A Performance Analysis on Inter-Cell Subcarrier Collisions Due to Random Access based upon SHARP Technique in Cognitive Radio Networks

Dissertation-II

Submitted in partial fulfillment of the requirement for

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In

Electronics and Communication Engineering

By

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(April 2015)

CERTIFICATE

This is to certify that the Dissertation-II titled "**A Performance Analysis on Inter-Cell Subcarrier Collisions Due To Random Access based upon SHARP Technique in Cognitive Radio Networks**" that is being submitted by **Priyesh Roushan** in partial fulfillment of the requirements for the award of MASTER OF TECHNOLOGY, is a record of bonafide work done under my guidance. The contents of this Dissertation-II, in full or in parts, have neither been taken from any other source nor have been submitted to any other Institute or University for award of any degree or diploma and the same is certified.

Mr. Surjeet Kumar
(Assistant Professor)
LPU, Punjab.

Objective of the Dissertation-II is satisfactory / unsatisfactory

Examiner I

Examiner II

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With great pleasure and deep sense of gratitude, I express my indebtedness to my supervisor Mr. Surjeet Kumar for his invaluable guidance and constant encouragement at each and every step of my thesis work. He exposed me to the intricacies of relevant topic through proper counseling and discussions and always showed great interest in providing timely support and suitable suggestions. I am greatly indebted to my head of department Mr. Shakti Raj Chopra for inspiring and motivating me to develop new ideas and implementing them. I am grateful to him for his invaluable guidance and encouragement throughout this work. I would like to take this opportunity to express my sincere and profound gratitude to him for the pains he has taken to accomplish this project.

I also extend my sincere thanks to all other faculty members of Electronics and Communication Department and my friends and colleagues for their support and encouragement.

Place: LPU, Jalandhar　　　　　　Priyesh Roushan

Date: April, 2015　　　　　　Reg. No: 11310473

DECLARATION

I hereby certify that the work, which is being presented in the report, entitled "**A Performance Analysis on Inter-Cell Subcarrier Collisions Due To Random Access based upon SHARP Technique in Cognitive Radio Networks**", in partial fulfilment of the requirement for the award of the Degree of Master of Technology and submitted to the Department of Electronics and communication Engineering of Lovely Professional University, Punjab, institution is an authentic record of my own work carried out during the period *January-2015* to *April-2015* under the supervision of Mr Surjeet Kumar. I also cited the reference about the text(s)/figure(s)/table(s) from where they have been taken.

The matter presented in this thesis as not been submitted elsewhere for the award of any other degree of diploma from any Institutions.

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ABSTRACT

Cognitive radio (CR) is an wireless technology of communication, in which transceiver can intelligently detect which communication channels are in usage and which channels are not, and instantly moves into vacant communication channels while leaving the occupied ones. CR optimizes the usage of the available radio frequency (RF) spectrum while minimizing the interference to the other users. This paper constitutes of an orthogonal frequency division multiplexing (OFDM) based CR spectrum sharing system that assumes an mechanism in which random access of primary network (PN) subcarriers or channels by secondary users (SUs) and the Spectrum Harvesting with ARQ Retransmission and Probing (SHARP) technique that performs sensing also. Since with sensing technique decrease the collision between PU and SUs. There are two varieties of spectrum sharing processes, which are conservative and aggressive SHARP methods. The SUs will randomly utilize the subcarriers of the PN and collides with the PU's subcarriers with a certain probability. Stochastic analyses of sensing as well as sharing the number of subcarrier collisions between the SU's and PU's subcarriers are consider.

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LIST OF ABBREVIATIONS

ACK	Acknowledgement
ARQ	Automatic Request
AWGN	Additive White Gaussian Noise
BER	Bit Error Rate
CR	Cognitive Radio
CSI	Channel Side Information
DMT	Discrete Multi Tone
DSA	Dynamic Spectrum Access
FFT	Fast Fourier Transform
FDM	Frequency Division Multiplexing
FCC	Federal Communications Commission
GSM	Global System for Mobile communications
HYPG	Hyper geometric Distribution
ICI	Inter Carrier Interference
IEEE	Institute of Electrical and Electronics Engineers
IFFT	Inverse Fast Fourier Transform
ISI	Inter Symbol Interference
LTE	Long Term Evolutions
MAN	Metro-Politian Area Network
NACK	Negative Acknowledgement
OFDM	Orthogonal Frequency Division Multiplexing
PMF	Probability Mass Function
PAPR	Peak to Average Power Ratio
PN	Primary Network
PR	Primary Receiver
PU	Primary User
RV	Random Variable
SHARP	Spectrum Harvesting with ARQ Retransmission and Probing
SNR	Signal to Noise Ratio
SINR	Signal to Interference plus Noise Ratio
SU	Secondary User

WLAN Wireless Local Area Network

WiMAX Worldwide Interoperability for Microwave access

CHAPTER 1
INTRODUCTION

1.1 Introduction:

Wireless communication has been the fastest growing technology of the communications field in the last decades. As a result, wireless systems have several applications (e.g., cellular telephony and wireless internet) and various devices (e.g., mobiles, laptops, and tablets). In addition, new applications like wireless sensor networks, automated factories, smart home appliances, remote telemedicine, and many more are emerging from research ideas to concrete systems. One of the emerging research fields is the Cognitive Radio.

1.2 Cognitive Radio:

With the incredible growth in the number of wireless systems and services, the availability of wireless spectrum has become critically limited. Even so, actual measurements carried out in various countries show that most of the radio frequency spectrum is inefficiently utilized with spectrum utilization usually in the range of 5 to 50% [1]. Therefore the real problem is not the spectrum scarcity but the inefficient spectrum usage. This inefficiency results from static spectrum allocations, strict regulations, fixed radio functions and restricted network coordination.

Cognitive radio offers a novel solution to overcome the underutilization problem by allowing an opportunistic usage of the spectrum resources. This is apparent from the definition of CR adopted by the Federal Communications Commission (FCC), Cognitive Radio is a radio or system that senses its operational electromagnetic environment and can dynamically and autonomously adjust its radio operating parameters to modify interference (collision), ease interoperability and access secondary user markets [2].

In cognitive radio terminology, a primary user (PU) is defined as a legacy user or a licensed user who has higher rights on particular band of spectrum. Examples of licensed technology are global system for mobile communications (GSM) [3], worldwide interoperability for microwave access (WiMAX) and long term evolution (LTE). While the examples of legacy technology are microphone and wireless local area network (WLAN). On the other hand, unlicensed cognitive users with lower priority are defined as secondary users (SUs). A SU can access spectral resources of a PU when the PU is not using them. However the SU has to vacate the frequency band as soon as the PU becomes active so that negligible (or no) interference is caused to the PU. Such opportunistic access of the PU resources by the SUs is called as dynamic spectrum access. A SU can opportunistically utilize different spectrum holes corresponding to different PUs in order to satisfy its bandwidth requirement without causing interference to the PUs as shown in figure. 1.1

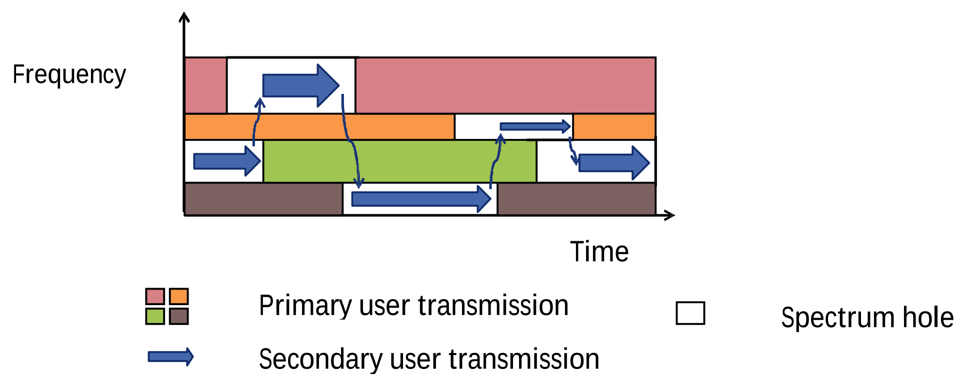


Figure 1.1 Cognitive Radio shows spectrum hole.

How Does a Cognitive Radio Get So Smart it can understand by the flow graph as shown in figure 1.2. This is the cognitive cycle and it shows the cognitive radio is so smart.

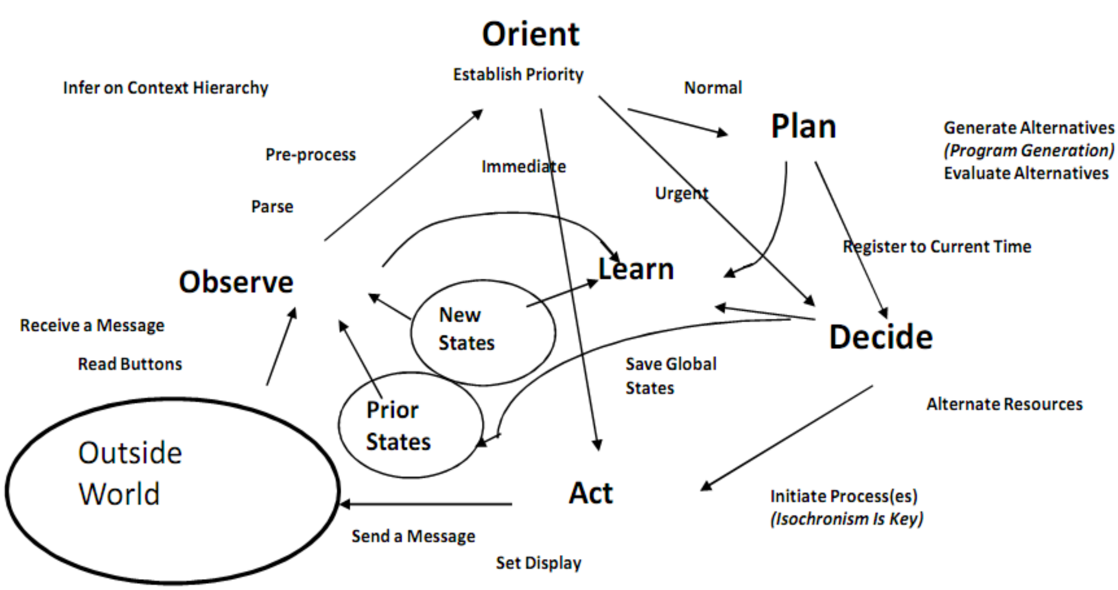


Figure 1.2 Cognitive based Cycles

1.2.1 Advantages of Cognitive Radio as follows:

a) It knows where it is

b) It knows what services are available in network, for example, it can get that and then use empty spectrum to communicate more efficiently

c) It knows what services the user want, and also knows how to get that services

d) It knows the available degree of needs and the probability of a specified outcome for its user

e) Learns and accredits usage patterns from the user

f) Applies "Model Based Reasoning" about user needs, local content and environmental context.

