SIMULATION OF INTELLIGENT SPECTRUM SENSING IN COGNITIVE RADIOS

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CERTIFICATE

Certified that the contents and form of project report entitled **"Simulation of Intelligent Spectrum Sensing for Cognitive Radios"** submitted by 1) Maj Muhammad Abdus Saboor(Project Manager), 2) Maj Nadeem Iltaf, 3) Capt Qaisar Khan have been found satisfactory for the requirement of the degree.

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ABSTRACT

Simulation of the Intelligent Spectrum Sensing in Cognitive Radios

Cognitive Radios are futuristic radio transceivers under research and development at present. These radios will be designed on the principle of finding medium for themselves through dynamic and exploratory sensing of the RF Spectrum in order to find free spaces in it. These free spaces in the RF spectrum are left unused by the licensed users (to whom the bandwidth is leased) either intentionally or unintentionally i.e., absence of any user and are termed as gaps or holes. These gaps are the opportunities for Cognitive Radios hopping onto these gaps for communicating with their peers or any other radio device static or mobile using a variety of modulation, channel encoding and other digital communication techniques and protocols. This is a dynamic process needing extensive but intelligent decision making and hence the name cognitive. At present there is no single dedicated simulator present for simulating the concept in part or as a whole. This project is a step ahead simulating the intelligent spectrum sensing part of the Cognitive Radios using an optimized technique of Radio Environment Mapping and Learning. The project aims at developing a simulator ab-initio to simulates the process of Intelligent Spectrum Sensing i.e., detection of holes or spaces in the given or selected band through repeated iterations in order to map the RF environment and form a hopping sequence comprising mostly available frequencies with priority formed through learning based on weights or knowledge scores. The project is implemented in C# with SQL database at the backend to form a complete picture of the environment. Initial and repeated location and date time aware scanning using a number of iterations is carried out to assign scores or weights to the found or available frequencies. The project was developed using a hybrid software engineering methodology using Spiral with prototyping. Agile project management methodology was used for development

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Keywords

SISS	simulation of intelligent spectrum sensing
CR	Cognitive Radio
TCP	Transmission Control Protocol
IP	Internet Protocol
UDP	User Datagram Protocol
Sx	Sensing Function
ISx	Intelligent Sensing Function
Cx	Communication Function
PU	Primary User
SU	Secondary User
FCC	Federal Communication Commission
LAN	Local Area Network
WLAN	Wireless Local Area Network
WMAN	Wireless Metropolitan Area Network
MAC	Medium Access Control
LOS	Line of Sight
SDR	Software Defined Radio
SNR	Signal to Noise Ratio
BER	Bit Error Rate
SS	Spectrum Sensing
CSS	Collaborative Spectrum Sensing
RF	Radio Frequency
QoS	Quality of Service
EM	Electromagnetic

CHAPTER 1
INTRODUCTION

1.1 Introduction

This chapter introduces the general purpose of Cognitive Radios, background of the project, its intended aims and goals, problem statement, project scope, motivation and achievements. It also elaborates the outline adopted to achieve the objectives.

1.2 Cognitive Radios

These are the futuristic devices which will operate as secondary users on licensed frequency bands without interfering with the primary users (Licensed Users). Cognitive Radios are intelligent devices capable of sensing the RF Spectrum, determining the gaps and holes among the frequencies.

The technology is likely to emerge as implementable by 2030.

1.3 Spectrum Sensing

A technique which enable the users to read the RF Spectrum through RF antennas and spectrum analyzers and determine its usage, that is the occupancy and vacancy state of the frequencies.

1.4 Intelligent spectrum sensing ISx

Isx is a derivative of spectrum sensing which senses the frequencies and allocate weight ages through comparison with previous patterns.

1.5 Problem Statement

Recent studies have showed that the paradox of apparent scarcity of radio spectrum while most of the bands are underutilized occurs mainly due to the inefficiency of traditional static spectrum allocation policies. This has prompted proposals for various dynamic spectrum sharing (DSS) techniques and approaches, such as our proposed knowledge base learning (KBL) of radio spectrum. As opposed to passive spectrum sharing by the primary users considered in many previous DSS proposals, leasing, as proposed in, means that the primary users have an incentive (e.g. monetary rewards as leasing payments) to allow secondary users to access their licensed spectrum. Therefore, the primary user plays an active role in interference management and dynamically controls how much interference must be allowed from the secondary system. In KBL the primary user is assumed to allow a limited interference. Which is the maximum total interference the primary user is willing to tolerate from secondary transmissions at any given time. Hence, we investigate the performance improvement that can be expected by a KBL based paradigm with respect to passive spectrum sharing schemes which do not allow dynamic primary-secondary network interaction based on proactive primary systems.

Cognitive Radios (CR) are RF Environment aware devices the proposed CR models use unintelligent sensing functions S_x followed by the Communication Functions C_x through interleaving. Addition of an Independent Intelligent Sensing Function IS_x will attribute to the continuum in communication without interruptions one of the IS_x technique is to assign weight ages to the learned or identified gaps or holes[@]. In the available range of frequency spectrum towards their perceived higher probability of availability for usage/hopping sequence by the secondary user. This weighted table like a routing table will have database of mostly available gaps or frequencies in the available frequency band and can readily provide prioritized shift or hopping sequence.

1.6 Purpose

The project specifically aims at indigenously developing a Simulator that will help us in discovering the viability of CR concepts/ environment.

The project aims at simulation of a part of the intelligent spectrum sensing technique in Cognitive Radios. A number of system models are under evaluation with an aim of finding an intelligent system for readily providing a hopping sequence to the communicating radio peers.

