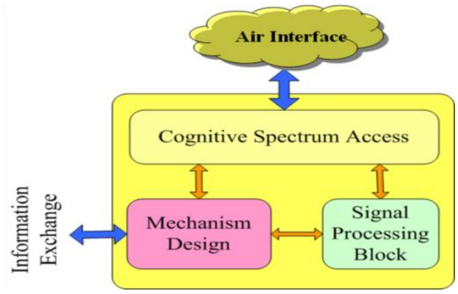
In dispersed situations, participation can be made and authorize through conventions, either as a major aspect of a standard or acknowledged as range sharing decorum. The requirement of participation is troublesome for direction experts however might be less demanding for a permit holder [25].

2.5 Spectrum Shearing in Unlicensed Bands

Consider the range partaking in unlicensed groups appeared in Figure 2.7 (a), where K secondary users existing together in a similar region go after range get to rights in an open, unlicensed band. The psychological radio engineering is appeared in Figure 2.7 (b), which would interface be able to with the radio condition to accumulate and trade channel estimations among circulated users, examine the gathered estimations by means of flag handling pieces, and dole out recurrence groups to particular users by component configuration to advance the range assignment proficiency [24].



1. Spectrum sharing in licensed/unlicensed bands



2. Cognitive radio architecture

Figure 2.5: System model and cognitive radio architecture.

2.6 Classification of Spectrum sharing schemes

The fundamental test after the recognition of accessible range is to facilitate the entrance among the auxiliary or Cognitive Radio (CR) users. There are two fundamental methodologies from the sharing point of view i.e. under and overlay as appeared in Fig. 3. We use the overlay range sharing way to deal with transmit information on the accessible range. In underlay approach the correspondence run next to each other with the transmission of primary users [21].The range sharing procedures can likewise be characterized on the premise of design as Intra and Inter-organize range sharing.

Figure 2.6: Spectrum Sharing Approaches (a) Underlay (b) Overlay

The unified range sharing plans depend on single substance while conveyed approach takes contribution from CR users to shape a timetable for range sharing. In incorporated Intra-arrange range sharing, range server facilitates the sharing of range among the CR users as appeared in the figure 2.8(a) [21]. The arrow points demonstrate the trading of control data between CR user and range server and along these lines displaying the helpful nature. The hover on specific element demonstrates its support in the sharing.

Figure 2.9 (b) shows the incorporated between organize range sharing. Every one of the elements is like intra connect with the main distinction that focal element called range merchant shares the range among the CR users of at least two than two unique systems. The range sharing choice is taken from the info Distributed Inter-arrange (d) [21]

Of the of more than one CR user networks.

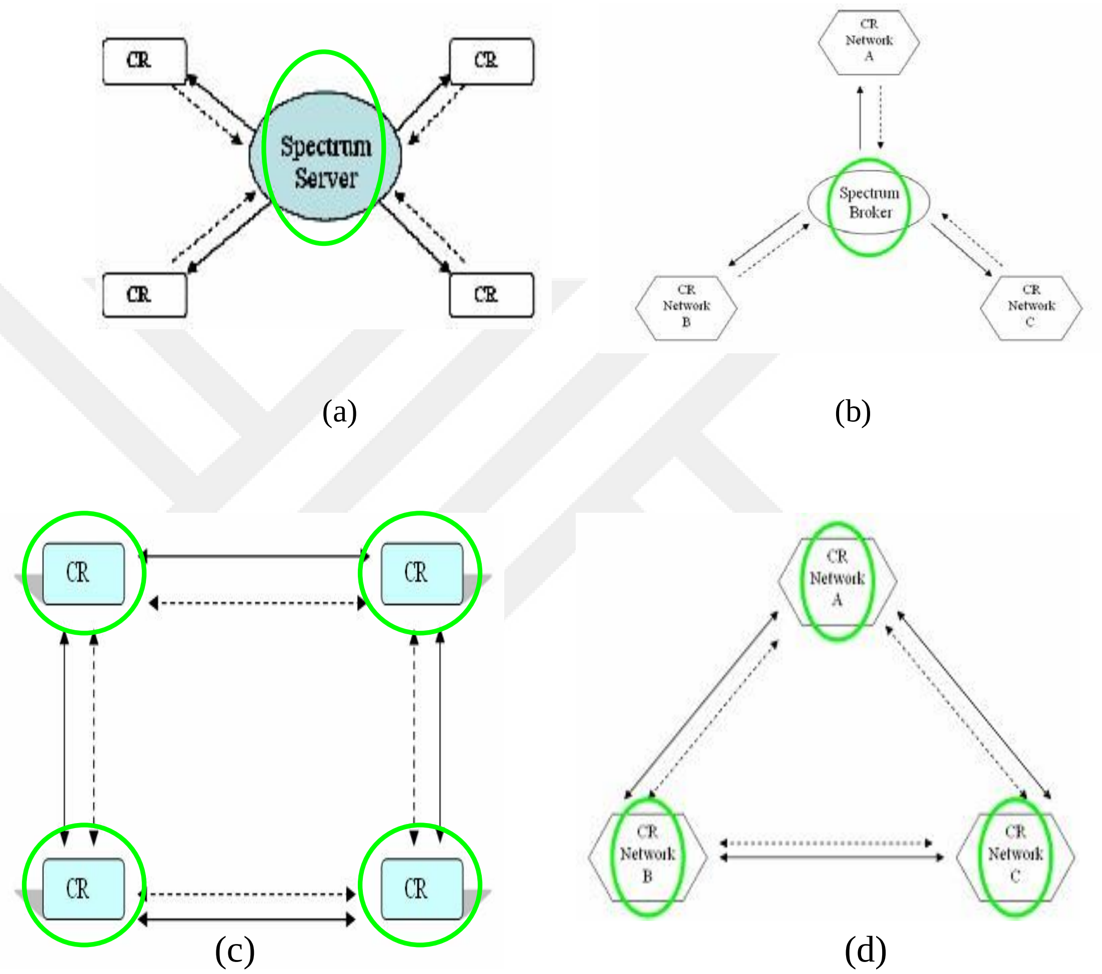


Figure 2.7: Spectrum Sharing: Centralized Intra-network (a) Centralized Inter –network (b) Distributed Intra –network (c)

The conveyed range sharing methodology in intra and bury organize is portrayed in figure 2.7. (c) And figure 2.7. (d). It is clear from the square graph that no single element holds the sharing choices. Every CR user in Intranet work and every CR arrange in Inter-organize assume its part in the sharing procedure.

2.7 Scheduling based Spectrum Sharing Schemes

Our proposed Dynamic Spectrum Sharing Scheme (DSSS) is an effective range sharing plan that uses the current booking based plans to satisfy the information necessity of individual user. DSSS has the accompanying capacities [19].

- Incorporate Changes in the Radio Environment
- Mobility Support
- Throughput
- Segmentation

As we realize that the radio condition is changing persistently so there is a solid need to delineate conduct inside the range sharing plan. Besides, the versatility conduct is likewise vital factor for the cognitive radio network in light of the fact that if the primary user will touch base to a similar band than CR user must need to leave that band with a specific end goal to stay away from the impedance from the primary users. Thirdly, the throughput is additionally an imperative thought for any kind of system. In the last division is primary stride with a specific end goal to boost the throughput by sending the distinctive bundle of same users on various accessible connections. All these four variables request the strength of sharing plan for the intellectual radio systems. The DSSS by considering all the previously mentioned four elements shares the accessible range in ideal path by utilizing one of the three methods specified in the writing [19].

2.8 Game Theory Concept

Diversion hypothesis gives expository devices to foresee the result of complex associations among judicious elements. Amusement hypothesis has been generally connected in financial matters, political science, science, and humanism and furthermore as of late in media transmission frameworks [28].

A diversion has three fundamental segments: players, an arrangement of conceivable activities, and an arrangement of utility capacities. In a rehashed amusement, players are thought to be impeccably judicious and to choose their activities in a deterministic way thus, in light of the past activities; every player can foresee the moves of different players and select the best methodology to the issue [29].

Amusement hypothesis is an arrangement of instruments for investigating the communication of leaders with clashing premiums initially, diversion hypothesis is utilized as a part of financial aspects examine for concentrate the activities of monetary specialists, for example, firms in a market. As of late, diversion hypothesis is turning into a compelling device to think about the practices of remote system specialists, in a decentralized way, in systems, for example, impromptu systems and subjective radio systems. In such systems, choices of a system hub frequently impact others and subsequently, the general system execution is influenced. Now and then, a few hubs can be narrowing minded as they settle on choices that expansion their own utilities while disregarding the general system execution debasement. Such circumstance and issues can be very much investigated and settled with the utilization of amusement hypothesis [29].

2.8.1 Type of Game Theory

we can classify the type of game theory One-person ,Two person and Two Person Zero Sum Game we view each of them as follow type of game theory are classified into:

1. **One-Person**

A one-individual diversion has no genuine irreconcilable situation. Just the enthusiasm of the player in accomplishing a specific condition of the diversion exists. Single-individual diversions are not intriguing from an amusement hypothesis point of view on the grounds that there is no foe settling on cognizant decisions that the player must manage. In any case, they can be intriguing from a probabilistic perspective as far as their inward many-sided quality [30].

2. **Two-Person**

Two-man diversions are the biggest classification of well-known amusements. A more confused amusement got from 2-man diversions is the n-individual diversion. These amusements are widely examined by diversion scholars. Be that as it may, in stretching out these speculations to n-individual recreations a trouble emerges in anticipating the collaboration conceivable among players since circumstances emerge for participation and intrigue [30].

3. **Two Person Zero Sum Game**

It is the game that have only two players for instance Player A and B. In this game, there is an equal opportunity for both the players such as the gain of one player is equal to the loss of the other and is known as the ‘two-person zero sum game’. It can be illustrated by giving the example of two chess players that if they decide before starting the game that the loser one would give some money to the winning one; from this it can be said that the sum of the gains and losses equal zero. In this way, this chess example can be termed as the two-person-zero sum game. For this game, the main thing which is required to be known by the person is the Payoff Matrix of the game. The payoff can be described as a quantitative measure of contentment which the player gets at the last of the game. The measure of the contentment is in terms of gains or losses; the specific strategies and approaches of the players can be signified in the form of a matrix which has been called as the ‘payoff matrix’ by many researchers. The zero sum of the game means that the loss of one person is equal to the gain of the other player and conversely. It can be summarized as the amount at the payoff table of one player is equal to the amount at the payoff table of the other player but having contradictory signs. It has been found that construction of payoff table for any one of the person is sufficient enough as there is no requirement to draw table for other player. For instance, if the approaches of player A are represented by A_1, A_2, --------, A_m and the strategies or approaches of player B are presented as B_1, B_2, -------, B_n than the total outcomes can be calculated by multiplying ‘m’ to ‘n’. In this manner, it can be said that each of the player playing the game is aware of the opponents’ potential course of actions. However, by an assumption it can be said that among the players, Player A is considered as the gainer while the loser would be the player B. The gains of the player A can be represented as the payoff ‘a_{ij}’, in which ‘i’ is the strategy of player A and ‘j’ is the strategy of player B [31].