1.3 OFDM Technology:

Orthogonal frequency division multiplexing (OFDM) is a key technology for the present and future broadband wireless communication systems. OFDM is a method of encoding digital data on multiple carrier frequencies. OFDM is a broadband multicarrier modulation method that offers superior performance and does well over older, more conventional single carrier modulation methods because it is a better fit with today's high-speed data requirements and operation in the UHF and microwave spectrum.

In OFDM, the sub-carrier frequencies are chosen so that the sub-carriers are orthogonal to each-other, so that the crosstalk between the sub-channels is eliminated and inter-carrier guard bands are not required in modulation. This method makes easily the design of both the transmitter and the receiver; so that like a conventional FDM, it not requires separate filter for each sub-channel. OFDM requires very accurate frequency synchronization between the receiver and the transmitter; with frequency deviation the sub-carriers will no longer be orthogonal, causing inter-carrier-interference (ICI) (i.e., cross- talk between the sub- carriers). Here we also use OFDM based cognitive radio.

1.3.1 Block Diagram of OFDM System:

The block diagram of OFDM system shown in fig.1.3 below. Frequency Division Multiplexing (FDM) is a technique where the main signal to be transmitted is divided into a set of independent signals, which are called subcarriers in the frequency domain.

Hence, the original data stream in FDM is divided into many parallel streams (or channels), i.e. one for each subcarrier. Then each subcarrier is modulated with a conventional modulation scheme and then all are combined together to create the FDM signal.

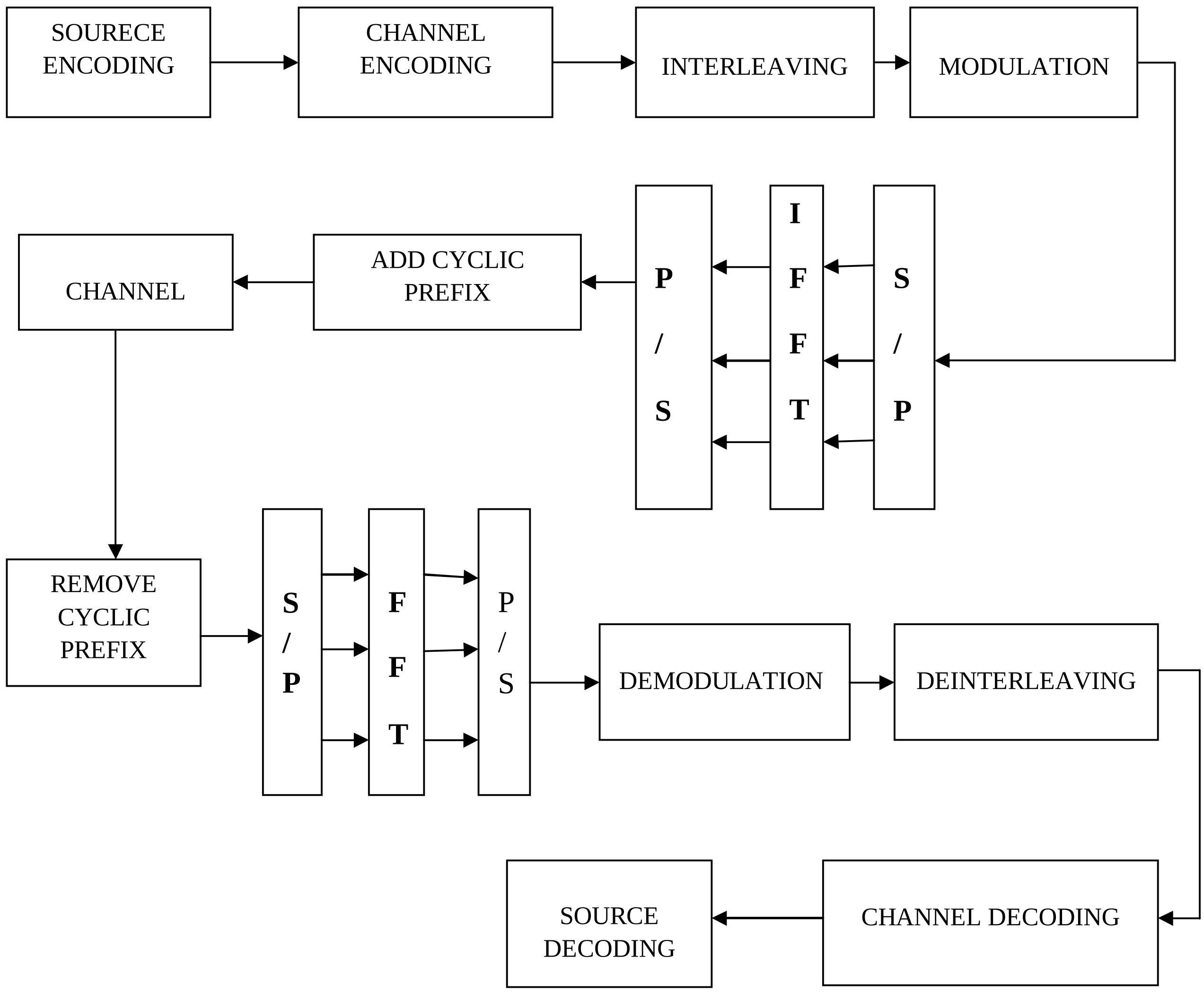


Figure 1.3: OFDM block diagram

In an FDM transmission, the receiver needs to be able to independently recover each of the subcarriers and therefore these signals need to fulfill certain conditions. For instance, they can have non overlapping spectra so that a bank of filters tuned to each of the different subcarriers can recover each of them independently. Even so, conventional filters require guard bands between the subcarrier bands and therefore the resulting spectral efficiency is low. If the subcarrier signals fulfill the orthogonality condition, their spectrum can overlap, improving the spectral efficiency. This technique is known as orthogonal FDM or OFDM. To see the main advantages offered by OFDM, it is useful to think about a set of packets which are transported in a truck. The whole set of packets can either be carried by one big truck or by several smaller ones, as shown in figure 1.4.

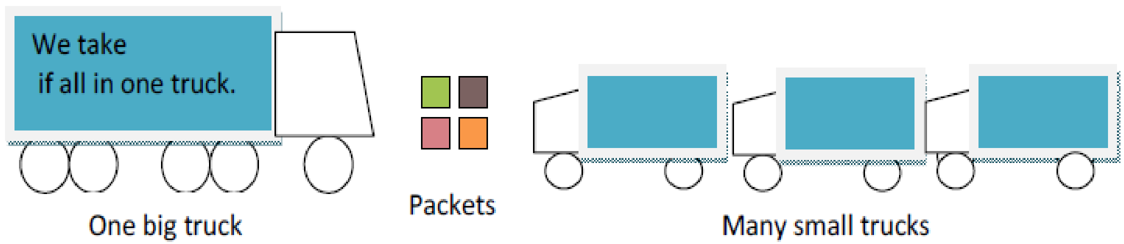


Figure 1.4: Examples of Subcarriers (many small trucks)

Suppose that each small truck uses a different road, where every available path has the same length and all the trucks drive at the same speed. If an accident happens in one of the roads and it gets blocked, part of the packets will not be received with the rest at the destination. So that, if all the packets are transported by a big truck that drives on the same road where the accident happens, the whole shipment will get stuck and will not arrive to the destination. Hence for an OFDM signal transmission, each subcarrier represented by a small truck, and the roads where data is going to be carried are an analogy of the different frequencies at which each subcarrier is going to be transmitted. Moreover, each packet containing goods represents the modulated portion of data to be carried by a subcarrier, called an information symbol.

FFT Logic: A fast fourier transform is an efficient algorithm to compute the discrete Fourier transform (DFT) and its inverse. This is applied to discrete data so the transforms are done by summing instead of integration. The Fast Fourier Transform is an algorithm representation that is used in computer codes.

The DFT is defined as :

$$X[k] = \sum_{n=0}^{N-1} x[n]e^{-\frac{i2\pi kn}{N}}; \quad 0 \leq k \leq N-1 \ldots\ldots\ldots..1.1$$

IFFT Logic: The inverse Fourier transform simply inverts the operation i.e. it converts from frequency domain back to time domain representation of the signal.

$$\mathrm{x(n)} = \frac{1}{N}\sum_{k=0}^{N-1} X[k]\, e^{\frac{i2\pi kn}{N}}; \quad 0 \leq n \leq N-1 \ldots\ldots\ldots\ldots.1.2$$

Twiddle Factor: A twiddle factor, in fast Fourier transform algorithms, is any of the trigonometric constant coefficients that are multiplied by the data in the course of the algorithm. It is also used to recursively combine smaller discrete Fourier transforms and is defined as

$$W_N = e^{\frac{-j2\pi}{N}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots....1.3$$

Add cyclic prefix: The robustness of any OFDM transmission against multipath delay spread is achieved by having a long symbol period with the purpose of minimizing the inter-symbol interference. This ISI is a great drawback of digital communication system. To avoid this problem we have used cyclic prefix. Remove cyclic prefix is the same as Add cyclic prefix. It works same as Add cyclic prefix. Here is the eye diagram of the received signal after removing cyclic prefix.

1.3.2 Advantages of OFDM:

a) Spectral efficiency is high as compared to other modulation schemes, spread spectrum, etc.
b) Easily adapt and good for channel conditions without complex time-domain levelling
c) Robust against co-channel interference due to narrow band
d) Robust against inter-symbol interference (ISI) and fading caused by multipath propagation
e) Easily implemented by Fast Fourier Transform (FFT).
f) For the time synchronization errors, low sensitive
g) Unlike conventional FDM it not requires tuned sub-channel receiver filters
h) Facilitates single frequency networks (SFNs); i.e., transmitter macro diversity.