1.7 Project Scope Statement

To develop Simulation system consisting of KBL tables providing the occupancy and vacancy of Radio Spectrum. Establish communication between Radio Peers, usage time calculation. Radio environment mapping, Frequency occupancy and vacancy, hopping sequence through a power versus frequency graph.

1.8 Motivation

The rapid growth of Radio technology and exponential growth of its users has overburdened the RF spectrum causing traffic congestion and busy network tones. This problem has been on rise in recent years and a need to explore the alternatives to present Spectrum allocation approach is felt largely to overcome this problem. Cognitive Radios are the most innovative and futuristic devices to succeed the present legacy of Radio environments and Radio band allocation policies. In this project we have made an effort to simulate such arena where Cognitive Radios will supersede the existing Radio Technologies. The Simulator is one step short of real implementation and in future if further explored, it will provide the first prototype Cognitive Radio to be used. The achievement of Hopping sequence and its further implementation means a full time CR.

1.9 Project Domain

Domain of our project is continuous sensing of RF Spectrum for searching of gaps/holes in it for further usage by secondary users, giving database based on a client/server architecture.

1.10 Achievements

This project was done with guidelines from MO directorate GHQ Rawalpindi.

Communication between two Radio Peers

Scanning of RF Spectrum

Usage time calculation

1.11 Future

This project can be further extended by connecting it to real time antennas to continuously sense the RF Spectrum and by adding further functionalities to it.

1.12 Organization of Report

This project report has been divided into eight chapters. Chapter 1 gives an introduction to the technology used and project statement and motivation behind under taking the project. Chapter 2 gives the literature review in detail along with the appropriate references. Chapter 3 is based on the detailed analysis of system requirements. Chapter 4 describes the system design and architecture and explains the way project is organized. Chapter 5 describes the system development with all the details of the system functions and explains the way they have been developed. Testing and validation of the system is explained in chapter 6, chapter 7 comprises of Results and Analysis and finally chapter 8 describes all the achievements of the project also including the future work that can be done in the project.

CHAPTER 2
LITERATURE REVIEW

2.1 Introduction

This chapter discusses the literature that we have studied so far. It includes the different approaches being considered for developing a very close to the real environment simulator of intelligence spectrum sensing, Different client architectures and the problems and shortcomings of those architectures. Further this chapter also includes a detailed description of exiting developed and studied spectrum sensing techniques and their related work and explains the main area of knowledge which one should have an idea before developing a simulator of intelligent spectrum sensing.

2.2 Evolution of CRs

Over the past 15 years, notions about radios have been evolving away from pure hardware-based radios to radios that involve a combination of hardware and software. In the early 1990s, Joseph Mitola[15]introduced the idea of software designed radios (SDRs) [11]These radios typically have a radio frequency (RF) front end with a software-controlled tuner. Baseband signals are passed into an analog-to digital converter. The quantized baseband is then demodulated in a reconfigurable device such as a _eld-programmable gate array (FPGA), digital signal processor (DSP), or commodity personal computer (PC). The reconfigurability of the modulation scheme makes it a software-defined radio. In his 2000 dissertation, Mitola took the SDR concept one step further, coining the term cognitive radio (CR) . CRs are essentially SDRs with artificial intelligence, capable of sensing and reacting to their environment. Figure 2.1 graphically contrasts traditional radio, software radio, and cognitive radio.

Radio Paradigms

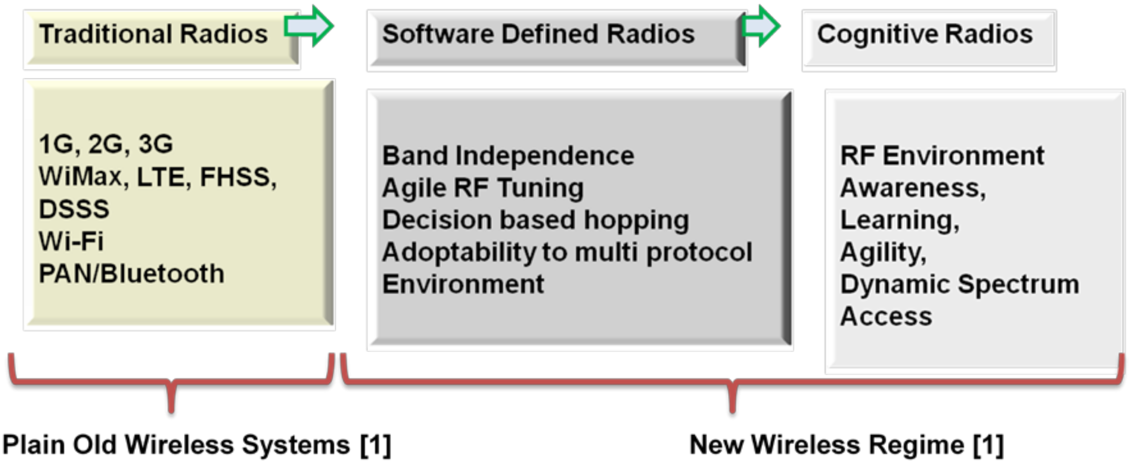


Figure 2.1 Logical diagram contrasting traditional radio, software radio, and cognitive Radio

In the past few years, many different interpretations of the buzz word \cognitive radio" have been developed. Some of the more extreme definitions might be, for example, a military radio that can sense the urgency in the operator's voice, and adjust QoS guarantees proportionally. Another example is a mobile phone that could listen in on your conversations, and if you mentioned to a friend you were going to hail a cab and ride across town, it would preemptively establish the necessary cell tower handouts.

Though more representative of Mitola's original research direction, these interpretations are a bit too futuristic for today's technology. A more common definition restricts the radio's cognition to more practical sensory inputs that are aligned with typical radio operation. A radio may be able to sense the current spectral environment, and have some memory of past transmitted and received packets along with their power, bandwidth, and modulation. From all this, it can make better decisions about how to best optimize for some overall goal. Possible goals could include achieving an optimal network capacity, minimizing interference to other signals, or providing robust security or jamming protection.