2.9 Game Theory Basics for Cognitive Radio Networks

In cognitive radio network, the primary user settles on keen choices on range use and correspondence parameters in view of the detected range elements and CR user' choices. Besides, the primary user who vies for range assets may have no motivating force to participate with each other, and act egotistically. Subsequently, it is normal to think about the shrewd practices and connections of childish primary user from the diversion hypothetical point of view [32].

Diversion hypothesis is a numerical instrument that examines the key communications among various leaders. Three noteworthy parts in a key shape diversion demonstrate are the arrangement of players, the procedures/activity space of every player, and the utility/result work, which measures the result of the amusement for every player. In cognitive radio network, the opposition and collaboration among the subjective primary user can be all around displayed as a range sharing amusement. In particular, in open range sharing, the players are all the secondary users that go after unlicensed range; in authorized range sharing, where primary users rent their unused groups to secondary users, the players incorporate both the primary and secondary users [33].

The procedure space for every player may shift as per the particular range sharing situation. For example, the procedure space of secondary users in open range sharing may incorporate the transmission parameters they need to embrace, for example, the transmission powers, get to rates, time term, and so on.; while in authorized range exchanging, their system space incorporates which authorized groups they need to lease, and the amount they would pay for renting those authorized groups. For the primary users, the procedure space may incorporate which secondary users they would rent each of their unused groups to, and the amount they will charge for each band. The utility capacities for various users are in like manner characterized to portray different execution criteria. In open range sharing, the utility capacity for the secondary users is frequently characterized as a non-diminishing capacity of the Quality of Service (QoS) they get by using the unlicensed band; in authorized range exchanging, the utility capacity for the users regularly speaks to the money related increases (e.g., income less cost) by renting the authorized groups. The fundamental components of the amusement [34] A detailed description about the strategic interaction between the players. Here strategy would encompass the full description about a player’s behavior, which describes the possible rational actions that a player would take if it has to take a decision [35].

- A set of constraints on the possible actions which the player can take. In any given scenario there are constraints and rules imposed by the environment where the modeling is done.
- A specification in the form of a preference function which gives the relative priority over the strategies in a given scenario.

CHAPTER THREE

PROPOSED ALGORITHM

3.1 Introduction

In this chapter we proposed the logic to build the dynamic resource allocation in cognitive radio networks. The CRN system has primary users (PUs) and secondary users (SUs) with dissimilar service requirements in heterogeneous networks. The secondary base station (BS) is in charge of asset share for various SU's present in the system. The secondary users have different scenario are: SU with minimum-rate guarantee, SU with minimum delay guarantee, SU with minimum rate and delay guarantee and SU with best effort service.

1. Transmitted total power of every channels of SU should be within modest power at secondary BS.
2. For minimum-rate guarantee, the transmission rate for SU ought to be more prominent than the base rate limit.
3. For minimum delay guarantee, the transmission delay for SU ought to be less than the target threshold.
4. For minimum rate and delay guarantee, the transmission rate ought to be more prominent than the base rate edge and the transmission postponement ought to be not exactly the due date edge.
5. For best effort service, fairness limitation ought to be satisfied.

3.2 System Model

The Cognitive radio works on primary user and secondary user communication system. The secondary users have a relative low range access power. Secondary user should constantly sense the band of spectrum density and should know the any adjustments in their remote system and roll out changes accordingly with correspondence improvements appropriately without making destructive interference with the primary user. The principle goal of the range detection is to discover accessible free-range assets (un-got to channels), gauge the channel quality, transmit the sharing spectrum and outline self-versatile transmitting waveform which fits range attributes taking into account correspondence needs. At the point when the channels are not got to by the primary user (PUs) the secondary user (SUs) can get to the unmoving channel ideally. What's more, occasionally check the capacity of the PU such that the Cognitive users' handovers the channel to the PU when a PU is identified. Consequently, the SU doesn't interference with the PU and just get to the unmoving channel when the PU is not getting to the given channel.

We mainly assume K_1SUs with minimum-rate guarantee, K_2SUs with minimum delay guarantee, K_3SUs with minimum rate and delay guarantee and K_4SU with best effort service. We also assume N ideal sub-channels in a given time slot. The number K_1, K_2, K_3, K_4 and N can vary dynamically in altered time periods.

Here, to diminish the complexity, we must consider K_1, K_2, K_3, and K_4 and relation defined for our approach as, $K_1=K_2=K_3=K_4$. Hence, we consider that there are equal numbers of heterogeneous SUs with all performance criteria.

We can make an optimal resource allocation in a given network with heterogeneous SUs and multiple PUs are satisfied the following assumptions.

In cognitive radio, we made an assumption that only one SU (N_3) with minimum-rate guarantee, one SU (N_4) with minimum delay guarantee, one SU (N_2) with minimum rate and delay guarantee and one SU (N_1) with best effort service Figure 3.1 and then consider $K_1=K_2=K_3=K_4=1$with four CR (Secondary User).

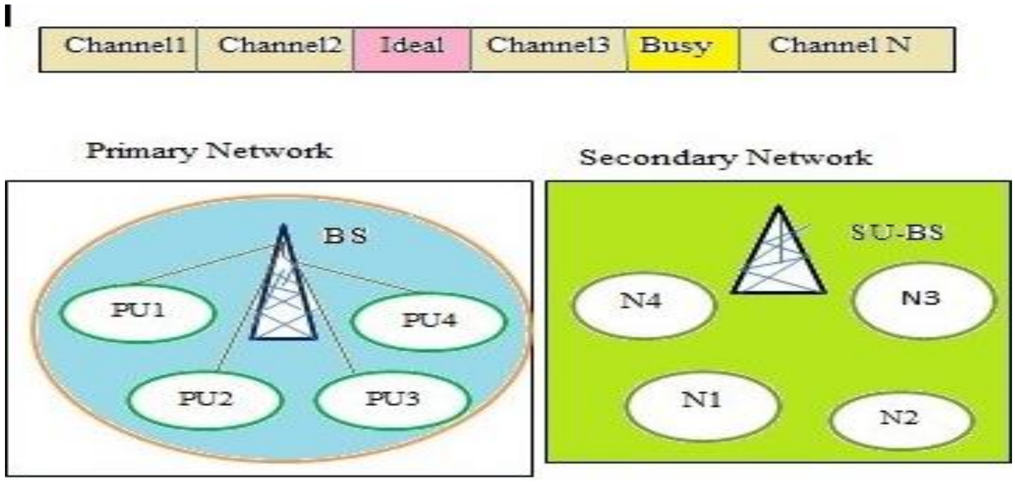


Figure 3.1: Network Model Assumption

1. Distinguish the presence of unmoving range. Here the PU does not possess the sub-channel being gotten to by the PU at a particular time.
2. In the event that the SU affirms the nearness of unmoving sub-channel, SU needs to occasionally distinguish the nearness of PU or inhabitance of the sub-direct by other SU keeping in mind the end goal to stay away from strife with other subjective users who are attempting to get to the same sub-channel.

We consider overcoming the limitations and complexities in channel sensing SU-BS. The Secondary network time-slot entails of the following time intervals:

- Time intervals for sensing
- Time intervals for resource distribution
- Time intervals for data transmission

In Figure 3.2, Sub-channel owed to PU2 is exposed idle and later a SU should use the channel till the PU turns back to use the origin.

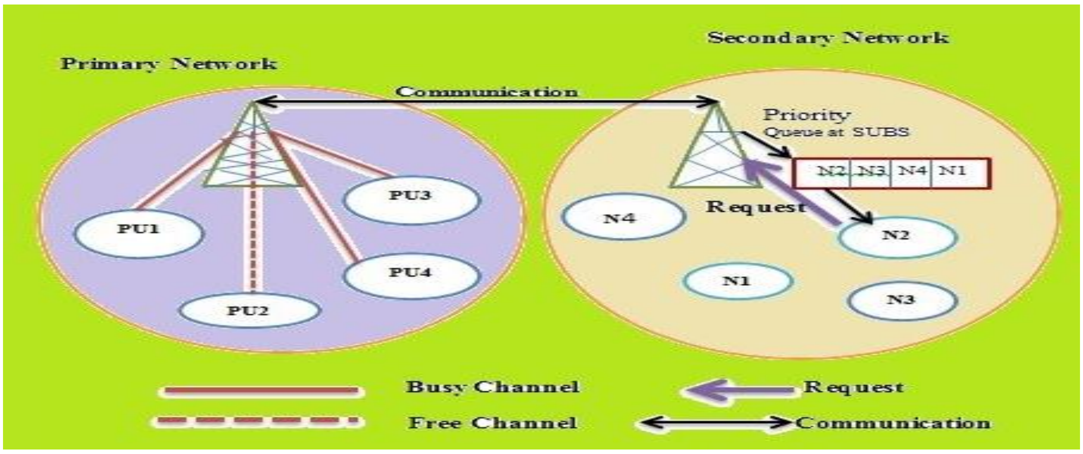


Figure 3.2: Network Model Operation

3.3 Dominance Rule

A dominance run is built up with a specific end goal to decrease the arrangement space of a gap space issue by adding new limitations to it, either in a system that expects to diminish the areas of factors, or straightforwardly in building fascinating arrangements.

We are thusly proposing an examination concerning what dominance rules are so as to share the gap space in intellectual radio system. So we give a meaning of a dominance lead with its diverse subtleties and break down how strength rules are by and large defined and what are the results of such definitions so as to get the unused data transfer capacity.

3.3.1 Instances of a problem

An example of a sharing issue is gotten by indicating specific unused band esteems value for all the issue parameters. This description of an issue case can be seen as a limited string of unused transfer speed looked over a limited information gap space as indicated by one specific settled encoding plan. The information length for an example of the issue is then characterized as the quantity of holes paces in the depiction of the case and it is utilized as the formal measure of occasion estimate. On account of a sharing issue, an occurrence is determined by its number of holes spaces and by the qualities given to the processing times. The occasion estimate is for the most part communicated as a different of the quantity of holes spaces, since the greatest number of symbols utilized for each value is by and large considered to be settled. Once modeled, a sharing problem can then be formally defined by:

- a n-tuple of variables $(x_1, x_2, ..., x_n)$, the value of each variable x_i belonging to a set $D(x_i)$ that we call the domain of x_i;
- a set C of constraints on variables.
- an objective function $\Phi : D(x1) \times D(x2) \times ... \times D(x_n) \rightarrow R$ which associates a value with each assignment.