1.3.3 Disadvantages of OFDM:

a) Sensitive to Doppler shift
b) Sensitive to the frequency synchronization problems
c) High peak-to-average power ratio (PAPR), requiring linear transmitter, that suffers from worst power efficiency
d) Due to cyclic prefix/guard interval, efficiency decreases.

1.4 Motivation:

The goal of any technology is that it meets some requirement in the best way possible for the low cost. So that the 1st thing of this, a cognitive network should provide, over a broadened period of time, improve end-to-end performance compare than a non-cognitive network. Cognition can be used to improve such performance as resource management, Quality of Service (QoS), access control, or throughput. Cognitive networks are only limited in application by the adaptability of the efficient uses of underlying network elements and the quality of being adaptable or variable of the cognitive process.

In examining another goal, the cost must justify the performance. Cognitive network (CN) costs are measured in terms of communications and utilization overhead, maintenance expenses, and operational complexity. These costs must be overbalanced by the performance improvement the CN provides. For an environment, such as static wired networks, it has not sense to convert to cognitive operation. Consider the other environments, like heterogeneous wireless networks. It may be ideal for cognition.

Cognitive networks observe the network performance as input to a decision making process and then provide an efficient output in the form of a set of actions and it can be implemented in the modifiable elements of the networks. Ideally, a CN should be forward-looking, rather than responsive, and try to adjust to problems before something occur. Since, the architecture work of a CN should be flexible, utilize for future improvements, network elements, and the goals.

Cognitive networks need a Software Adaptable Network (SAN). SAN implement the real network functionality and allow for the cognitive process to adapt the network utilization. Similarly to CR, which depends on a Software Define Radio (SDR) to improve the radio operation (like: time, frequency, bandwidth, code, and waveform). An example of a SAN in a wireless network is directional antennas.

Wireless communication has been the fastest growing technology of the communications field. With the incredible growth in the number of wireless systems and the services, the availability of better quality wireless spectrum has become severely limited. So, Cognitive radio (CR) has been recently proposed as a promising technology to improve the spectrum utilization.

1.5 Organization of the Thesis:

This thesis gives the overview of some of the known existing techniques through the investigation and compared with the known technique. It includes the certificate, contents, list of figures, list of table and List of Abbreviation.

In chapter-1, it includes the introduction of cognitive radio, introduction of OFDM and their advantages. It also includes the motivation.

In the chapter-2, includes the brief introduction about the new emerging technology, i.e., Cognitive Radio. The literature survey is done in this chapter. The entire literature survey is based on the following papers taken from various organizations such as IEEE.

In the chapter-3, represent the introduction about the Cognitive Radio. Also the brief introduction about Inter-Cell Subcarrier Collisions due to Random Access in OFDM-Based Cognitive Radio Networks, SHARP technique and its mathematical analysis.

In the chapter-4, includes the methodology of the thesis work and Planning. The Cognitive radio (CR) design aims to increase spectrum utilization.

In the chapter-5, contains various results of the methodology have been placed which are implemented in Matlab software.

In the chapter-6, contains the conclusion and future scope.

CHAPTER 2
LITERATURE SURVEY

2.1 Introduction:

This chapter consists of description about cognitive radio and its overview. The entire literature survey is based on the cognitive radio that utilizes the complete spectrum in smart manner. The entire papers taken from various organizations (eg. IEEE) and their citation mentioned.

2.2 Overview of Cognitive Radio :

In cognitive radio research, learning is a significant part of it. Rondeau and Bostian, both have studied the techniques of Genetic based Algorithm (GA) and also to learn how a radio might give best respond to a spectral environment. They have developed paradigms that show that a radio can successfully learn proper adaption to a spectral environment and that optimize for the objective metrics.

How to apply game theory to a radio in the cognitive network, these studied by the Neel and Reed. They were able to analyze protocols with the game theory and determine whether cognitive based radio behavior could result in stable network behavior, and they conclude that it can. Mitola, Kokar, and Kovarik have independently studied about cognitive radio and conclude that a cognitive radio would need to perform reasoning functions. Mitola proposes that a radio should be able to reason about the owner’s voice and visual characteristics should be able to take verbal commands, should be able to visually recognize locations and conditions.

So that, I conclude that Cognitive Radio technology is a media in which one radio or spectrum or even a network of radios are able to learn a useful degree of adaptivity and utilization, that aids the user (PU or SU), the network, and/or the spectrum owner or operator. There are powerful economic incentives to provide new capabilities, through existing telecommunications infrastructure, and cognitive radios will provide those capabilities. As new services are offered by the operators, more spectrums will be required and cognitive radios will provide the efficient uses for radios to communicate with greater spectrum efficiency [29].

Feature	**Function**	**Examples (RF; vision; speech; location; motion)**
Cognition	Monitor & Learn	Get to know user's daily patterns & model the local RF scene over space, time, and situations
Adaptation	Respond to changing Environment	Use unused RF, protect owner's data
Awareness	Extract information from sensor Domain	Sense or perceive
Perception	Continuously identify known, unknowns and backgrounds in the sensor domain	TV channel; Depth of visual scene, identity of objects; location of user, movement and speed of Self
Sensing	Continuously sense & pre-process single sensor-field in single sensory domain	RF FFT; Binary vision; binaural acoustics; GPS; accelerometer; etc.

Table-2.1: Features of Cognitive Radio. [29]

2.3 Review of the Research Papers:

The entire papers taken from various organizations like IEEE.

(a) S. Haykin - IEEE 2005. [4]

In this paper, they have proposed the cognitive radio, built on a software defined radio (SDR), and SDR defined as an intelligent wireless communication system that is aware of its environment and using the methodology of understanding to learn from the environment and adapt to statistical variations in the inputs, with two main objectives that are:

- Extremely reliable communication whenever needed
- Efficient management of the radio spectrum/frequency.

This paper entirely focused on three basic cognitive tasks.

1) Radio spectrum analysis.

2) Channel state estimation and prognostic modelling.

3) Transmit-power management and dynamic spectrum utilization.

This paper also discusses the emergent behaviour of cognitive radio.

(b) L. Musavian - IEEE 2009. [6]

In this paper, they analyze the capacity gains of opportunistic spectrum-sharing channels in fading environments with imperfect channel information. In particular, they consider that a SU may access the spectrum allocated to a PU as long as the interference power, effects the transmission of the SU, remains below predefined power limits at the transmitted end and investigate the capacity gains offered by this spectrum-sharing approach when only partial channel information of the link between the secondary's transmitter and primary's receiver is available to the SU.

(c) L. Musavian. IEEE 2009.[7]

In this paper they investigate the fundamental capacity limits of opportunistic spectrum-sharing channels in fading environments. The concept of timeserving spectrum access is motivated by the new technology of cognitive radio which offers a tremendous potential to improve the utilization of the radio spectrum by implementing efficient sharing of the licensed spectrum. In this spectrum-sharing technique, a secondary user may utilize the primary user's licensed band as long as its interference to the primary receiver remains below a tolerable level. Herein, they consider that the secondary user's transmission has to adhere to limitations on the resulting received power at the primary's receiver, and inquire the gain of capacity offered by this spectrum-sharing mechanism in a Rayleigh fading environment. Specifically, they derive the fleeting channel capacity of a secondary user subject to both average and peak received-power restraints at the primary's receiver.

(d) Z. Rezki - IEEE 2012. [8]

A spectrum-sharing communication system where the secondary user is aware of the instantaneous channel state information (CSI) of the secondary link but knows only the statistics and an estimated version of the secondary transmitter and primary receiver link are inquired. The optimal power and the ergodic capacity of the secondary user link are derived for general fading channels [with a continuous probability density function (pdf)] under the average and peak transmit power and with respect to the following two different interference constraints:

- an interference outage restraint and
- a signal-to-interference outage restraint.

Hence for a Rayleigh fading channels, our results show, that the interference constraint is harmful at the high-power region, because the capacity does not increase with the power, whereas at the low-power region, it has a marginal impact and no-interference performance in it, which corresponds to the ergodic capacity under peak or average transmit power constraint in the absence of the primary user, may be achieved.

(e) Y. U. Jang - IEEE 2011. [9]

In this, they consider a hybrid cognitive radio (H-CR) where the primary transmitter (PT) transmits message to the primary receiver (PR) whenever the traffic occurs by allowing interference level (I) from the secondary transmitter (ST) to the primary receiver. Hence the ST transmits messages to the secondary receiver (SR) by controlling the transmitting power based on interference level and spectrum sensing. The secondary transmitter opportunistically adopts maximum power when it detects that the PT is not transmitting and controls the transmitting power to restrict the interference level from secondary transmitter to PR below I when alerted that the PT is transmitting. So closed expressions of the average rates for the hybrid cognitive radio are derived. Hence based on the analytical result, the detection probability and interference level are optimized to maximize the average rate of the secondary transmitter by guaranteeing the average rate of the PT. The average rate for the ST of the hybrid cognitive radio is better than that of two existing CRs where the ST transmits messages to the SR with maximum power only when the ST recognizes that the PT is not transmitting or with controlled power to limit an interference level from the ST to the primary receiver below a constant irrespective of the PT's activity.

(f) James C. F. Li (IEEE 2013) [28].

This paper proposes and explains about an artificial transmission scheme which may be vulnerable to the interference causing because of sharing the entire available spectrum, known as SHARP, in which the concerned secondary cognitive user try to coexisting with the primary system using the ARQ based transmission and mechanism. Depending on the received ACK/NAK packet messages from the respected primary user only, the proposed concepts of the SHARP schemes used to utilize the several probing time divisions for obtaining a normal perspective about the respective primary channel conditions, and used to run accordingly with the desirable respective transmission modes. They have analyzed the proposed schemes and formalized through with using the prescribed Monte Carlo simulations. Moreover, it has been concluded that the proposed aggressive SHARP technique can achieve a best throughput for the secondary users than the respective conservative scheme with the small negligible primary loss in the throughput. Whereas the proposed respective conservative SHARP technique doesn't make any negative effect on the respective primary system, and used to work and execute better than the respective legacy based systems in terms of the throughput of the primary user.