Another contentious difference in interpretation has to do with drawing the line between SDR and CR. Often times, frequency agile SDRs with some level of intelligence are called CRs. However, others believe that SDRs are just a tool in a larger CR infrastructure. Remote computers can analyze SDR performance and reprogram them on the y. For example, this remote intelligence could decide none of the SDRs' modulation schemes are sufficient for their current environment. It could create a new scheme on the y, generate hardware description language (HDL) and new FPGA loads, and reload them over the network to add this new functionality. The SDR is accessed via a CR application programming interface (API) that allows the CR engine to configure the radio, and sense its environment. The policy-based reasoning engine takes facts from the knowledge base and information from the environment to form judgments about RF spectrum accessing opportunities.

In addition to a simple policy-based engine, a learning engine observes the radio's behavior and resulting performance, and adjusts facts in the knowledge base used to form judgments. A fundamental problem with a system like this is its complexity. Can the proposed learning and reasoning be done in near real time, to keep up with an ever changing RF environment? Can we come up with a simple set of metrics that can perform well without being overly computationally complex? This research aims to identify such metrics and control algorithms for implementing them. We do not overly delve into the artificial intelligence aspects of how reasoning and learning can be done in a generalized way, but apply basic principles to the metrics and algorithms we implement.

Seeing the advances in smart radio technology, the FCC began researching ways in which CRs could use licensed bands, provided they didn't interfere with existing licensees. A motion to allow operations to operate was recently approved and adopted by the FCC,[11] and allows cognitive radios to operate in certain frequency bands. The FCC also proposed the interference temperature model the instantiation of which is the subject of much of this dissertation.

2.3 Spectrum Sensing Techniques

Cognitive radios are aware of their surroundings and bandwidth availability and are able to dynamically tune the spectrum usage based on location, nearby radios, time of day and other factors.

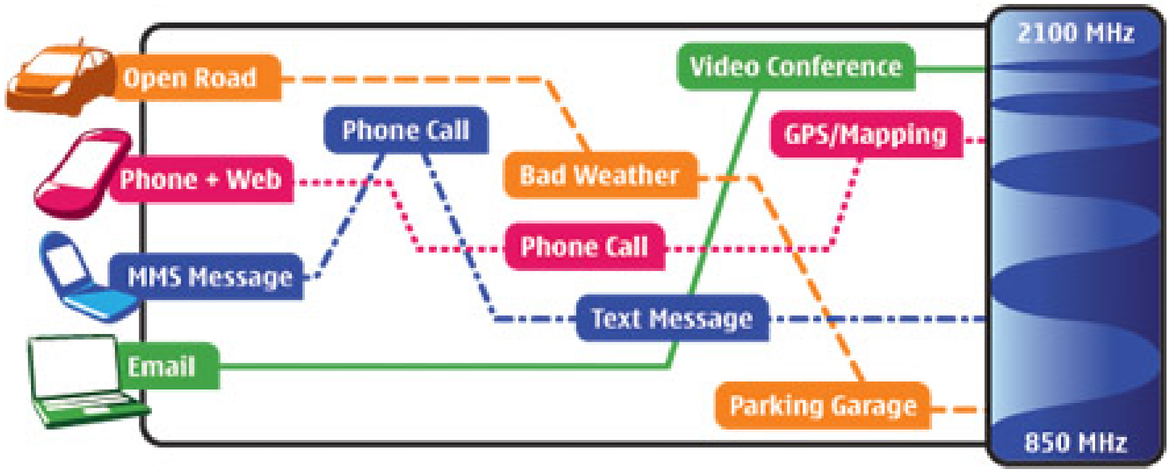


Fig 2.2 Spectrum sensing technique [1]

This provides for a more efficient use of the spectrum as well as reducing power consumption, and enabling high priority communications to take precedence if needed.

Spectrum sensing techniques can be classified into three categories:

Transmitter detection

Cooperative detection

Interference based detection.

2.4 Sx techniques / Isx

Spectrum Sensing is detecting the unused spectrum and sharing it without harmful interference with other users. It is an important requirement of the Cognitive Radio network to sense spectrum holes[1]. Detecting primary users is the most efficient way to detect spectrum holes.

2.4.1 Spectrum Management

capturing the best available spectrum to meet user communication requirements while not creating undue interference to other (primary) users. Cognitive radios should decide on the best spectrum band to meet the Quality of service requirements [5]over all available spectrum bands, therefore spectrum management functions are required for Cognitive radios. These management functions can be classified as:

spectrum analysis

spectrum decision

2.4.2 Intelligent Spectrum sensing

Addition of an Independent Intelligent Sensing Function IS_x will attribute to the continuum in communication without interruptions. One of the IS_x technique is to assign weight ages to the learned or identified gaps or holes[@] in the available range of frequency spectrum towards their perceived higher probability of availability for usage/hopping sequence by the secondary user. This weighted table like a routing table will have database of mostly available gaps or frequencies in the available frequency band and can readily provide prioritized shift or hopping sequence.

2.5 Cognitive Radio Architecture

The CR is at maximum a three tier architecture consisting of the cognitive functionalities at application or higher layers i.e., layer comprising learning and reasoning engines more preferably implementable in form of software applications which can be enhanced and upgraded when ever required[5]. At the middle tier the intermediate functionalities comprising of requisite operating system are there and at the bottom underlying all are the hardware functionalities. The lower two tiers collectively form the SDR. This tiered conceptual architecture is shown in figure.