3.3.2 Solving a problem

Once modeled, solving a problem consists of assigning a value to each variable. An assignment has to be chosen from the Cartesian product

$\Omega = D(x1) \times D(x2) \times ... \times D(x_n)$ in such a way that:

1. the set C of constraints is satisfied;
2. The objective function Φ is minimized.

Note that maximizing an objective function is equivalent to minimizing the negative of the same function. Thus, the above formulation also covers maximization problems.

In this thesis we look at that as a sharing issue is any issue as characterized above which is decidable, i.e. for which there exists a calculation taking care of the issue in a limited number of steps. Satisfy all constraint and minimized all objective function.

We wish to acquire a task fulfilling every one of the requirements and which limits the objective function Φ which represent to the saddle point in this thesis. In this manner, an objective function is required to connect with every task an incentive from among a given set of values referred as $D(\varphi)$. We stretch out the objective function to subsets of solutions: for any subset S of solutions, we characterize $\Phi(S) = \min_{z \in S} \Phi(z)$. The presence of a task fulfilling the requirements of the issue is generally not some portion of the inquiry. Regularly, the quantity of such conceivable assignments is unprimary and the only thing that is in any way important is to locate an optimal assignment. That is the reason why we discuss "optimization problem".

3.3.3 Formulations of dominance rules

In this segment, we give a formal meaning of the dominance run idea with its diverse subtleties.

Barely any meanings of strength rules are to be found in the accompanying way: "dominance properties give conditions under which certain potential solutions can be ignored ".

Definition should be possible in various ways. The conceivable changes which can be performed by the dominance manage being considered are very subject to the attributes of property A and on the definition which utilizes this property.

Note that a substantial scope of adaptability is allowed in the declaration of A. In this way, utilizing a dominance govern includes putting oneself helpless before the property A, since distinguishing solutions fulfilling A may or may not be straightforward.

We now break down various details of a strength control as indicated by a given property A and we demonstrate what sort of modifications can be performed by a definition.

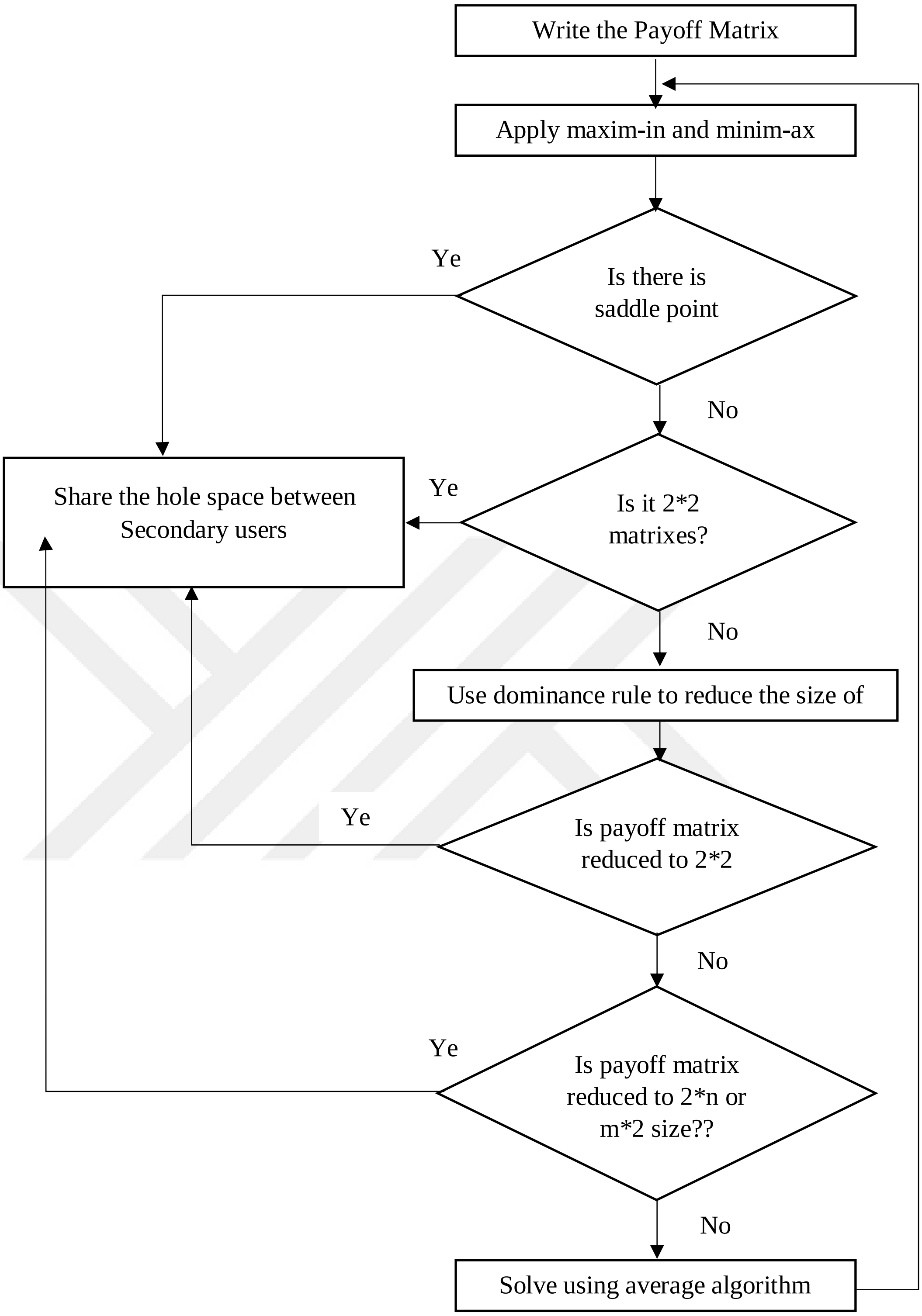


Figure 3.3: Flowchart of Dominance Reduction algorithm

3.4 Proposed Algorithm

In a cognitive radio system, numerous secondary users sense the spatial channels and share the spectrum use with incumbent primary users. Every secondary transmitter competes with others to expand its own data rate while creating restricted aggregate obstruction to the primary recipients.

The goal of the work is to outline an instrument that empower reasonable and effective sharing of resources between SUs. In this thesis a range access in cognitive radio systems will be demonstrated as a rehashed cooperative. The theory and acknowledgment of agreeable range sharing is displayed in detail, where we came to realize that there is a PU and a few SUs to settle on a choice or pick a best band from a few decisions. The benefits of cooperative sharing are explained via simulation.

This thesis show to the different alternatives and payoff in matrix would then be able to determine the best single band or mix of bands utilizing payoff matrix techniques from linear programming. However, game theory is additional design of matrix algebra besides linear programming. Keeping in mind the end goal to expand the entirety rate of the cognitive radio system, the issue of secondary user transmission is demonstrated as a cooperative game. The technique of every secondary user is the transmit covariance matrix, and the utility is an estimate of the data rate. The secondary users consult over the distribution of the spectrum packet plan and reach at a dealing solution that maximized the network utility. An effective distributed method is created that merges rapidly to the optimal solution with moderate signaling inside the network. Numerical outcomes demonstrate the performance enhancement in entirety rate of the cognitive radio system at solution of the cooperative game contrasted with computation game. Along these lines, this approach has been proposed to isolate spectral gaps.

It is appeared by numerical outcomes that the proposed system could achieve the greatest aggregate benefit for SUs with better objectivity. Another arrangement is presented in this thesis, which is complete through by presenting reputation game between SUs.

3.5 Assumptions and system model: PU's and SU's and their allocation function

In the accompanying segments, we consider a range overlay-based subjective radio remote framework with one PU and N SU's. The PU will share some bit (b_i) of the free range (F) with SU_i. The PU inquires each SU an installment from c for every unit transfer speed for the spectrum share, where c is a component of the aggregate size of range accessible for sharing by the SU's. The income of SU_i is indicated by r_i per unit of achievable transmission rate. A simple example is shown in Figure 3.7.

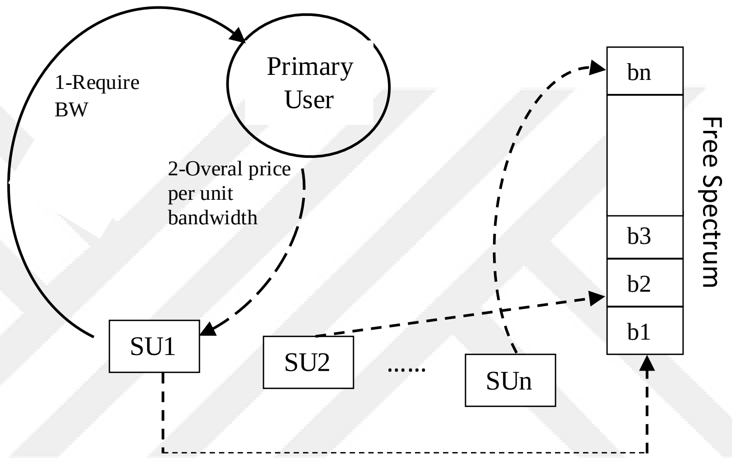


Figure 3.4: System model for spectrum sharing.

In this work the distributed decision is presented. In the previous case, each SU is supposed to have the capacity to distinguish the systems expected by additional user (i.e., whichever the users can examine their data between them, or the PU sends refresh of each SU share). In the last case, the variety for strategy sharing is performed in a distribution mode in light of correspondence between each of the SUs and the PU just (i.e., the secondary users are unable to watch the techniques and payments of each other). The least value of time will be deleted based either the min/max algorithm or the average process.

In This section includes the steps of how the proposed algorithm, work as shown in follow:

Table 3.1: Components of spectrum sharing games in cognitive radio networks

	Open spectrum sharing	**Licensed spectrum sharing (auction)**
Players	Secondary user that compete for an unlicensed spectrum band.	Both primary and secondary users
Actions	Transmission parameters, for example, transmission power, and access rates, waveform, and so on.	secondary users: which authorized band they need to lease and the amount they would pay for renting the authorized bands; Primary users: which secondary users they will rent each unused band to and the charge.
Payoff	The quality of services via using the spectrum	Financial additions, via renting the authorized range.