Both of the proposed SHARP techniques doesn't try to generate any unnecessary breakdowns to the respective primary system, and as well as they are able to provide the efficient throughput gains to the secondary user without any complete well known CSI at the transmitter side.

(g) H. A. Suraweera - IEEE 2010. [10]

Cognitive radio (CR) design aims to increase spectrum utilization by allowing the secondary users (SUs) to coexist with the primary users (PUs), so the interference caused by the SUs to each PU is properly modulated. At the SU, channel-state information (CSI) between its transmitter and the PU receiver is used to calculate the maximum allowable SU transmit power to limit the interference. They assumed in this paper that CSI is imperfect; this is an important scenario for cognitive radio systems. The peak received interference power constraint, an upper limit to the secondary user transmit power constraint is also considered. They derive a closed-form expression for the mean SU capacity under that scenario. Due to imperfect CSI, the SU cannot fulfill the peak received interference power constraint at the PU and has to back off its transmit power. So the resulting capacity loss for the SU is quantified using the cumulative-distribution function of the interference at the PU. They also investigate the impact of CSI quantization. They investigate the SU error performance; a closed-form average bit-error-rate (BER) expression was also derived.

(h) P. J. Smith - IEEE 2012. [11]

They examine the impact of limited channel knowledge on the secondary user (SU) in a cognitive radio (CR) system. Under a minimum signal-to-interference noise ratio (SINR) constraint for the primary user receiver, they determine the SU capacity under five channel knowledge suppositions. They derived the analytical expressions for the capacity cumulative distribution functions (CDF) and the probability of secondary user blocking as a function of allowable interference. They also show that imperfect knowledge of the PU–PU link gain by the SU-Transmitter often prohibits secondary user transmission a high interference level at the PU. They also show that errorful knowledge of the PU–PU channel is more beneficial than statistical channel knowledge and that imperfect knowledge of the SU-Tx to PU-Rx link has limited impact on secondary user capacity.

(i) K. Hamdi - IEEE 2009. [21]

Cognitive radio (CR) has been recently proposed as a promising technology to improve the spectrum utilization. In this paper, they consider the spectrum sharing between a large number of cognitive radio users and a licensed user in order to enhance the spectrum efficiency in the cognitive network. With the preparation of the M antennas at the cognitive base station, a timeserving spectrum sharing approach is proposed to maximize the downlink throughput of the cognitive radio system and limit the interference to the PU. In the proposed approach, cognitive users whose channels are nearly orthogonal to the primary user channel are pre-selected so as to minimize the interference to the primary user. Then, the M best cognitive users and the channels are mutually near orthogonal to each other, are scheduled from the preselected cognitive users (CUs). And there a lower bound of the proposed cognitive system capacity is derived.

(j) D. Li - IEEE 2010. [13]

In this paper, they investigate the performance of uplink cognitive cellular networks with opportunistic scheduling with respect to the average bit error rate (BER) and mean capacity of the scheduled cognitive user (CU). In this system, both the primary user (PU) and CUs share the same base station (BS). In contrast to existing CU scheduling schemes, the cognitive user which causes the minimum interference to the PU is selected for transmission. As well, the transmit power of the selected cognitive user should also satisfy the outage probability requirement of the primary user. An interesting observation is that both the upper bound on the average BER and the mean capacity of the scheduled cognitive user are independent of the number of CUs and the transmit power of the primary user.

(k) T. Yucek - IEEE 2009. [17]

The spectrum sensing problem has gained new aspects with cognitive radio (CR) and opportunistic spectrum access concepts. It is one of the most challenging issues in cognitive radio (CR) systems. In this paper, they survey of spectrum sensing methodologies for cognitive radio is presented. Various aspects of spectrum sensing problem are studied from a CR perspective and multi-dimensional spectrum sensing concept is introduced. Challenges associated with spectrum sensing are given and enabling spectrum sensing methods are reviewed in this paper. In paper explains the cooperative sensing concept and its various forms. Hence the external sensing algorithms and other sensing methods are discussed in this paper. Moreover, statistical modeling of network traffic and efficient utilization of these models for prediction of primary user behavior is studied.

CHAPTER 3
PROBLEM STATEMENT

3.1 Introduction

The drawback of only spectrum sharing is that collision between PU and SUs and results decreases in capacities. So, here introduced sharing and sensing both the technique in cognitive radio to increases the performance of spectrum utilization. The brief explanation about Inter-Cell Subcarrier Collisions due to Random Access in Cognitive Radio Networks , SHARP techniques and its mathematical analysis.

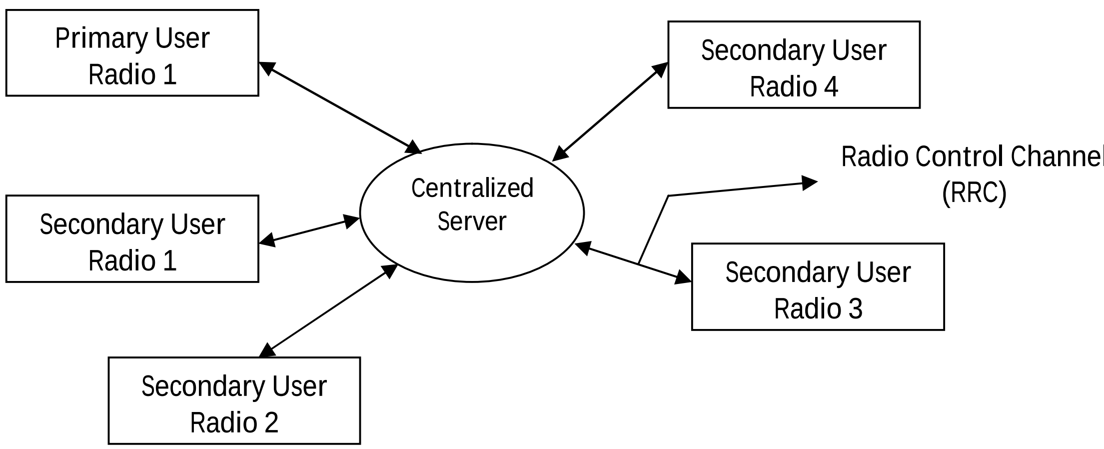
3.2 Cognitive Radio

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

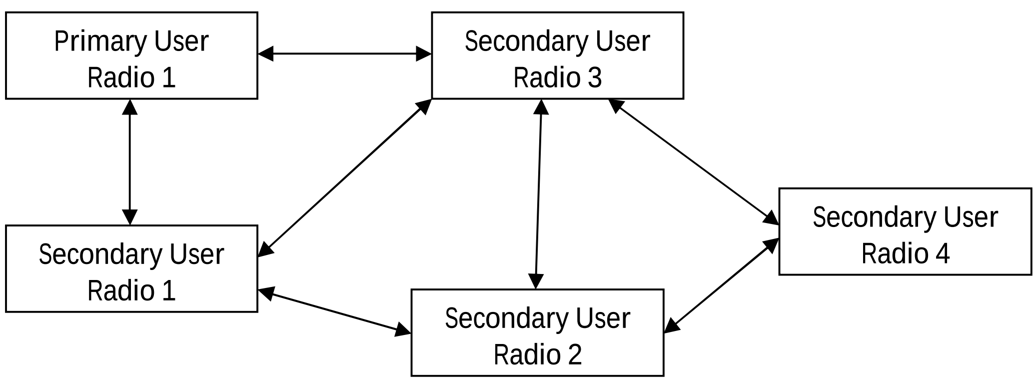
It was a new approach in wireless communications, that Mitola later described as: The point in which wireless personal digital assistants (PDAs) and the related networks are sufficiently computationally intelligent about radio resources and related computer- to-computer communications to detect user communications needs as a function of use circumstance, and to provide radio resources and wireless services are most appropriate to those requires. A radio in which some or all of the physical layer functions are Software Defined is said to be Software Defined Radio (SDR). In simpler words, the software is used to determine the specifications of the radio and what does it do. If the software within the radio has changed, its performance and functions may change. Cognitive radio utilizes the existing infrastructure and no need to install a new infrastructure for operating its own operations. [5]

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

Cognitive radio is a self learning mechanism which adapts according to the environment for sensing, reconfiguring, sharing, etc to provide unused spectrum to its secondary users, the centralized and distributed spectrum sharing approaches of CR as shown in the figure 3.1.



(a): Centralized



(a): Distributed

Figure 3.1: Centralized and Distributed Spectrum Sharing Approaches of CR

3.3 Terminology of Cognitive Radio:

Depending on transmission and reception parameters of cognitive radio, there are mainly two types of cognitive radio:

*Full Cognitive Radio (*also called *Mitola radio),* in which every possible parameter observable by a wireless node (or network) is considered. [12]

Spectrum-Sensing CR, in Spectrum-Sensing CR only the radio frequency spectrum is considered.

Other types are dependent on parts of the spectrum available for CR:

Licensed-Band Cognitive Radio, capable of using bands assigned to licensed users (except for unlicensed bands, such as the U- NII band or the ISM band. The IEEE 802.22 working group is developing a standard for wireless regional area network (WRAN), which will operate on unused television channels [17].

Unlicensed-Band Cognitive Radio, in which only utilize unlicensed parts of the radio frequency (RF) spectrum. One such system is described in the IEEE 802.15 Task Group 2 specifications, which focus on existence of IEEE 802.11 and Bluetooth.

Spectrum mobility: Process by which a cognitive radio user changes its frequency of operation. CR networks aim to use the spectrum in a dynamic pattern by allowing radio terminals to operate in the best available spectrum band, maintaining unseamed communication requirements during transitions to better spectrum.

Spectrum sharing: Spectrum sharing cognitive radio networks allows cognitive radio users to share the spectrum bands of the licensed- band users. However, the CR users have to restrict their transmit power so that the interference caused to the licensed- band users is kept below a certain threshold.

Sensing-based Spectrum sharing: In sensing- based spectrum sharing cognitive radio networks, CR users first listen to the spectrum allocated to the licensed users to detect the state of the licensed users. Based on the detection results, cognitive radio users decide their transmission strategies. If the licensed users are not using the bands, cognitive radio users will transmit over those bands. If the licensed users are using the bands, cognitive radio users share the spectrum bands with the licensed users by restricting their transmit power.