Intermediate Functionalities Database, SDR Software, Operating System (Middle Tier)

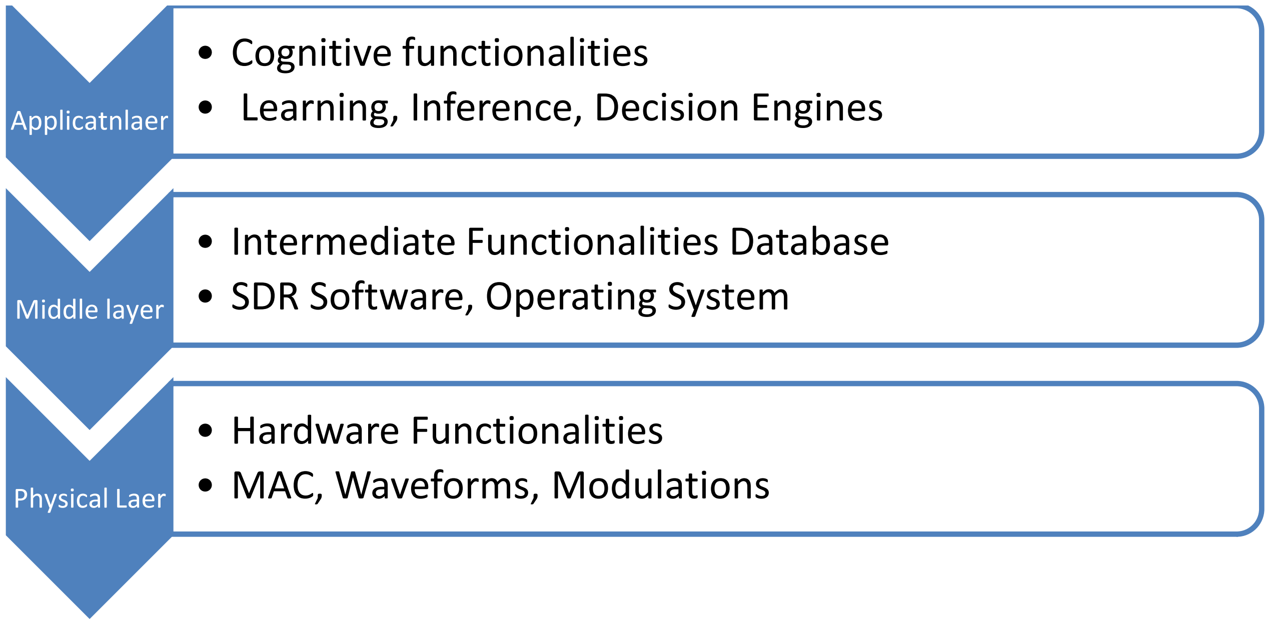


Figure 2.3: Cognitive Radio main tiers

2.6 Related Topics

2.6.1 Code Division Multiple Access

CDMA is a channel access method used by different radio communication technologies. One of the basic concepts in data communication is the idea of allowing several transmitters to send information simultaneously over a single communication channel. This allows several users to share a band of frequencies[2]. This concept is called multiple access. CDMA uses spread-spectrum technology and a special coding scheme (where each transmitter is assigned a code) to allow many users to be multiplexed over the same physical channel.

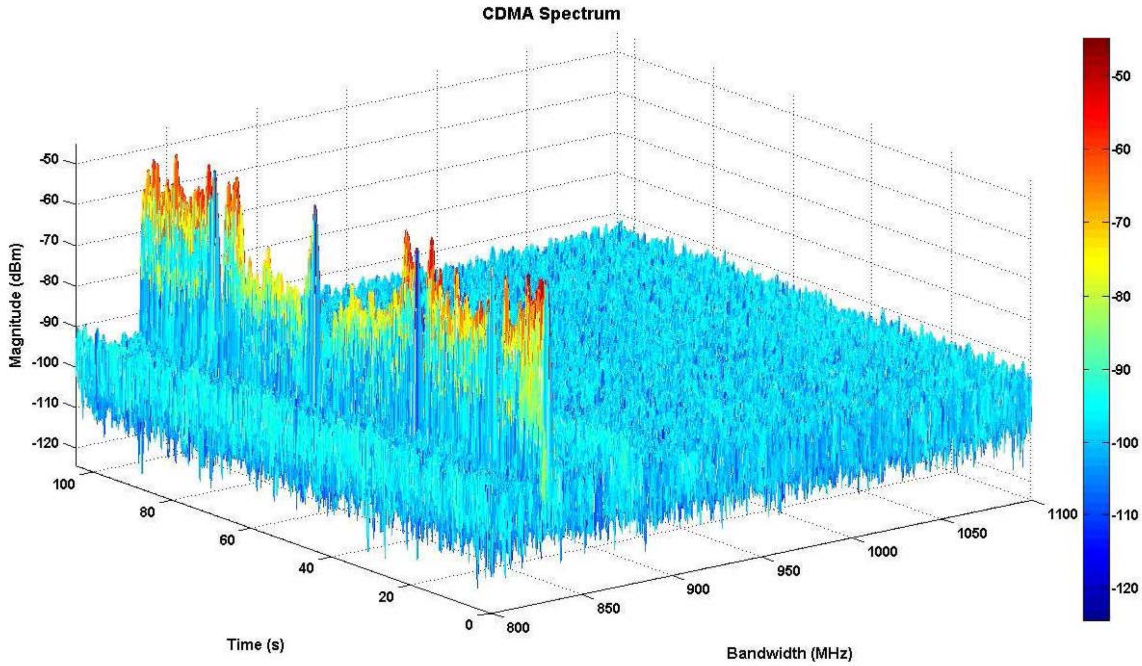


Fig 2.4 CDMA Spectrum

An analogy or similarity to the problem of multiple access is a room (channel) in which people wish to talk to each other simultaneously. To avoid chaos and confusion, people could take turns speaking (time division), speak in pitches (frequency division), or speak in different languages (code division). CDMA is analogous to the last example where people speaking the same language can understand each other, but other languages are perceived as noise and rejected. Similarly, in radio CDMA, each group of users is given a shared code. Many codes occupy the same channel, but only users associated with a particular code can communicate.