The strategy of this work is move dominates another if every one of its payoff are in any event as invaluable to the player as the comparing ones in the other move. As far as the result network, we can state it along these lines:

1. Row A in the payoff matrix control on row B if every payoff in row A is ≥ the comparing payoff in row B.

2. Column A in the payoff matrix control column B if every payoff in column A is ≤ the comparing result payoff in column B. Note that if two rows or column are equivalent, at that point each dominates the other. A row or column control another if the one control the other and they are not equivalent.

Every player following the standards of game theory will repeatedly remove dominated row besides column. (In the event that two row or column are equivalent, at that point there is no motivation to pick one over the other, so either might be removed.) This procedure is called reduction by dominance.

A saddle point represented as payoff that is concurrently row minimum in additional to column maximum. To find this point, circle the row minima and box the column maxima. Therefor these points are these items circle and box.

A game is entirely decided whether it has at less one saddle point. The following statements are valid about entirely decided game.

1. All saddle points in a game have a similar payoff rate.
2. Choosing the row and column through any saddle point gives smaller than expected max methodologies for the two players.in other words, the game is solving by means of the utilization of these (immaculate) methodologies.

3.6 Proposed Model of the Network

A system having p = 1, 2, 3 … P of PUs besides c=1, 2, 3, 4 … C CR user working in a similar pattern in figure 3.8. Every CR user performs detecting operation on n = 1, 2, 3... N primary channels of same cell and forward this estimation to the central entity identify as CR base station. The transmission on nth channel for CR user c utilizing can be displayed as (channel statues flag) Csf n (t). The Csf n(t) = 0 denotes to the idle state, though Csf n (t) = 1 demonstrates the busy state of channel. The CR user can transmit only during the idle state of the channel. The length of the slot represented as ‘l’ has been sub-divided in three sub-slots. The sensing time used by a specific CR user is represented by the symbol ‘τ’, however, the channel expulsion time duration is presented as ‘ε’ while the data transmission duration is represented as td.

Scientifically, the slot length is represented in figure 3.8 below:

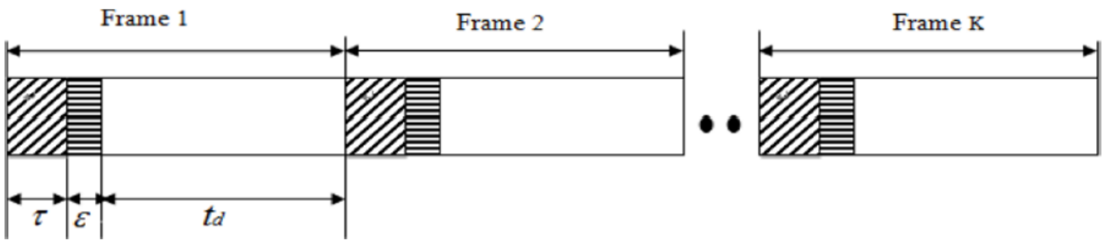


Figure 3.5: Format of the Frame having ‘τ, ε, and td’

$$\lambda = \tau + \varepsilon + td \qquad (3.1)$$

$$td = \lambda - \tau - \varepsilon \qquad (3.2)$$

$$\varepsilon << \tau << td \qquad (3.3)$$

It has been assumed that the time of the channel deportation is very limited and small by comparing it to the sensing time, whereas as time of the real statistics communication is considerably better than the sensing time for a given time slot. In addition, the allotment is executed after every time slot and it is assumed that the situation remnants similar for the period of a specified time slot.

3.7 The Activity of PU Arrival

The spectrum band of Pus has been used by the CRN in a prospective way purely on the basis of lease. In the PUs point of view, there is a significant element according to which CR should check out the channel in order to circumvent the interventions and diminish the retransmission number whenever PU requires a spectrum band. On-off activity of PU has been presented in figure 3.9 which has been considered for the simulation outcomes on three diverse channels. In the beginning, all of the three channels considered are in an inoperative condition (which, Csf n(t) = 0 ∀ n); however, they are accessible for all the CR communications. During the slot number two, PU disembarks on the channel one while the status changes from inoperative state to the operative state (mathematically it is represented as: Csf n(t) = 1 for n = 1. At some point of the sensing interval, the influx activity of PU has been sensed by CRs while vacating the channel immediately by executing channel deportation activity by the EC block.

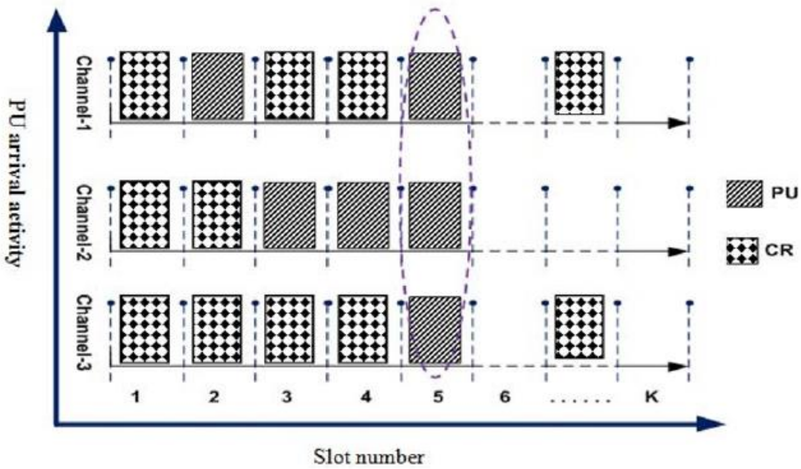


Figure 3.6: The Activity of PUs Arrival

3.8 Spectrum Sharing using Dominance Reduction and Average Algorithms (SSDR/AA)

Many steps can be explained from this algorithm listed as follows:

Step 1: Define 'n' sub channels SUs K_1, K_2…….K_n

Step2: monitor the PU arrival activity, so sense the presence of PU, it yes handoff and Csf =1, otherwise the Csf =0, so the sensing the channel is free and allocation for SU.

Step 3: the eviction state (the switch of state) monitor the channel statues flag for different channel. For instance if Csf of a particular channel is equal to 1, the eviction controller inform the CR user and handoff from this channel.

Step 4: select the channel slot idle from the database that stored SU-BS which discovered in step 2 & 3.

Step 5: Composition of two-dimension matrix and given the initial value of matrix (G) which represents the initial value of spectrums (spectrum holes that discovering in spectrum sensing step).

Step 6: Computing the minimum value of each row and maximum value of each column through make the relation between values of same row and same column, and then we get minimum value from row and maximum values from column which represents the spectrum hole.

Step 7: Apply the maxim method in the results of step 6, for each value (minimum and maximum values spectrum holes which obtained from row and column of G matrix.

Step 8: Computing the saddle point (S.P.) if the max-min value equal min-max value, otherwise compare between all rows to get the row which has a less weight among them and then deleting it form the computing process.

Step 9: Searching the second dominance for the largest column after compare it with other columns and then deleting it, after that go to step 6 for process of preprocessing of saddle point.

Step 10: apply the average algorithm by addition the each entity corresponding row and divided by two and apply the same operation on column.

Step 11: Using the same matrix in step 5 if contain the approximated value in each rows and column, then make cooperative process between two rows and two columns through addition these values.

Step 12: Repeat steps (6, 7, 8 and 9) to find the saddle point (S.P) in order to develop the stability point.

Step 13: implement the switch operation in order to achieve the scheduling step by using round robin algorithm.

Step 14: compute the average waiting time and average service time by using the following equation.

Average waiting time= (No.user – all.user-1)* TimeSlice / No.user

Average service time= ∑ round.user / No.user

Step 15: Termination steps.

The above algorithm can be explained in figure 3.7below:

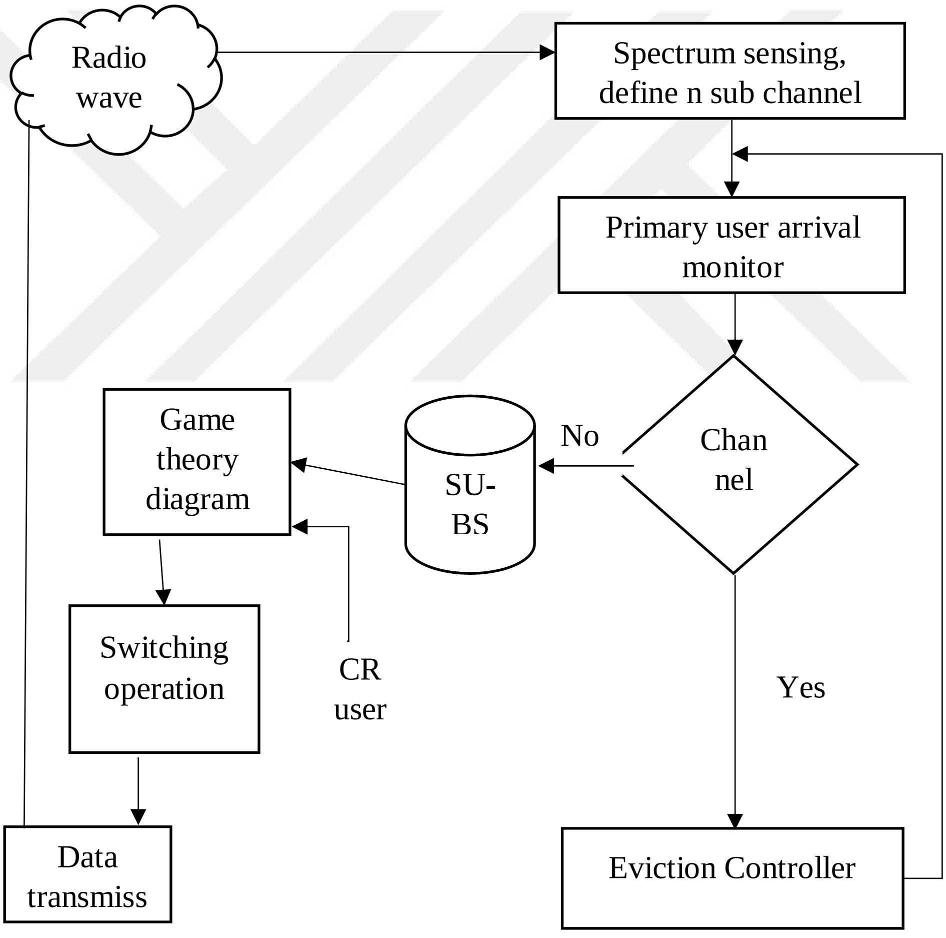


Figure 3.7: The overall Spectrum Sharing operation

CHAPTER FOUR

Results and Discussion

4.1 Introduction

This chapter represents the proposed algorithm which has been quantified while presenting the simulation outcomes. MATLAB has been used for simulating of the program. However, analysis has been performed for some particular case to exemplify the results despite the uncertainty of the simulation outcomes for most of the general cases. The approach which has been selected for this particular study is diverse from other researches in the same field in regards to the sharing of the spectrum contradiction due to the asymmetrical PU activities and all the other alterations happen in the radio environment. Comparison has been made with recent and the other previous studies in terms of the proposed approach specifically addressing the power expenditure for the broadcast of the CR user's information folder. In table 4.1, the utilized parameters in this particular study for simulation have been represented below:

Table 4.1: Parameters of Simulation

Parameter	Values
Slot length	1s
Transmission period	0.4s
CR user pairs	2
Minimum data requirement	[1.0, 2.0, 3.0]

4.2 Demonstrable Cases:

In this section we will demonstrate two cases that express the behavior of our model

Case 1: The first example we show, how we can obtain the:

$$G = \begin{bmatrix} 7 & 8 & 4 & 2 \\ 9 & 0 & 7 & 4 \\ 5 & 1 & 5 & 3 \\ 6 & 7 & 9 & 1 \end{bmatrix}$$

We obtain the minimum element in each row, and the maximum element in each column

Min-row

$$G = \begin{bmatrix} 7 & 8 & 4 & 2 \\ 9 & 0 & 7 & 4 \\ 5 & 1 & 5 & 3 \\ 6 & 7 & 9 & 1 \end{bmatrix} \quad \begin{matrix} 2 \\ 0 \\ 1 \\ 1 \end{matrix}$$

maxmin
2

Max-column

9 8 9 4

minimax
4

2≠4

So that 2< v < 6

Not Saddle point

Since 2 not equal 4, then it's not a saddle point. Sum of rows and sum of columns must be found to detect and delete the lower row and the highest column.

Sum-row

$$G = \begin{bmatrix} 7 & 8 & 4 & 2 \\ 9 & 0 & 7 & 4 \\ 5 & 1 & 5 & 3 \\ 6 & 7 & 9 & 1 \end{bmatrix} \quad \begin{matrix} 21 \\ 20 \\ 14 \\ 23 \end{matrix}$$

14 → Delete lower row

$$G = \begin{bmatrix} 7 & 8 & 4 & 2 \\ 9 & 0 & 7 & 4 \\ 6 & 7 & 9 & 1 \end{bmatrix}$$

Sum-column

22 15 20 7

Delete highest column

For the resulted 3×3 matrix we will have the minimum element in each row and the maximum element in each column.

Min-row

$$G = \begin{bmatrix} 8 & 4 & 2 \\ 0 & 7 & 4 \\ 7 & 9 & 1 \end{bmatrix} \quad \begin{matrix} 2 \\ 0 \\ 1 \end{matrix}$$

maxmin
2

Max-column

8 9 4

minmax
4

Sum-row

$$G = \begin{bmatrix} 8 & 4 & 2 \\ 0 & 7 & 4 \\ 7 & 9 & 1 \end{bmatrix} \quad \begin{matrix} 14 \\ 11 \\ 17 \end{matrix}$$

11 → Delete lower row

$$G = \begin{bmatrix} 8 & 4 & 2 \\ 7 & 9 & 1 \end{bmatrix}$$

Sum-columns

15 13 3

15 ↓

Delete highest column

Min-row

$$G = \begin{bmatrix} 4 & 2 \\ 9 & 1 \end{bmatrix} \quad \begin{matrix} 2 \\ 1 \end{matrix}$$

max-min
2

Max-column

9 2

min-max
2

The saddle point is 2

Case 2: The second example shows another example by giving the matrix:

$$G = \begin{bmatrix} 4 & 5 & 1 & 4 \\ 3 & 5 & 2 & 5 \\ 2 & 3 & 5 & 4 \\ 6 & 4 & 2 & 7 \end{bmatrix} \quad \begin{matrix} 14 \\ 15 \\ 14 \\ 18 \end{matrix}$$

Average step view

By summation the first row with second row that we have (3×4) matrix:

$$G = \begin{bmatrix} 7/2 & 10/2 & 3/2 & 9/2 \\ 2 & 3 & 5 & 4 \\ 6 & 4 & 2 & 7 \end{bmatrix}$$

$$G = \begin{bmatrix} 3.5 & 5 & 1.5 & 4.5 \\ 2 & 3 & 5 & 4 \\ 6 & 4 & 2 & 7 \end{bmatrix}$$

Sum-column

11.5 12 8.5 15.5

Average two columns

By summation the first column with second column that we have (3x3) matrix:

$$G = \begin{bmatrix} 3.5 & 5 & 1.5 \\ 2 & 3 & 5 \\ 6 & 4 & 2 \end{bmatrix}$$

Min-row

$$G = \begin{bmatrix} 3.5 & 5 & 1.5 \\ 2 & 3 & 5 \\ 6 & 4 & 2 \end{bmatrix} \begin{matrix} 1.5 \\ 2 \\ 2 \end{matrix}$$

maxmin
2

max-column

6 5 5

minmax
5

2≠5… ()

2<v<5 Not saddle point

sum-row

$$G = \begin{bmatrix} 3.5 & 5 & 1.5 \\ 2 & 3 & 5 \\ 6 & 4 & 2 \end{bmatrix} \begin{matrix} 10 \\ 10 \\ 12 \end{matrix}$$ → Delete lower row

$$G = \begin{bmatrix} 2.75 & 4 & 3.25 \\ 6 & 4 & 2 \end{bmatrix}$$

Sum-column

8.75 8 5.25

↓

Delete the highest column

Min-row

$$G = \begin{bmatrix} 4 & 3.25 \\ 4 & 2 \end{bmatrix} \quad \begin{matrix} 3.25 \\ 2 \end{matrix}$$

maxmin
3.25

Max-column

$$4 \quad 3.25$$

minmax
3.25

The saddle point is 3.25

4.3 Selection Channels and Evaluation Service

In the proposed work, there are N channels that will be used in order to achieve the cognitive radio network, figure 4.1 below explain the sample of used.

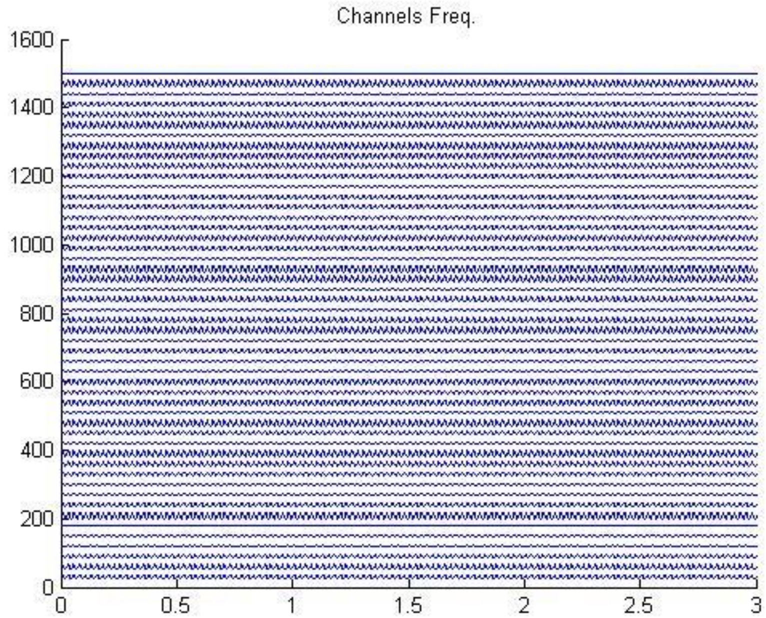


Figure 4.1: Frequency of Channels

In this part there are random unused band that will be used for secondary users where Cfs=0, in figure 4.2 there are 26 channels that may be secondary users use it from 50 sample channels note that the number of channel are randomly because the system is randomly.

The selecting channels of transmission (TM) on the throughput have been showed in figure 4.3. It can be seen that the transmission modes describe the on-off PU of the obtainable channels. For example, only 50’s channels with 2 up to 8 SU TMs have been considered. For instance, channels has been found as the best channel having best quality and having usage time of 10 to 1000 timeslot for all channels. The reason behind this reduction in the usage time is the interference of co-channels between the CR users. The co-channel interference has been noticed as the maximum when all the channels are active. The distinction in the total waiting time accomplished for time slots have been depicted in figure 4.3. It has been specified beforehand that the suspicions in this postulation give same information rate on every single accessible channel. Consequently, we plot the varieties just for total waiting time divert in Figure 4.3. At first, the information of total waiting time on the given channel is 30-time unit yet information time diminishes amid second and third schedule openings. This scheduling in information time is a result of the best channel condition. The information time builds again to 24-time unit amid vacancy. The most extreme information time of 20-time unit and least information time is 18-time unit are accomplished amid availability. The figure 4.4 displays the result of comparison between reduction algorithm and randomly selection in spectrum shearing for total waiting time for secondary users. It`s noticeable that the randomly selection is finished before the reduction algorithm because of the PU arrival on this channel, this explains the reduction algorithm selection of the most stable channel in the random selection.