3.4 Analysis and Discussion of Inter-Cell Subcarriers Collision:

A frequency channel that occupies only a portion of RF bandwidth (spectrum) allocated to the carrier and, therefore, has a smaller information capacity, which is called subcarrier. A subcarrier sometimes is used for signaling between stations on a network. Spectrum measurements around the globe have revealed the fact that the available spectrum is under-utilized [1]. Hence, efficient utilization of the spectrum represents a crucial issue in the wireless communications field [4]. One of the most remarkable solutions to cope with the under-utilization of spectrum is the concept of cognitive radio (CR) [5]. There have been reported numerous studies to investigate the performance of CR networks with spectrum sharing features, in which the SU capacity is mostly used as performance metric. The ergodic and outage capacities of spectrum sharing systems in Rayleigh fading environments were studied in [7]. Assuming imperfect channel side information (CSI), [6], [8], [10], [11] conducted capacity analysis and power allocation studies. Besides the SU average and peak transmit power constraints, in [13], the PU's outage loss is assumed as a constraint to maintain PU's QoS requirement. However, most of the studies require either knowledge of spectrum occupation by PU via the mechanism of spectrum sensing [9], [14] or knowledge of CSI between the PU-transmitter and PU-receiver to implement the interference level constraint for protecting the operation of PU.

One of the most challenging issues in the implementation of CR networks is the acquisition of information about the spectrum occupancy of PU(s) [15], [16]. Deploying an efficient spectrum sensing mechanism is difficult because of the uncertainties present in the propagation channels at device and network-level, the hidden PU problem induced by severe fading conditions and the limited sensing duration.

- The analysis of such a communication set-up can provide useful insights and can be utilized as a benchmark for performance comparison studies for CR spectrum sharing systems that assume the availability of spectrum sensing information.
- The main advantage of random subcarrier access (utilization or allocation) is to uniformly distribute the SUs interference among the PUs subcarriers, a

phenomenon which can be termed as interference spreading. Hence, the probability of accessing all subcarriers of a single PU by SU is considerable low. In order words, the SU's interference will not focus on a single PU, it will be distributed among the all the PUs' subcarriers.

In [15], they proposed a random subcarrier allocation technique and studied its performance in terms of average capacity and multiuser diversity by taking into consideration the effect of collisions between multiple PUs and SUs in a set-up that assumes multiple SUs in a single secondary network (cell). Nonetheless, considering practical systems (multiple secondary networks or cells), there may exist inter-cell subcarrier collisions not only between SUs and PUs but also among the SUs themselves due to the random access scheme. Therefore, in this paper, two different SU transmitter and receiver pairs belonging to different cells are considered, and the performances in terms of capacity and rate loss due to collisions (interference) between SUs in addition to that of PU are studied.

3.4.1 System And Channel Models :

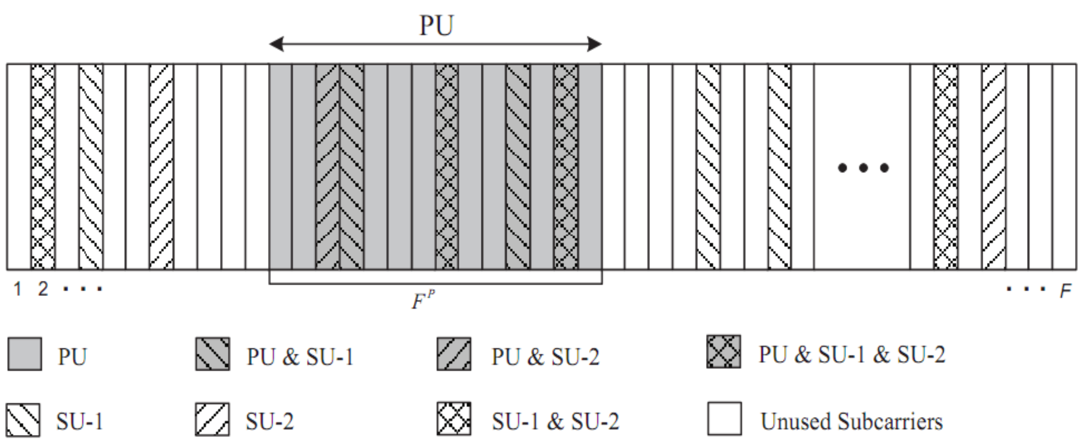


Figure 3.2 OFDM-based CR system for SUs in different secondary networks (cells) with subcarrier collisions with each other and PU due to the random access method.[27]

The orthogonal frequency-division multiplexing (OFDM)- based CR system is illustrated in Figure 3.2, where a PU and SUs are assumed to be present in the primary and secondary networks, respectively, where each SU transmitter and receiver pair belongs to separate cells. The total number of available subcarriers in the primary network is denoted by F, and the number of PU's subcarriers is denoted by F^p. The number of subcarriers utilized by SU-1 and SU-2 are represented by F_1^s and F_2^s , respectively. SUs randomly access the available subcarriers set, F, in the primary network without having access to the PU's channel occupancy information. Subcarrier collisions occur when SUs randomly employ subcarriers, which are in use by PU and/or other SU, and the probabilistic model for the number of subcarrier collisions follows a hypergeometric distribution. Due to the random access (allocation) of subcarriers by SUs in different secondary cells, collisions occur with a certain probability between the subcarriers of SUs and PU. In addition, inter- cell collisions between the subcarriers of SUs might occur in addition to those that are utilized by PU. This set-up could be considered as the worst case scenario, where the collisions among the SUs subcarriers severely affect the performance due to the overall caused interference. One can observe from Figure 1 that the occurrence of collisions can be classified into different groups such as collisions between PU and SU-1, PU and SU-2, SU-1 and SU-2, and the worst case situation that assumes collisions among PU, SU-1 and SU-2.

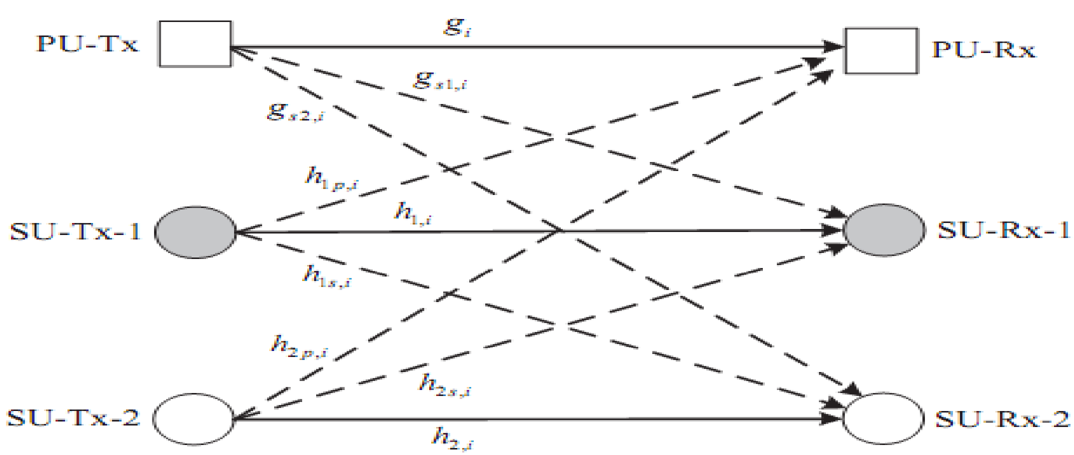


Fig. 3.3 Channel model for the ith subcarrier, i ∈{1,...,F}, with SUs and PU-transmitter and receiver pairs, the performance of shaded SU pairs (SU-1) is of interest.[27]

In Figure 3.3, the channel model at the ith subcarrier (∈ {1,…,F }) is shown. The channel power gains from PU-Tx to PU-Rx, SU-Rx-1, and SU-Rx-2 are denoted by gi, gs1,i and gs2,i respectively. Similarly, h1,i , h1p,i and h1s,i represent the channel power gains from SU-Tx-1 to SU-Rx-1, PU-Rx, and SU-Rx-2, respectively. In addition, h2,i , h2s,i and h2p,i denote he channel power gains for the ith subcarrier from SU-Tx-2 to SU-Rx-2, SU-Rx-1 and PU-Rx, respectively. The performance analysis of shaded SU (SU-1) is of interest in this work. To preserve the QoS requirement of PU, the interference power levels caused by the SU-transmitters at the PU-Rx must not be larger than a predefined value for each subcarrier, referred to as the interference temperature (power) constraint.

3.4.2 Statistical Analysis of the Number of Subcarrier Collisions:

Throughout this section, the number of subcarriers required by PU and SUs is assumed fixed. In order to properly assess the effect of the random access scheme on the subcarrier collisions:

- Single Secondary Cell: Here, only a single SU (SU-1) is assumed to be available in the system. In the case of N PUs in the primary network, the SU-1 might experience subcarrier collisions with up to N PUs. In such a case, the resultant joint PMF of the number of subcarrier collisions follows a modified multivariate hypergeometric distribution [15].
- Two Secondary Cells: In this scenario, due to the random access method, there can be inter-cell collisions between the subcarriers of SUs (belonging to the separate cells) in addition to those that collide with PU subcarriers.