2.6.2 GSM Spectrum

Definition: GSM, stands for *G*lobal *S*ystem for *M*obile communications, rules as the world's most widely used cell phone technology [3]. Cell phones use a cell phone service carrier's GSM network by searching for cell phone towers in the nearby area.

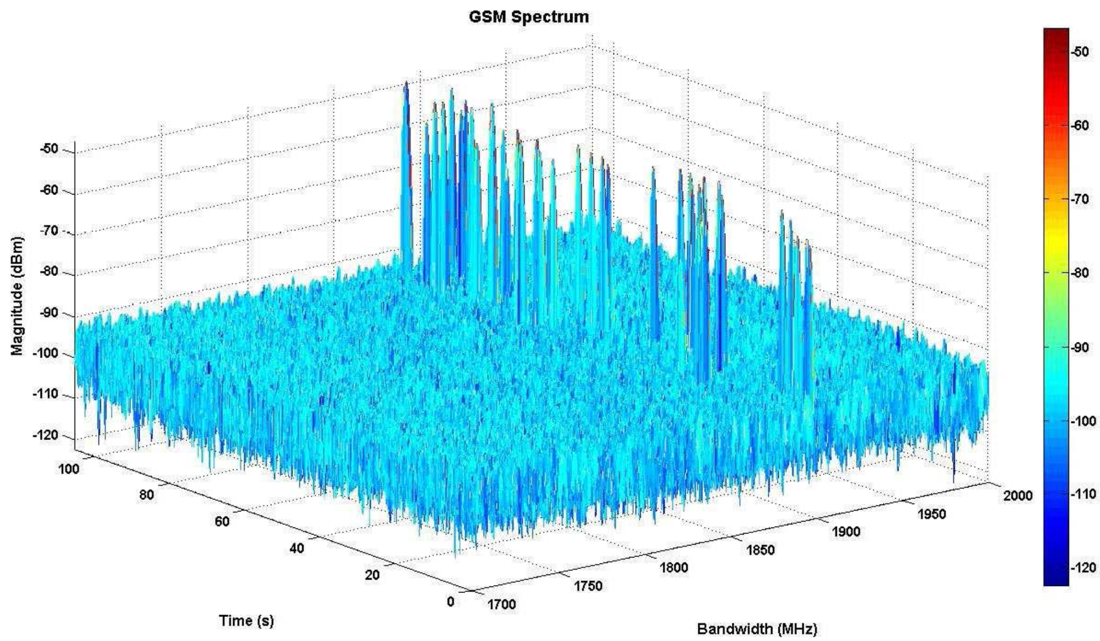


Figure 2.5 GSM Spectrum

The start of GSM can be traced back to 1982 when the Groupe Spécial Mobile (GSM) was created by the European Conference of Postal and Telecommunications Administrations (CEPT) for the purpose of designing a pan-European mobile technology. It is estimated that 80 percent of the world uses GSM technology when placing wireless calls, according to the GSM Association (GSMA), which represents the interests of the worldwide mobile communications industry. This amounts to nearly 3 billion global people.

2.6.3 WI-Fi Spectrum

Wireless Fidelity means a group of technical standards enabling the transmission of data over wireless networks [4].