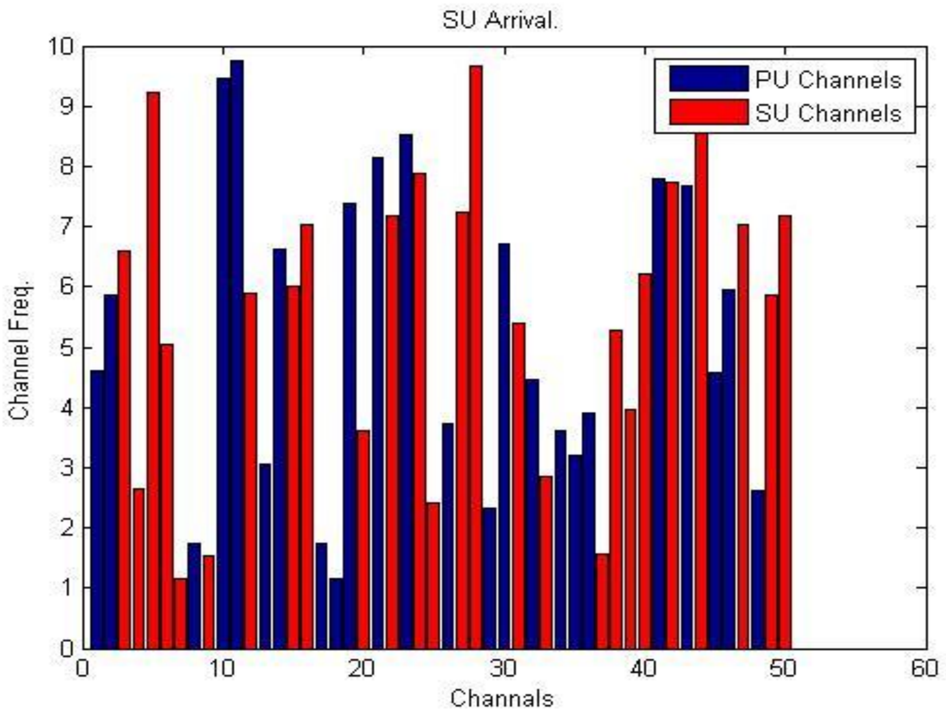


Figure 4.2: SU Arrival on Channels

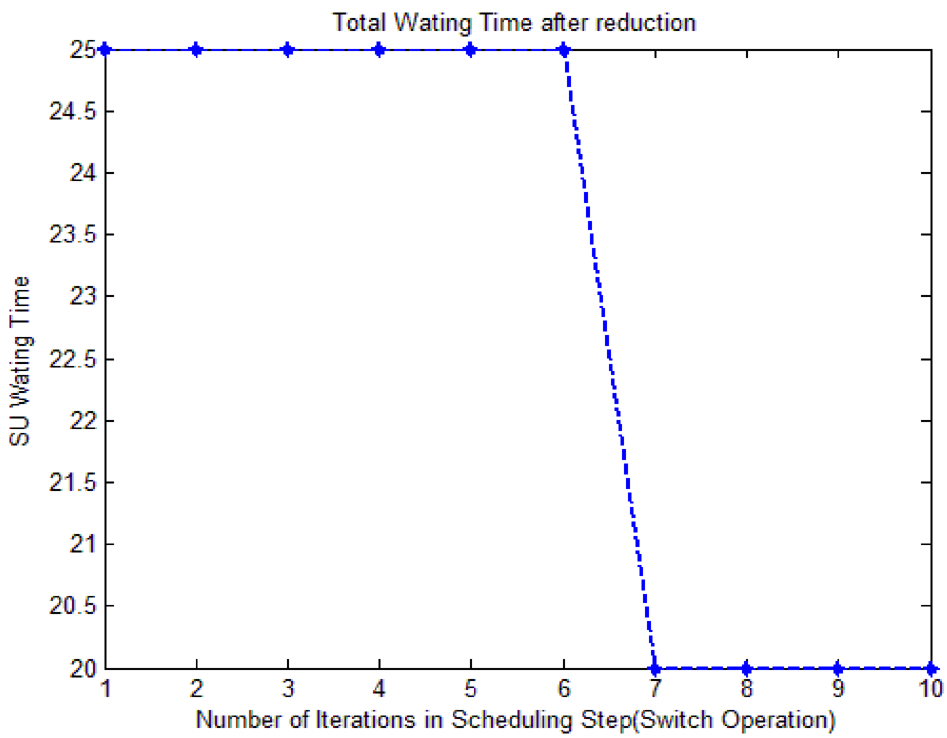


Figure 4.3: Total Waiting Time for SU

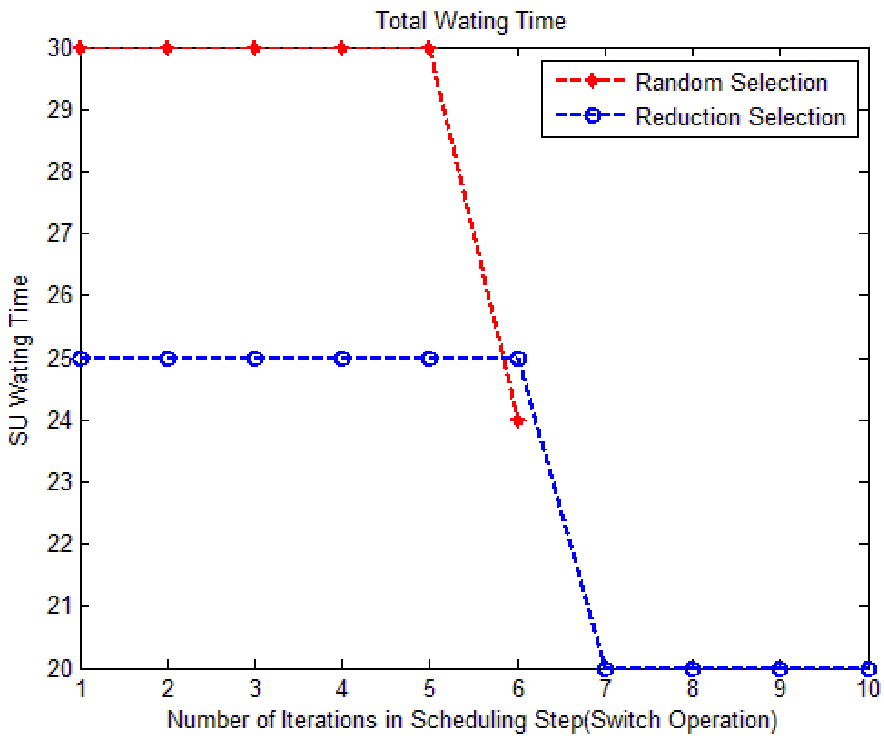


Figure 4.4: Comparison between Reduction Selection and Random Selection

4.4 Channel Eviction Activity, and Average waiting time of Channel Sharing

In the beginning, in the first time slot all Primary channels are in the idle condition. Therefore, these channels can be used for CR correspondence. In the second slot, a PU reaches on channel 1. For this situation, the PU arrival monitor block sets the Csf = 1 for channel 1 and educate the range allocator about the influx of PU at this time slot. The range allocator ousts CR from channel 1 by setting off the channel removal mechanism. This may lead slight derogation in CR user's throughput working at the cost of obstruction evasion.

The impact of channel removal on the Average waiting time is outlined in figure 4.5. The aggregate time is the total of information time accomplished on all channels by all CR users. For instance, in current case, we consider channel and the Average waiting time is equivalent to the expansion of accessible information rates on all channels. The result demonstrates that the average waiting time for the case in which channel is accessible for CR users. The whole time is most extreme amid time of SU group. The figure 4.6 displays the result of comparison between reduction algorithm and randomly selection in spectrum shearing for average waiting time (network delay) for secondary users. It`s noticeable that the randomly selection is finished before the reduction algorithm because of the PU arrival on this channel, this explains the reduction algorithm selection of the most stable channel in the random selection.

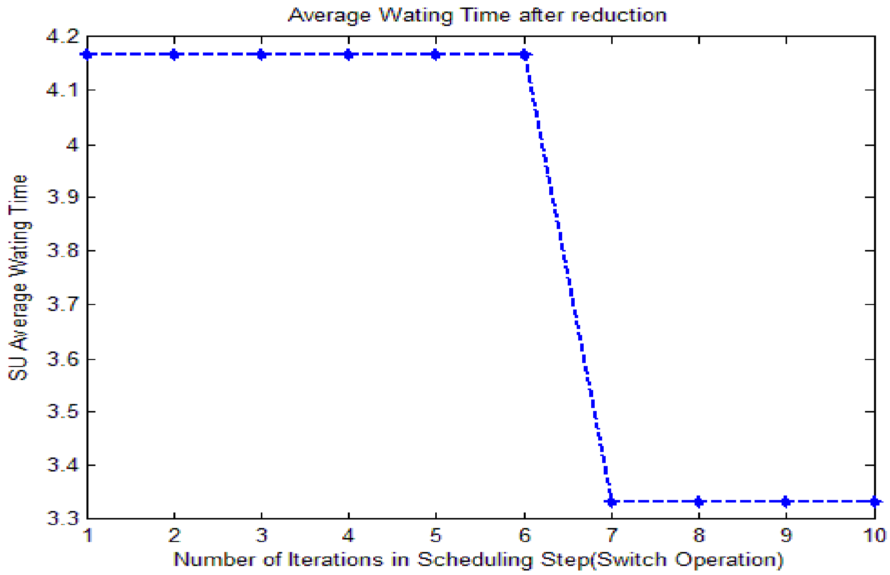


Figure 4.5: SU Average Waiting Time

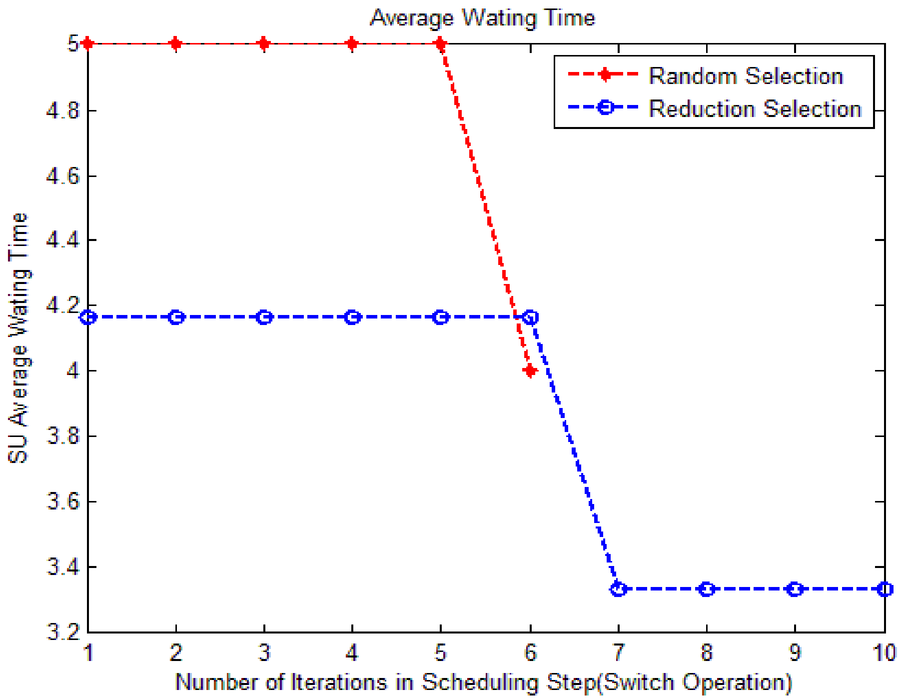


Figure 4.6: Comparison between Reduction Selection and Random Selection

4.5 The Evaluation of System Model

In this part we show the criteria of efficiency of system model in terms of Impacts of SU's service time, timeslot losses and throughput.