There are four possible cases of subcarrier collisions for the target SU (say SU-1):

- Case 1: collisions between SU-1, PU and SU-2 subcarriers: k_{p12}.
- Case 2: collisions only between SU-1 and PU subcarriers: $k_{p1}^{0} = k_{p1} - k_{p12}$
- Case 3: collisions only between SU-1 and SU-2 subcarriers: $k_{12}^{0} = k_{12} - k_{p12}$
- Case 4: collisions-free subcarriers of SU-1: $k_{f1} = F_1^s - k_{p1}^0 - k_{12}^0 - k_{p12}$

Hypergeometric Distribution [18]: Suppose that an urn contains balls n, of which r are red and (n-r) are white. Let K denote the number of red balls drawn when taking m balls without replacement. Then, K is a hypergeometric random variable (RV) with parameters r, m and n , and its PMF is given by:

$$P_r(K = k) = p(k) = \binom{r}{k}\binom{n-r}{m-k}\Big/\binom{n}{m} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.1$$

3.4.3 Random Number of Subcarriers

In the preceding section, the number of utilized subcarriers by both PU and SUs is assumed to be fixed. However, considering practical scenarios, the number of subcarriers required by PU or SUs can vary. Based on either PU or SUs rate requirements, the number of subcarriers utilized by users can be different at any time instant. Next the long term average performance of the system is investigated by using a stochastic model for the required number of subcarriers for PU and SUs. Intuitively, the number of subcarriers required by a user can be variable based on its communication needs throughout a period (a day or a week), such as QoS, BER, and rate [22]. Therefore, it is reasonable to model the number of used subcarriers as a discrete random variable. The distribution of the required number of subcarriers can be approximated either by a uniform or binomial distribution [22]

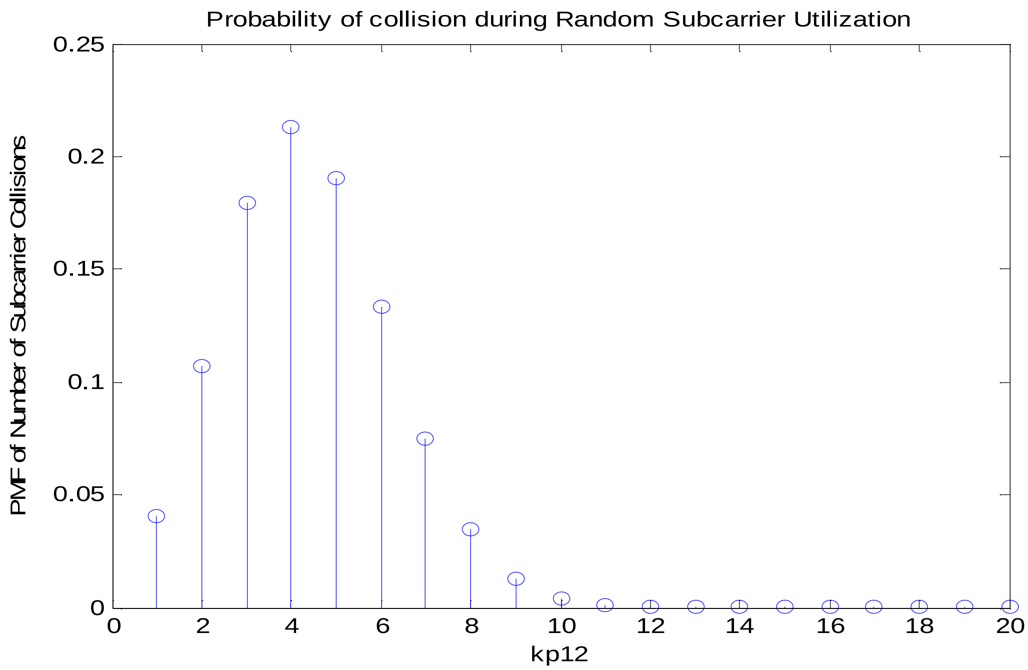


Figure 3.4 PMF of the number of subcarrier collisions between the PU, SU-1 and SU-2 for F =50, F^p =35, F_1^s =25, F_2^s =20.

In Figure 3.4, the PMF of 12 is plotted for arbitrary values of parameters F =50, F^p =35, F_1^s =25, F_2^s =20. As it can be observed, the simulation results above.

F= Total number of available subcarriers

F^p= Total number of PU subcarriers

F_1^s = Total number of SU1 subcarriers

F_2^s=Total number of SU2 subcarriers

3.4.4 Performance Analysis of Secondary User:

In this section, the performance of the target SU (SU-1) is investigated by using the average capacity as performance measure. In addition, the capacity (rate) loss of SU-1 due to the subcarrier collisions with the subcarriers of PU and SU-2 is studied.

Average Capacity of SU:

The expressions for the instantaneous and average capacity of SU-1 over an arbitrary channel fading model with a random access scheme are presented.[23][24][27]

Let $S_{p1,i}^{o}$, $S_{12,i}^{o}$ and $S_{p12,i}$ denote the signal-to-interference plus noise ratio (SINR) levels for the ith subcarrier of SU-1 with interference component coming only from PU, only from SU-2 and from both PU and SU-2, respectively. Similarly, let 1 stand for the signal-to-noise ratio (SNR) for the ith collision-free subcarrier of the SU-1.

Mathematically, the SINRs and SNR are defined as:

SINR level for ith subcarrier of SU1 for four cases are:

- Interference from PU only

$$S_{p1,i}^{o} = \frac{h_{1,i}P_{1,i}}{g_{s1,i}P_i + \sigma^2} \quad \text{3.2}$$

- Interference from SU-2

$$S_{12,i}^{o} = \frac{h_{1,i}P_{1,i}}{h_{2s,i}P_{2,i} + \sigma^2} \quad \text{3.3}$$

- Interference from both PU and SU-2

$$S_{p12,i} = \frac{h_{1,i}P_{1,i}}{g_{s1,i}P_i + h_{2s,i}P_{2,i} + \sigma^2} \quad \text{3.4}$$

- With no interference

$$S_{f1,i} = \frac{h_{1,i}P_{1,i}}{\sigma^2} \quad \text{3.5}$$

Where P_i , $P_{1,i}$ and $P_{2,i}$ represent the transmit powers of PU-Tx, SU-Tx-1 and SU-Tx-2 for the ith subcarrier, respectively. The thermal additive white Gaussian noise (AWGN) is assumed to have circularly symmetric complex Gaussian distribution with zero mean and variance σ^2.

Let, $S^{o}_{p1,i}$, $S^{o}_{12,i}$ and $S_{p12,i}$ denote the signal-to-interference plus noise ratio (SINR) levels for the ith subcarrier of SU-1 with interference component coming only from PU, only from SU-2 and from both PU and SU-2, respectively. Similarly, let $S_{f1,i}$ stand for the signal-to-noise ratio (SNR) for the ith collision-free subcarrier of the SU-1.

Also, $h_{1,i}$, $h_{1p,i}$ and $h_{1s,i}$ represent the channel power gains from SU-Tx-1 to SU-Rx-1, PU-Rx, and SU-Rx-2, respectively. Similarly, $h_{2,i}$, $h_{2s,i}$ and $h_{2p,i}$ denote the channel power gains for the ith subcarrier from SU-Tx-2 to SU-Rx-2, SU-Rx-1 and PU-Rx, respectively.

Then, the instantaneous capacity of SU-1 with the random access method is expressed as Capacities of subcarriers for SU-1, SU-2 and PU. Where the expected values of capacities at the ith subcarrier for the four different cases $C^{o}_{p1,i}$, $C^{o}_{12,i}$, $C_{p12,i}$ and $C_{f1,i}$ over the Rayleigh channel fading model [25], [27].

$$C^{o}_{p1,i} = \sum_{i \epsilon K^{0}_{p1}} \log(1 + S^{o}_{p1,i}) \ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.6$$

$$C^{o}_{12,i} = \sum_{i \epsilon K^{0}_{12}} \log(1 + S^{o}_{12,i}) \ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.7$$

$$C_{p12,i} = \sum_{i \epsilon K_{p12}} \log(1 + S_{p12,i}) \ldots\ldots\ldots\ldots\ldots 3.8$$

$$C_{f1,i} = \sum_{i \epsilon K_{f1}} \log(1 + S_{f1,i}) \ldots\ldots\ldots\ldots\ldots\ldots . . 3.9$$

Where $C^{o}_{p1,i}$, $C^{o}_{12,i}$, $C_{p12,i}$ and $C_{f1,i}$ denotes the capacities for the ith subcarrier of SU-1 with the presence of only PU, only SU-2, both PU and SU-2 and collision free, respectively.

Hence the instantaneous capacity is as:

$$C_{s1} = C^{o}_{p1,i} + C^{o}_{12,i} + C_{p12,i} + C_{f1,i} \ldots\ldots\ldots .3.10$$

Capacity Loss Due to Collisions:

The upper bounds for the SU-1 instantaneous and average capacity loss due to subcarrier collisions are given by the following result.

Corollary 1: The maximum capacity (rate) loss of SU-1 due to subcarrier collisions is upper-bounded by $\frac{1}{\sigma^2}\left[\sum_{i\epsilon K_{p1}} g_{s1,i}P_i + \sum_{i\epsilon K_{p12}} h_{2s,i}P_{2,i}\right]$. Mathematically,

$$\Delta C_{s1} = C_{s1}^{f} - C_{s1} \leq \frac{1}{\sigma^2}\left[\sum_{i\epsilon K_{p1}} g_{s1,i}P_i + \sum_{i\epsilon K_{p12}} h_{2s,i}P_{2,i}\right] \ldots\ldots\ldots\ldots 3.11$$

Where C_{s1}^{f} is the capacity of SU-1 when all of its subcarriers are collision-free, and is defined as

$$C_{s1}^{f} = \sum_{i=1}^{f_1^s} \log\left(1 + h_{1,i}P_{1,i}/\sigma^2\right) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.12$$

Note that the expressions of the exact capacity loss can be obtained as

$$E[\Delta C_{s1}] = E[C_{s1}] + E\left[C_{s1}^{f}\right] \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.13$$

So that, the expectation of exact capacity loss is the addition of expectation of instantaneous capacity of SU-1 when all of its users are present (with collision) and expectation of capacity of SU-1 when all of its subcarriers are collision-free.

3.4.5 Capacity Over Rayleigh Channel Fading :

Rayleigh fading is a statistical model for the effect of a propagation environment on a radio signal, such as that used by wireless devices. Rayleigh fading models assume that the magnitude of a signal that has passed through such a transmission medium (also called a communications channel) will vary randomly, or fade, according to a Rayleigh distribution - the radial component of the sum of two uncorrelated Gaussian random variables. Rayleigh fading is viewed as a reasonable model for tropospheric and ionospheric signal propagation as well as the effect of heavily built-up urban environments on radio signals [1].

In this section, the average capacity expressions at the ith subcarrier for the four different collision cases, given in Section III, will be studied. Various methods have been proposed to protect the operation of PU by maintaining the QoS requirements above some predefined threshold, and in this regard peak or average interference power constraints are two well known methods [15], [20]. In this paper, to investigate the performance of the proposed random access scheme, the well known peak interference power constraint at each subcarrier is adapted. It is assumed that the peak transmit powers of SUs are the same for a tractable analysis P1 = P2 = Ps . Therefore, the transmit power of the SU-1 is adapted to protect PU, and is given by[26]

$$P_s^T = \begin{cases} P_s , & \beta P_s \leq I \\ \frac{I}{\beta} , & \beta P_s > I \end{cases} = \min\left\{P_s, \frac{I}{\beta}\right\} \quad \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \quad 3.14$$

Where $\beta = h_{1p} + h_{2p}$, and I is the interference power constraint. It is worth to note that due to the random access scheme, the transmit power is adopted (regulated) considering the worst case scenario, as if there are collisions between both SUs and PU (interference from both SUs at PU-Rx. This condition assures the QoS requirement of PU. Notice also that considering the Rayleigh channel fading model, all the channel power gains are exponentially distributed with unit mean.