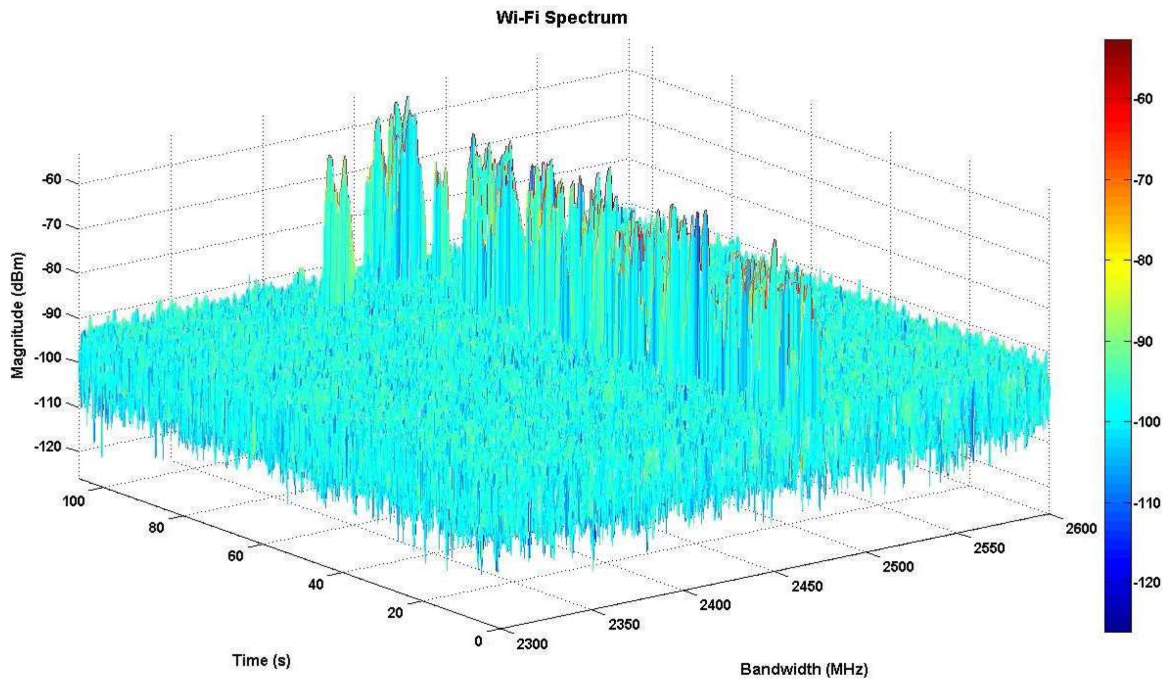


Fig 2.6 Wi-Fi Spectrum

Wi-Fi is the standard for computers connections to wireless networks. Mostly all computers now have built in Wi-Fi cards that enables users to search for and connect to wireless routers. Numerous mobile devices, video game systems, and other standalone devices also have Wi-Fi capability, enabling them to establish connection to wireless networks as well. These devices may be able to connect to the Internet using a Wi-Fi signal. However, it is must to understand that the Wi-Fi connection only exists between the device and the router. Most routers are connected to a DSL or cable modem, and that provides Internet access to all connected devices.

2.6.4 Multiple Accesses:

There are many users all simultaneously trying to communicate with each other. In order to support everyone, there must be a way to share the communications channel.

To achieve this, we use a multiple access scheme for multiplexing users' communications. This multiplexing can be done in time, frequency, or code. In time-division multiple access (TDMA), users are multiplexed in the time domain, each being allocated a certain window in which to communicate. Time is typically segmented evenly into short windows, and each device in the network is assigned recurring time slots when they are scheduled to transmit. This scheduling typically requires a centralized controller in the network with knowledge of the capacity needs of each device. A slight variant of TDMA is carrier-sense multiple access (CSMA).

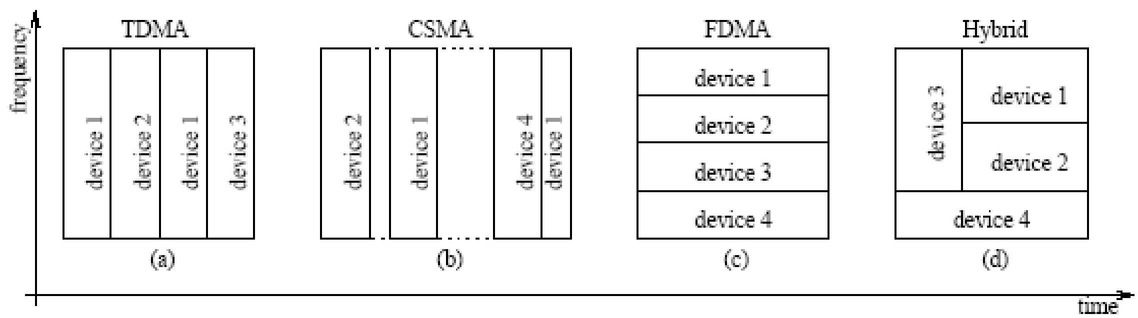


Figure 2.7 Multiple Accesses

CSMA also multiplexes in time, but it does so in a less organized manner. In particular, when a device has data to transmit, it first listens. If no other devices are transmitting, it transmits. If the channel is in use, it waits until the channel is idle. A major problem in this scenario is devices transmitting simultaneously, causing interference and data loss. The advantage to CSMA is that no centralized controller is needed, but the disadvantage is that communications resources are often used insufficiently. Moving on to the frequency domain, we have frequency-division multiple access (FDMA). Here, each device is assigned a frequency for communication, much like frequency modulation (FM) radio. FDMA also users typically cannot switch frequencies on the y to use idle channels if they have a lot of data to send. There are several hybrid approaches that combine TDMA and FDMA. A centralized controller schedules data transmissions in both the frequency and time domain. A common example of this is called orthogonal frequency division multiple access (OFDMA), which is based on orthogonal frequency division multiplexing (OFDM). The technique, called code division multiple access (CDMA) is more difficult to explain because it multiplexes neither in the time nor frequency domain. To understand CDMA, a basic understanding of direct sequence spread spectrum (DSSS) communications is required.

In DSSS, before being transmitted, analog waveforms are multiplied by a high frequency pattern from the set f_1; 1g1 called a spreading code. The effect is that the signal's power is \spread" over a larger bandwidth. With CDMA, all devices implement DSSS and communicate simultaneously at the same frequency, however devices are all assigned unique, mutually orthogonal spreading codes. Only with the right spreading code can a receiver transform the spread signal into the original narrowband signal. The orthogonality helps minimize noise introduced into the narrowband signals. Thus at any given time, many users could be transmitting data, creating a wideband mass of spectral energy. Receivers use spreading codes to then recover the desired narrowband signal from the mass. One implementation issue for CDMA involves receivers knowing which spreading code to use. In most systems today, all wireless devices communicate only with a centralized controller, and the controller has access to all the spreading codes. For distributed, ad hoc environments, the idea of receiver-oriented codes can be used, where each receiver has an assigned code, and communications are essentially addressed using particular spreading codes. Additionally, there has been much research into techniques for dispreading DSSS signals without knowledge of the original spreading code. Such approaches generally require short, repeating spreading codes and cyclostationary channels. Most of these schemes will yield similar overall channel capacity, as seen by the Shannon-Hartley law. For example, in FDMA, the total bandwidth B will be subdivided into n frequency bands, yielding a fractional C=n capacity for each user. In TDMA, each transmitter will have a duty cycle of 1=n, giving them a total capacity of C=n. It is important to notice that we can utilize the Shannon-Hartley theorem that since spreading and dispreading are symmetric operations, interference power is distributed at whitened. when measuring the capacity of CDMA in the presence of interference. Interference is inherently non-white, but the CDMA dispreading process whitens interference, as long as there is no correlation between the interference and the spreading code. Overall, this chapter should have given the average reader some background in the topics discussed in this dissertation.