Figure 4.7 demonstrates the Average service time of administration time. In this situation, we demonstrate the main features of selected channel after reduction step as shown in table 4.2

Table 4.2: The Properties of Channel Selection

Properties of Channel	Value
Frequency	5.9407
Usage time	247
Speed rate	43
Index	47

In sample case, there are 6 secondary users each has specific requirements in order to accomplish the communication requirements, the requirements explain in table 4.3 as shown below.

Table 4.3: Secondary User's Requirements

Secondary User ID	Slot Requirement
SU_1	172
SU_2	191
SU_3	163
SU_4	40
SU_5	84
SU_6	102

For each secondary user there, average service time for each switch operation that will implemented in scheduling step (in this thesis we use Round Robin algorithm), the figure 4.7 demonstrated all cases of SU average service time for specific period of time. The figure 4.8 displays the result of comparison between reduction algorithm and randomly selection in spectrum shearing for average service time for secondary users. It`s noticeable that the randomly selection is finished before the reduction algorithm because of the PU arrival on this channel, this explains the reduction algorithm selection of the most stable channel in the random selection.

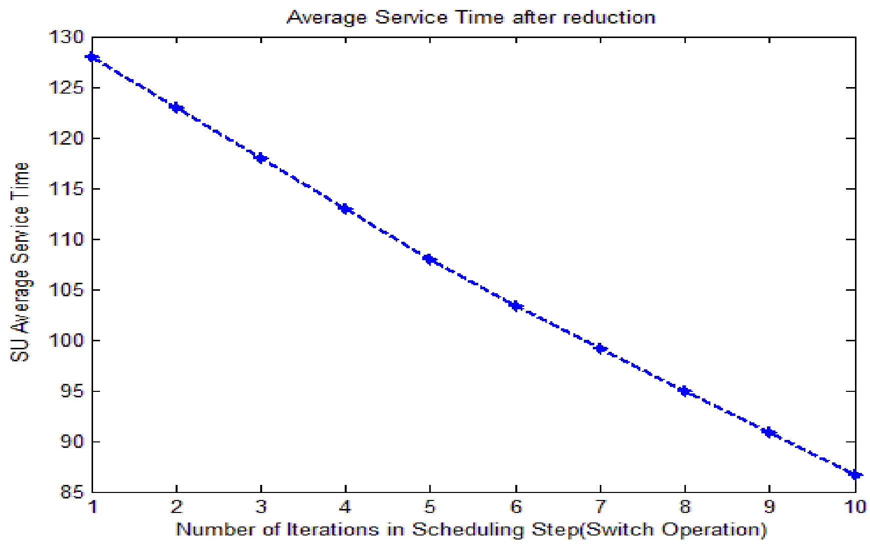


Figure 4.7: Impacts on Average Service Time

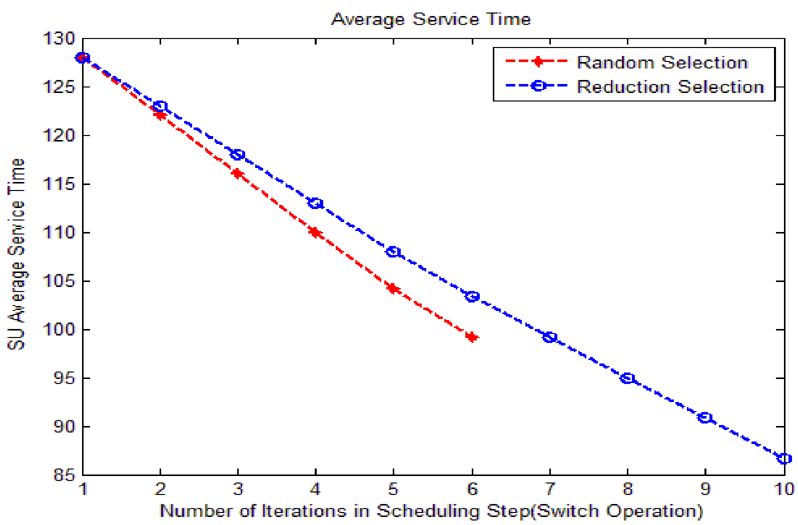


Figure 4.8: Comparison between Reduction Selection and Random Selection

Each secondary user may be having a loss in term of number of timeslot that un serviced in the operation of scheduling algorithm, figure 4.9 explain the amount of loss in each secondary user, as we shown, there is no loss in secondary user number 4, 5, and 6 while there is 40% loss in secondary user number 1, 48% for secondary user number 2 and 38% for secondary user number 3.

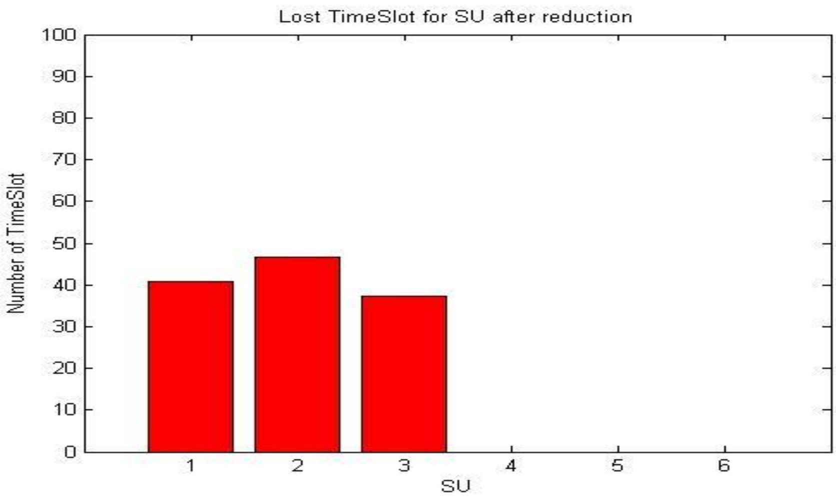


Figure 4.9: Lost Timeslot in SU

The figure 4.10 displays the result of comparison between reduction algorithm and randomly selection in spectrum shearing for lost timeslot in secondary users. It`s noticeable that the amount of lost timeslot of secondary user in random selection is greater than the amount of lost timeslot of secondary user in reduction algorithm, figure 4.10 explains this situation.

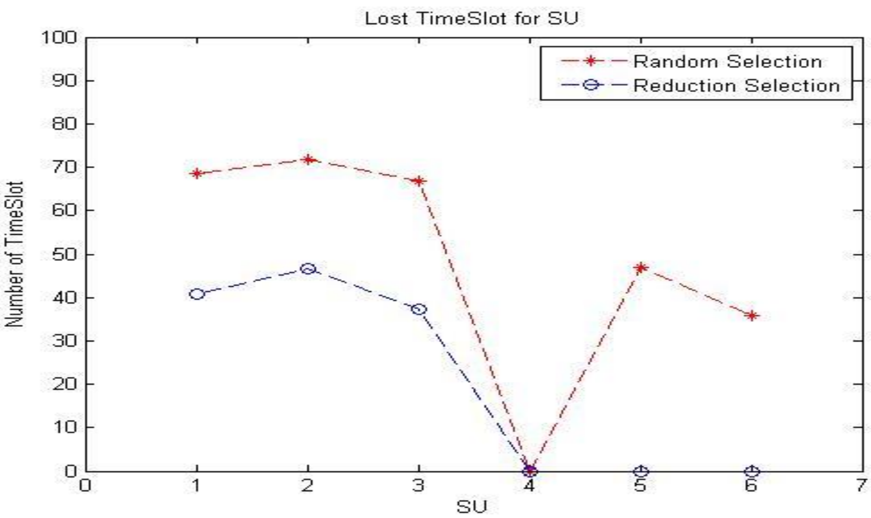


Figure 4.10: Comparison between Reduction Selection and Random Selection

The figure 4.11 explains that there is excellent throughput in overall secondary user's channels after loss completion, most of these channel reach to 100% in term of throughput. The figure 4.12 displays the result of comparison between reduction algorithm and randomly selection in spectrum shearing for throughput timeslot in secondary users. It`s noticeable that the amount of throughput timeslot of secondary user in random selection is less than the amount of throughput timeslot of secondary user in reduction algorithm, figure 4.12 explains this situation.

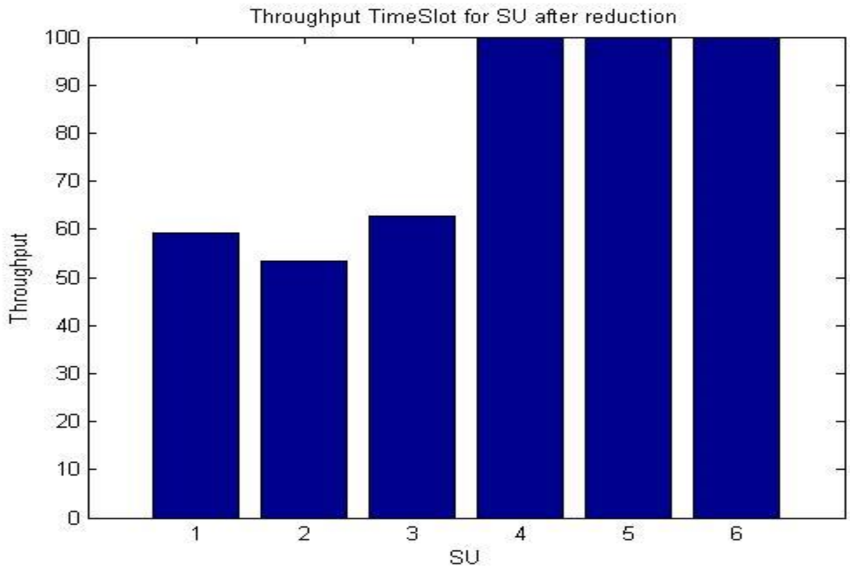


Figure 4.11: Secondary User's Throughput of Channel Used

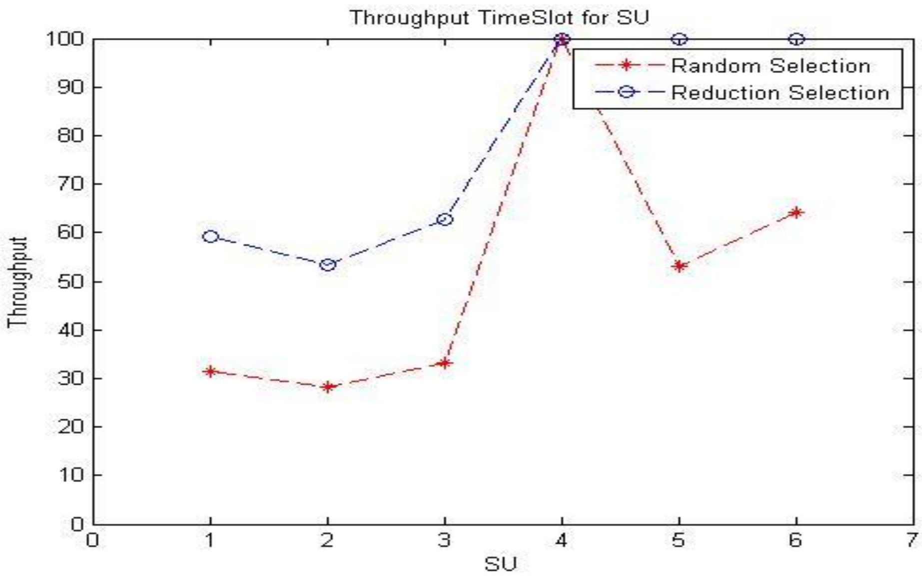


Figure 4.12: Comparison between Reduction Selection and Random Selection

4.6 Comparison between Proposed Algorithm and PFS, MFS

In this section, we explosion the performance of our proposed algorithm, and compare it with Maximum Frequency Selection (MFS), Probabilistic Frequency Selection (PFS) and Optimum [38], by considering the average delay and network throughput.