3.4.6 ARQ Based Technique

I have simply taken a simple ad-hoc network where ARQ based spectrum sharing taking place without using the traditional CSI (channel state information) at the secondary transmitter. ARQ means automatic repeat request and the mechanism used in the process is whenever the source node transmits a message to the destination user, if the message received successfully by the destination then it sends ACK-acknowledgement signals back to the sender such that sender assumes that message reached successfully.

If at all message doesn't reached the destination, then it will send NACK-negative acknowledgement signal to the sender such that sender assumes that message should be retransmitted.

We are now considering another two additional things in this process cycle [28]:

(1) Each of the primaries ARQ mechanism will now carries the information regarding the channel gains that has been taking place in multiple time intervals.

(2) Each of the secondary transmission creates interference on the primary user in the network; therefore the following ARQ now carries further information back to the secondary regarding the relative strength of the primary and values of the cross channel coefficients.

In the aggressive sharing, the secondary will only transmit whenever it has possible to do so without sending the primary into breakdown, even though it will degrade the performance of the primary throughput.

In the Conservative sharing, the secondary will only transmit when there has been no negative effect on the primary throughput. We can now determine the probing or searching and as well discovery mechanism. The probing of the system have determined by the secondary transmission decisions only.

The primary packet is sent by only one transmission cycle and two cycles in the other mentioned SNR regions. The packet is the only successfully decoded at the primary receiver. As a result, the throughput for the primary user in the aggressive SHARP is given as

$$G_p^A = RpP\{S1\} + \frac{Rp}{2}\sum_{i=2}^{5} P\{Si\} \ldots\ldots\ldots\ldots\ldots 3.15$$

Where, the 'A' denotes the aggressive and $R_p/2$ is taken due to the fact that it consumes two consecutive transmission cycles.

Accordingly, the throughput of the secondary user in aggressive sharing can also be derived and given as,

$$G_s^A = \begin{pmatrix} R_s(P\{S1\} + P\{S2\} + P\{S6\}) \\ + \frac{Rs}{2}(P\{S3\} + P\{S4\}) \end{pmatrix} \{1 - P^{OS}\} \ldots\ldots\ldots\ldots\ldots 3.16$$

Apart from exploiting and digging the transmission opportunities for the secondary, which makes no harmful effect to the existing primary operating system, the secondary user may slows down the primary by forcing it to use two transmission cycles instead of one. In addition to these, the secondary is allowed to transmit when there is two interference-free transmissions are not good enough to support the primary user.

The conservative sharing aims to avoid any negative adverse effect on the primary user by allowing the secondary to transmit only when the channel is good enough to support simultaneous communication for both the primary as well as the secondary [28].

The conservative scheme also precludes the transmission and leaves the primary operation alone. Consequently, the throughput of the primary as well as the secondary in the conservative sharing are given by

$$G_p^C = Rp(P\{S1\} + P\{S_2^1\}) + \frac{Rp}{2}(P\{S4\} + P\{S5\}) \ldots\ldots\ldots\ldots..3.17$$

$$G_s^C = \left(R_s\left(P\{S1\} + \frac{1}{2}P\{S4\} + P\{S6\}\right)\right)\{1 - P^{OS}\} \ldots\ldots\ldots\ldots..3.18$$

Where, the ‘C’ denotes the conservative and S1, S2, S3, S4, S5 and S6 are the different regions. Here I have taken probabilities of different regions.

CHAPTER 4
RESEARCH METHODOLOGY

4.1 Introduction

The performance of wireless communication systems is mainly governed by the wireless channel environment; the wireless channel is rather dynamic and unpredictable, which makes an exact analysis of the wireless communication system often difficult. In recent years, optimization of the wireless communication system has become critical with the rapid growth of mobile communication services. So, Cognitive radio (CR) design aims to increase spectrum utilization.

4.2 Methodology

In this semester, after Consulting with my mentor they told us what we want to do in the thesis. We search from the web about the topic of thesis. Since, Wireless communication has been the fastest immerging technology of the communications field because of with the incredible growth in the number of wireless systems and services; the availability of high quality wireless spectrum has become severely limited. Cognitive radio offers a novel solution to overcome the underutilization problem by allowing an opportunistic usage of the spectrum resources. A CR can intelligently detect whether any portion of the spectrum is in use, and can temporarily use it without interfering with the transmissions of other users but I found, In cognitive radio terminology, a primary user (PU) or a licensed user (GSM) who has higher rights on particular part of spectrum and on the other hand, unlicensed cognitive users (WLAN) with lower priority are defined as secondary users (SUs). It has a drawback that when they are sharing the spectrum there will be collisions between SUs and PUs due to randomness access. I read different types of journals. Finally I choose my proposed topic “A Study on Inter-Cell Subcarrier Collisions due to Random Access in Cognitive Radio Networks”. In this related topic I search from the internet and its all part including the references etc. I studied its related topic. While studying these I found improvement can be done by using some other techniques. Due to collision between PU, SU-1 and SU-2, the capacities of the parameters decreases and this happen due to only sharing of the spectrum. Here I also employ a sharing technique to reduce the interference and increase the capacities. Here I used a SHARP sensing technique. I simulate these using MATLAB and got the improved results.

4.3 Research Methodology:

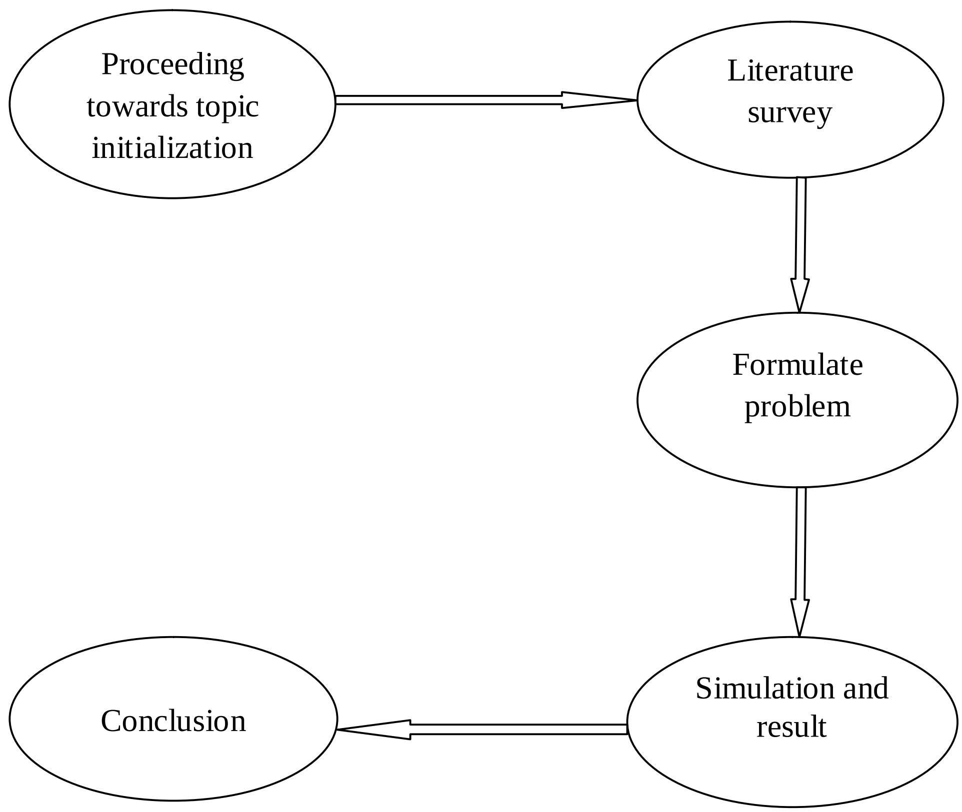


Figure 4.1 Flow chart of Research

Design Process:

In order to precede research, topic selection is more important, because which topic is critical with the rapid growth of technology. After that literature survey is must be done related the topic. Literature survey is to exploit the research and gather information about methods to approach. After doing literature survey next step is to formulate the hypothesis which can lead to better results and then formulate the problem based on the analysis.

CHAPTER 5
RESULTS AND DISCUSSION

5.1 Introduction

The simulation has been done by using Matlab software, the obtained simulation results of the proposed techniques that are discussed. The simulation result has been obtained using MATLAB software version 7.10.0.499 (R2010a).

5.2 Simulation Results and Discussion

The numerical and simulation results are presented to confirm the analytical results and investigate the impact of various system parameters on the performance of CR networks. Further, equal transmit powers of SUs are assumed to verify the simulation results with the numerical ones and the unit noise variance $\sigma^2 = 1$, is used in all these plots. In this paper we have performed both sharing a\nd sensing technique and also reduced the transmitted power from P=5dB to P=1dB. Thereafter, comparing the results with the simulation diagram has shown.

5.2.1 Average capacity at the ith subcarrier versus peak transmit power

If we compare simulation result in fig.5.1 and fig.5.2, we can observe that the simulation result of fig.5.2 is better than fig.5.1 and in fig.5.2 the capacities of $C^{o}_{p1,i}$ and $C_{p12,i}$ is increased.

5.2.2 Average capacity at the ith subcarrier versus interference power constraint

Similarly compare fig.5.3 and fig.5.4 than the simulation result of fig.5.4 is better.

In both comparison the capacities is better than previous cases and also requires less transmitted power. That is instead of P=5dB it requires P=1dB.