2.7 Radio Environment Mapping and learning

The radio environment map (REM) is proposed as an abstraction of real-world radio scenarios. Which are represented by an integrated database consisting of multi-domain environmental information and prior knowledge.[4] Such as the geographical features, available networks and services, spectral regulations, locations and activities of radios, policies of the users and/or service providers, and past experience .

The REM can be exploited by the cognitive engine for most cognitive functionalities, such as situation awareness, learning, reasoning, planning, and decision support.

CHAPTER 3
REQUIREMENT ANALYSIS

3.1 Requirement Engineering

Requirements analysis encompasses those tasks that go into determining the needs or conditions to meet for a new or altered product, taking account of the possibly conflicting requirements of the various stakeholders, such as beneficiaries or users. Systematic requirements analysis is also known as requirements engineering.

Software requirements elicitation is the process in which the customers' needs in a software project are identified. This process is considered as one of the most important parts of building a software system. Because during this stage it is decided exactly what has to be built. In this process there is a need of needs close interaction between developers and end-users of the system.

* requirements elicitation

* requirements analysis

* requirements specification

* requirements validation

Requirements analysis of SISS is done in this chapter.

3.2 Existing System

The present system of communication is based on fixed/static Spectrum allocation policies which underutilizes RF Spectrum. The Communicating peers are allocated the frequencies which they are supposed to possess without any sharing concept.

3.3 Problems with Existing System

The existing software or hardware based Radios and communicating peers causes a huge Burdon over the electromagnetic Spectrum. This phenomenon causes huge underutilization of bandwidth and traffic congestions thus reducing the service qualities provided by the Mobile Telephone companies and ISNs.

3.4 Requirements Consolidation

Based on the problems of the current system and guidelines provided by the Supervisor(both internal and external), requirements for our project were consolidated. It was desired that the application should allow communication among the Peers through networking. Another critical requirement was to make the system simpler for a common user. The system fulfils all these requirements. SISS offers functions for networking, calculate usage time, and simulate the electromagnetic spectrum with a graphical view.

3.5 Functional Requirements

The requirements related to the functionality of the system are functional requirements of the system. Following are the functional requirements of our system.

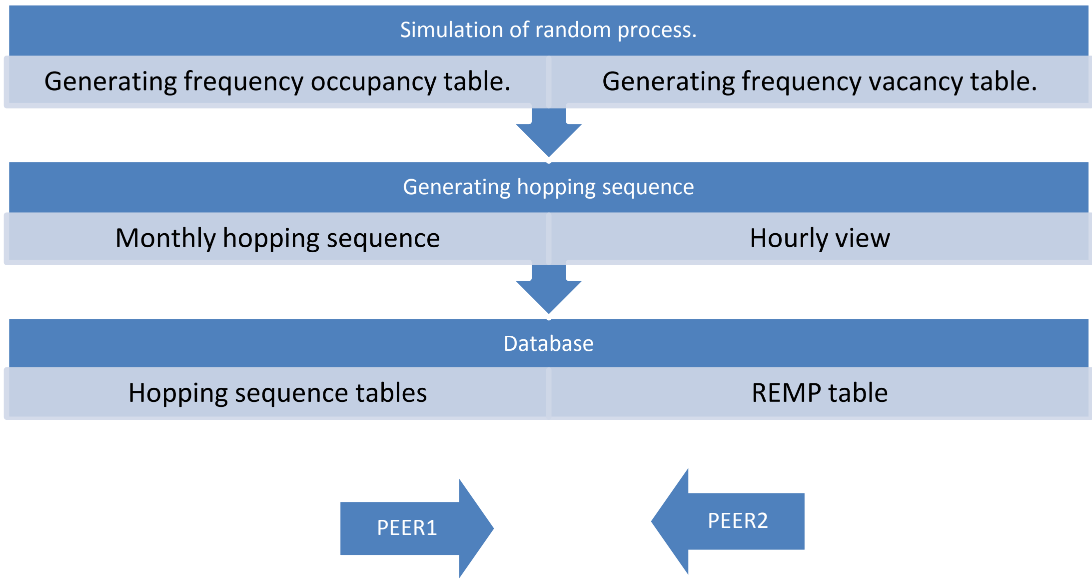


Figure 3.1 Domain Expert Evaluations

Here we start Simulating a random process and then generate frequency occupancy table.

The second step is generating frequency vacancy table, generating hopping sequence.

Knowledge base learning by assigning weights to frequencies is our third step along with creating a Graph with frequency to power ratio.

The application basically consist of three parts;

The quick menu which host user queries.

The display module which also contains all the tools to manipulate the uploaded data.

The Frequency allocation and usage module which enables the users to adopt a frequency and communicate it to its Peer.

3.6 Mathematical Model

Following mathematical model has devised to calculate the Hopping sequence for a particular range of frequency and further allocate the frequency to the peers for communication.

$$W = \frac{\sum_i^n w_i\,(t, d, f_i)}{n} \quad \begin{cases} W_i = 1, \forall \in_{f_i} \; (dB) \leq 0 \\ \end{cases}$$

W is the weight assigned to a particular frequency 'f_i' at time 't' and day 'd'
'i' is the index of iterations.

Equation 3.1Mathematical Model

Fi		Scan1 week1	Scan2 week2	Scan3 week3	Scan4 week4
		A	N	A	A
Weight	Iterations/weeks	1/1	½	2/3	¾

Table 3.1Example

3.7 Interface Requirements

The user interface is key to application usability. The application should include content presentation, application navigation, and user assistance.

The SISS is to be used by the ordinary people as a Simulator for Cognitive Radio environments. They are not supposed to be expert computer programmers, rather they have a little knowledge of the system. Keeping this constraint in mind, the SISS is designed to be very user friendly. The user can enter the required Frequency Range through a quick menu. The self-explanatory tools are available for further usage. The GUI is depicted in the figure.