The average waiting time of all algorithms are explained in Figure 4.13 The average waiting time of proposed algorithms is lower than those of the other algorithms due to the following reasons that our system model is more accurate as it considers because the reduction step.

Because the scheduling decisions are known by SUs in advance, they can use these silent time slots to switch to the new frequency. If the number of silent time slots is enough to reach the total frequency switching, SU becomes ready to use the new frequency in the upcoming busy time slot. In this case, SU does not misuse any portion of the busy time slot for frequency switching and hence it can use the full busy time slot for data transmission. Otherwise, SU utilizes the silent time slots to achieve some portion of the frequency switching. The enduring switching is completed at the beginning of the next busy time slot. If the silent time slots and portions of the busy time slot are still not enough to achieve the frequency switching and no available time ruins in the busy time slot for data transmission, then it means that no packets can be sent by the SU using the new frequency in the busy time slot.

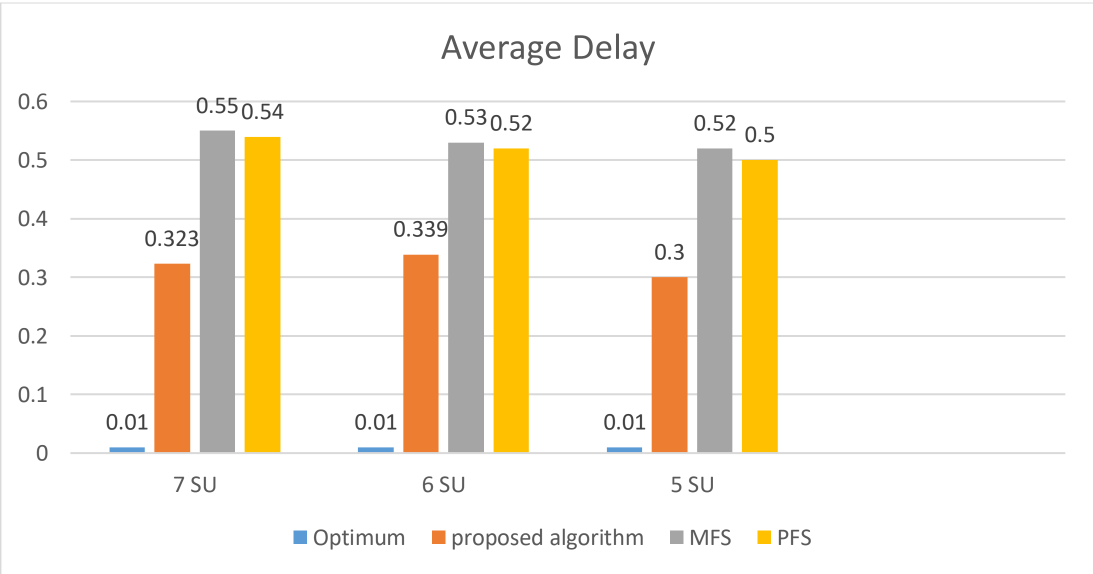


Figure 4.13: Average Network Delay

Figure 4.14 illustrate the average network throughput, where the number of cognitive nodes varies between 2 and 8; the throughput values almost variables at each iteration as well as the number of secondary nodes.

It is observed that our algorithms outperform others significantly. The main reason is that our model estimates the total delay more accurately and selects the accurate channel after the reduction step.

On the other hand, compared with other algorithms obtains a higher long-term throughput and also illustrate the impact of the SU activities, the number of available channels, and the number of flows on the average throughput.

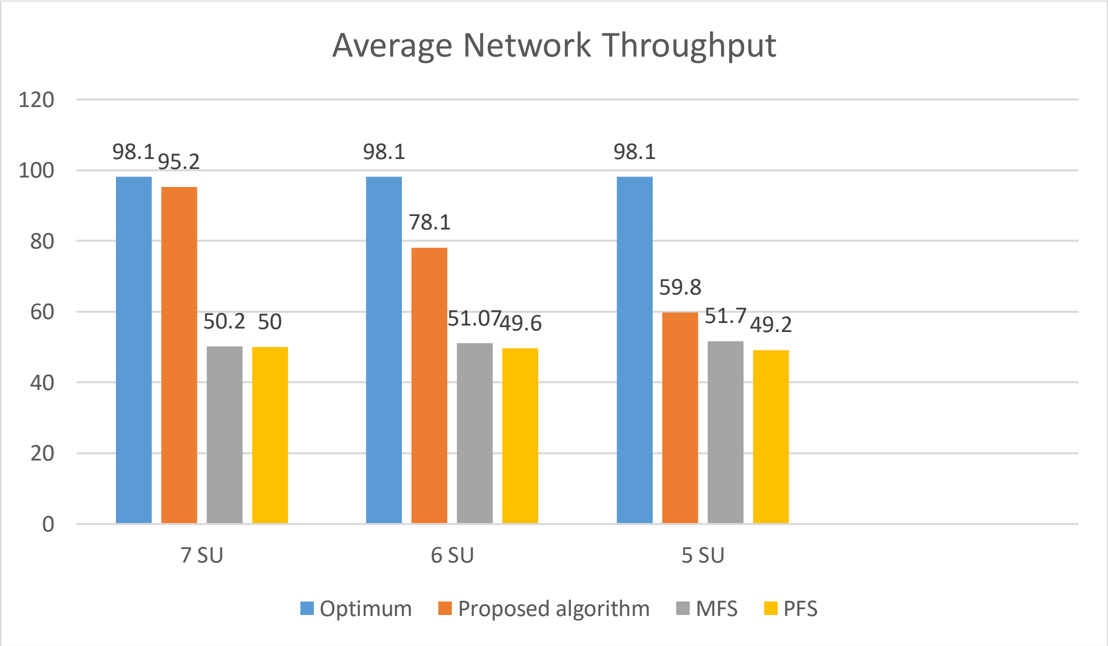


Figure 4.14: Average Network throughput

CHAPTER FIVE

CONCLUSION AND FUTURE WORK

5.1 Conclusions and Discussion

By reviewing the spectrum sharing in CRNs, it has been found that it is more challenging that the local wireless networking because of the continuous variation of spectrum bands transversely in the space and time in the context of accessibility and eminence. Due to the fluctuating character of the range, it strain for a radio surroundings having optimized-spectrum-allocation machinery. This thesis in the field of spectrum sharing represents a scheme in terms of spectrum sharing. This scheme allows scheduling of the sensed spectrum holes between cognitive radio users by deeming the alterations happen in the radio environment along with the activity of PU on existing in-use channels. A slotted structure has been presented in the assumptions as it has been considered as the proposed framework for this study in which each CR executes sensing functions at the initiation of each time slot. The in-use channel for PU activity is monitored by the CR; however, if the channel is still inactive, it will carry out the transmission on the identical channel or else it looks for some other channel for transmission or remains still throughout the intact time slot to evade intrusion with PU.

Therefore, many conclusions can be obtained from this project listed as follows:

1-The cognitive radio is found to get the spectrum with less time and less cost

2- The sensing of spectrum in cognitive radios is to find the holes in the primary user transmission in terms of interference, to be used by the secondary also, allows more than one secondary user using one spectrum in different times.

4- Game theory has provided the best time to use the spectrum through the spectrum sensing and distributed among the users as the most appropriate, therefore algorithm of domination and average show us the possibility to delete some unstable spectrum, Which has little time to get the maximum use of time and shared between users therefore the performance of the game can approach that of the centralized optimization scheme.
5- Our numerical results show that properly modeled games may provide a gain in terms of system-level throughput, with respect to full spread and orthogonal spectrum sharing scenarios over the time.
6- We have logically researched the dependability of this dynamic refreshing conduct utilizing the diversion hypothesis and performance of the algorithm is analyzed based on the spectrum utilization, capacity and data rate for secondary networks.
7- By the study, it has been found that the demand of the additional spectrum sharing is exceeding faster than the other existing technology specialized in increasing the spectral effectiveness, even though the latest studies and researches has gotten incredible success in order to augment spectral effectiveness and ability in the radio communication.
8. The recreation comes about demonstrate that our proposed plot outflanks in sparing the transmission control while guaranteeing required throughput and decency. Also, we analyze the administration time and throughput of CR user against various record sizes. The PU landing movement on the accessible channels debases the execution of the CRN however in our plan, the intermittent checking altogether improves the execution by lessening the quantity of retransmissions.

5.2 Future work

The suggestions for the future works are:

1- Study the central unit that handles the allotment of spectrum and admittance to techniques, and camper the result with our proposed method (distributed) sharing.
2- Use another types of strategy in game theory such as mixed strategy to sharing more than one user to using spectrum at the same time.
3- Diminish communication visual projection between the neighbor nodes; however, the other research direction can be related to the mobile CRN.

4- Use another models of spectrum sharing such as sharing between two secondary by use coexistence method.

5- Furthermore, boosting the throughput and minimizing the danger of covering the scope of CRNs.

6- Try to study another technique in Cognitive Radio Network such as spectrum decision and spectrum mobility to manage the all functionality n in cognitive radio network.

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