5.2.3 Simulation Graphs using Matlab Software

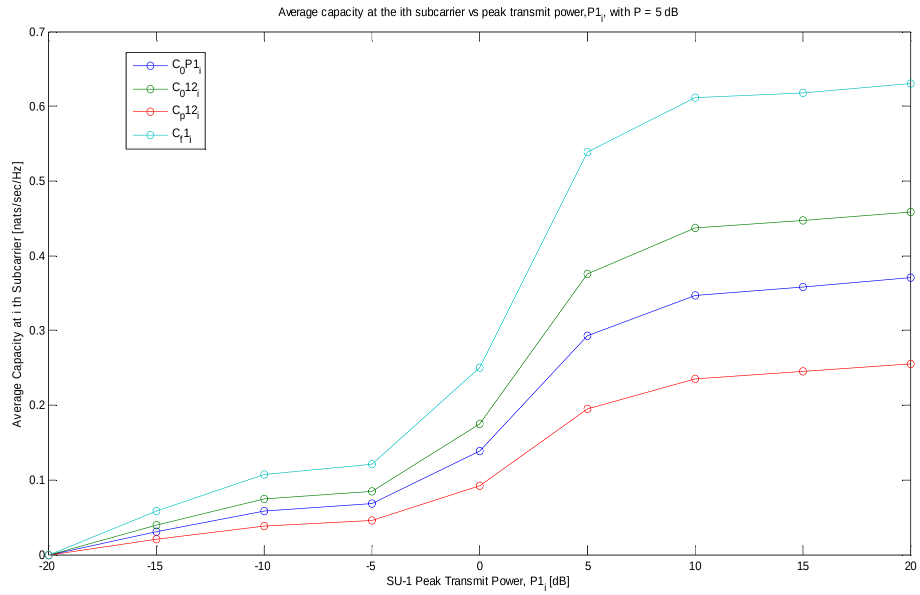


Fig.5.1 Average capacity at the ith subcarrier versus peak transmit power, Ps, in case of collision-free and interference from only PU, only SU-2 and both PU and SU-2 with P =5 dB and I =2 dB.

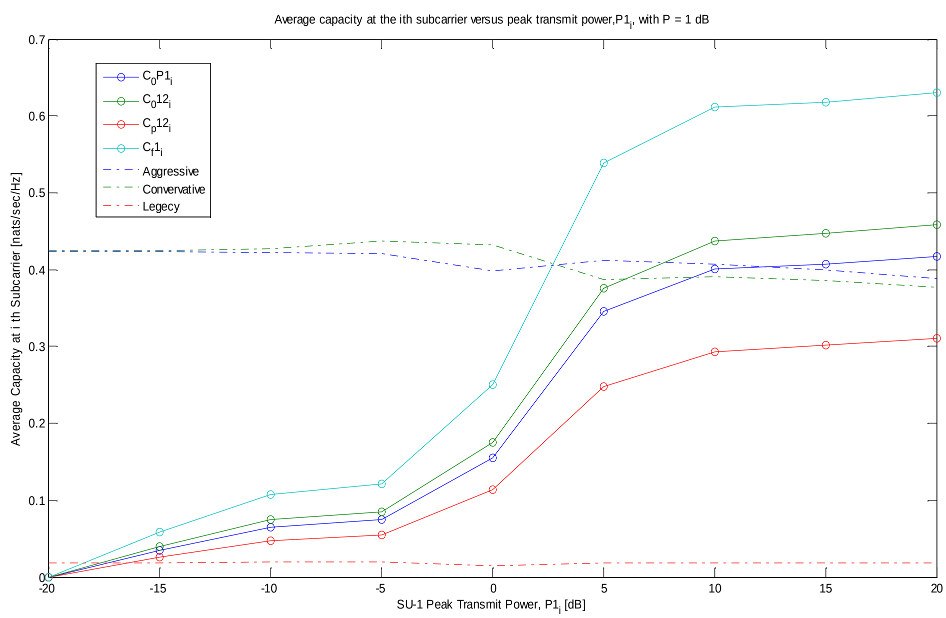


Fig.5.2 Compare to fig.5.1, it include SHARP and with P=1 dB

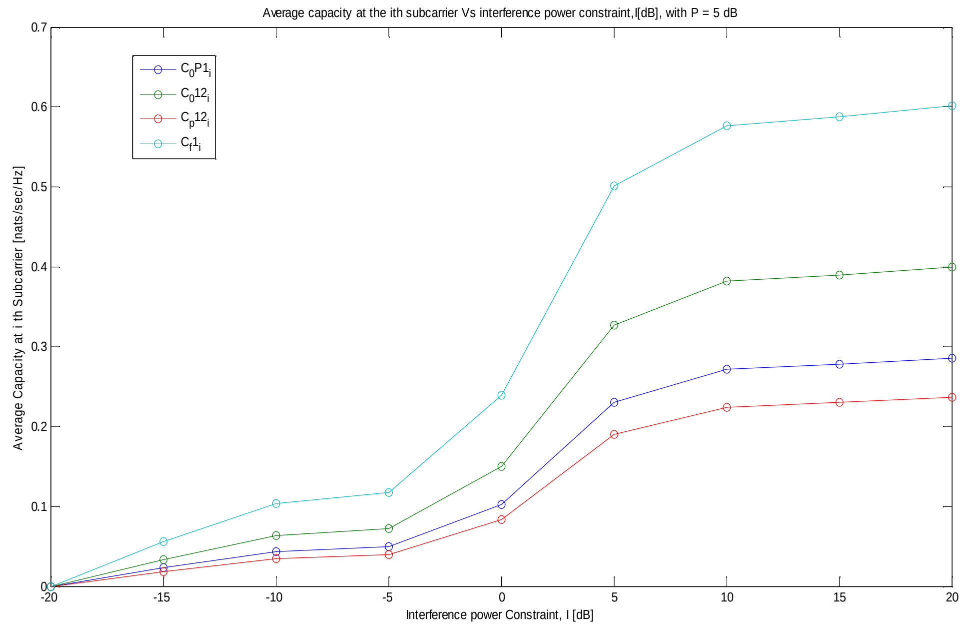


Fig.5.3 Average capacity at the ith subcarrier versus interference power constraint, I, in case of collision-free and interference from only PU, only SU-2 and both PU and SU-2 with P =5 dB and Ps =0 dB

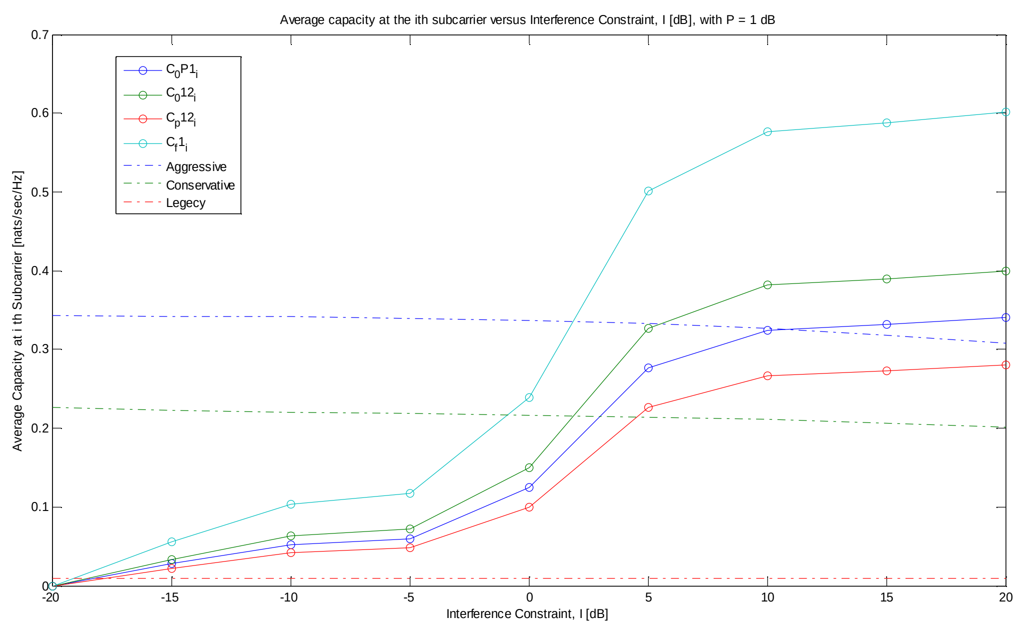


Fig.5.4 compare to fig.5.3, it include SHARP and with P=1 dB

The average capacity loss due to subcarrier collisions is investigated in the simulation. The percentage of average capacity loss versus the ratio of available subcarriers to the utilized subcarriers, $R_a = F/T_{s1}$, F= 40,.....,200 and T_{s1} = 40, is shown for different values of PU's transmit power. It is immediate to observe that an increase in the number of available subcarriers in the primary network, leads to a larger number of collision-free subcarriers for SU-1.

Therefore, SU-1 average capacity loss decreases as the number of available subcarriers increases. Notice also that an increase in PU transmit power results in higher interference at SU-1, and hence higher capacity loss on the average.

CHAPTER 6

CONCLUSION AND FUTURE SCOPE

6.1 Introduction

This chapter gives the various inferences of the research based on the results that have been given in the chapter 4 which have been derived from the chapter 3 and also mentioned the related future scope that can be done in future regarding the concerned research work.

6.1 Conclusion:

The key contribution of this paper was about the research process is centered on the random subcarrier access scheme which is considered for an OFDM-based CR system with spectrum sharing features and two different secondary networks (cells). It is assumed that no spectrum sensing is performed, Such that, the randomness of the access scheme and as well as the absence of cooperation between the SUs, there can be possibly inter-cell collisions between the SUs' subcarriers with a certain probability. The expressions for the PMFs and as well as the average of the number of subcarrier collisions, considering both fixed and random (to obtain the long term average) number of subcarriers utilized by PU and SUs, are derived. The performance of the random access scheme is analyzed by using the average capacity as a performance measure. To maintain the QoS of the PU, here we have also introduced the Spectrum Harvesting with ARQ Retransmission and Probing (SHARP) technique that also performs sensing in it. Therefore the collision between the PU and SUs will reduce and capacity will increase. In this paper I also reduced the transmitted power from P=5dB to P=1dB.

6.2 Future Scope:

This work is related to study of performance of Secondary user with primary user transmission in a Cognitive radio. The channel/subcarrier access is based on spectrum sharing and the spectrum sensing, to reduce the collision between PU and SUs. So the proposed method increased the capacities of PU and SUs and reduces the interference between them. Also reduce the transmitted power. So, by using the other spectrum sensing technique with random access method to reduces the collision between PU and SUs.

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