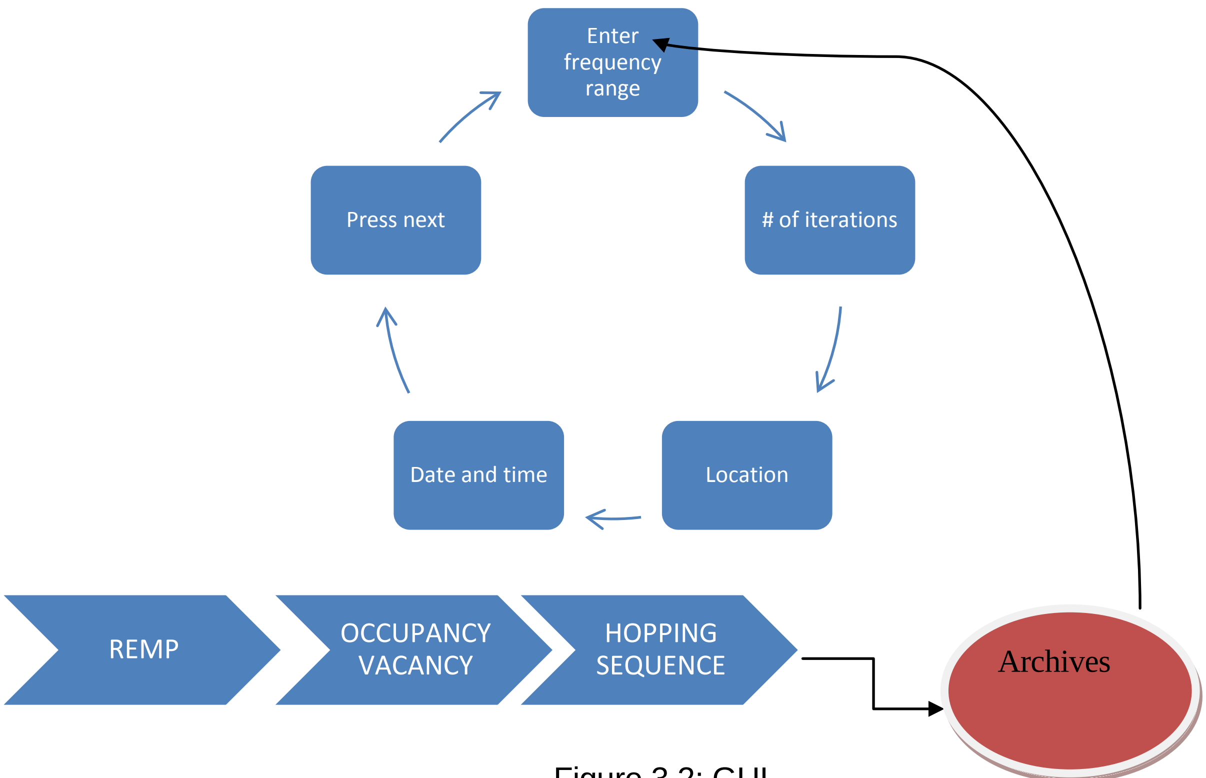


Figure 3.2: GUI

3.8 Performance Requirements

The requirements related to the performance of the system are performance requirements of the system.

3.8.1 Speed

The application used here has to encompass the entire RF spectrum which will reduce the processing speed therefore we decided to pick a small portion of it maintain speed of processing. Therefore system should provide the user with quick responses when displaying frequency vacancy table.

3.8.2 Memory

The system would be using data of whole Pakistan and its surrounding areas and satellite images are very heavy, so system with greater memory is required at server side.

3.9 Non-functional Requirements

A non-functional requirement is a requirement that specifies criteria that can be used to judge the operation of a system, rather than specific behaviors. This should be contrasted with functional requirements that define specific behavior or functions.

3.9.1 Security

The system should be secure because the data being used by SISS is classified. The data is made secure by specifying user rights and making data available only for registered users.

3.9.2 Reliability

The system is to be used by to Simulate Electromagnetic spectrum. So the system's reliability is important for working and availability. It should be reliable enough to work well on the user inputs. Its reliability is most important in case of its output. Wrong output may result into the failure of a link establishment. It is required and expected to be available to the user all the time. Any chances of unavailability and malfunctioning should be minimized.

3.9.3 Maintainability

The SISS data changes with time. Therefore, the system should be an easy-to-maintain one. System should be able to incorporate any changes in the data. The system should be maintainable so that in case of any complaints from the users, the system should be modified to meet the new requirements.

3.9.4 Portability

The system need to be portable because it has to be deployed at communicating Peers.

3.9.5 Compatibility

The system will be made portable enough that any system with Microsoft Windows installed will be able to access the system's features.

3.10 Summary

The SISS is required to display and simulate the RF Spectrum at any given range. It should allow the user to make correct choice of frequency and export it to opposing Peer for establishing link. Since, CR are complex in nature; the best utilization can only be made if they are simplified for the users. So, the SISS is required to be user friendly for the user's ease to use it.

CHAPTER 4
SYSTEM DESIGN

4.1 Introduction

System design is a very important phase in the software development process. The succeeding implementation phase is performed taking into consideration the design constraints. The software design of a program or computing system is the structure or structures of the system, which comprise software components/modules, the externally visible properties of those components/modules, and the relationships between them. This chapter covers the layout of our project. The components designed and their link with each other is explained here in detail.

4.2 High Level Design

The high level design focuses on the main modules of the system and not considering their inner details. The Figure 4-1 identifies the fundamental modules of the project. It can be depicted from the figure that the system is basically integration of different tools. We will explain each of these modules one by one.

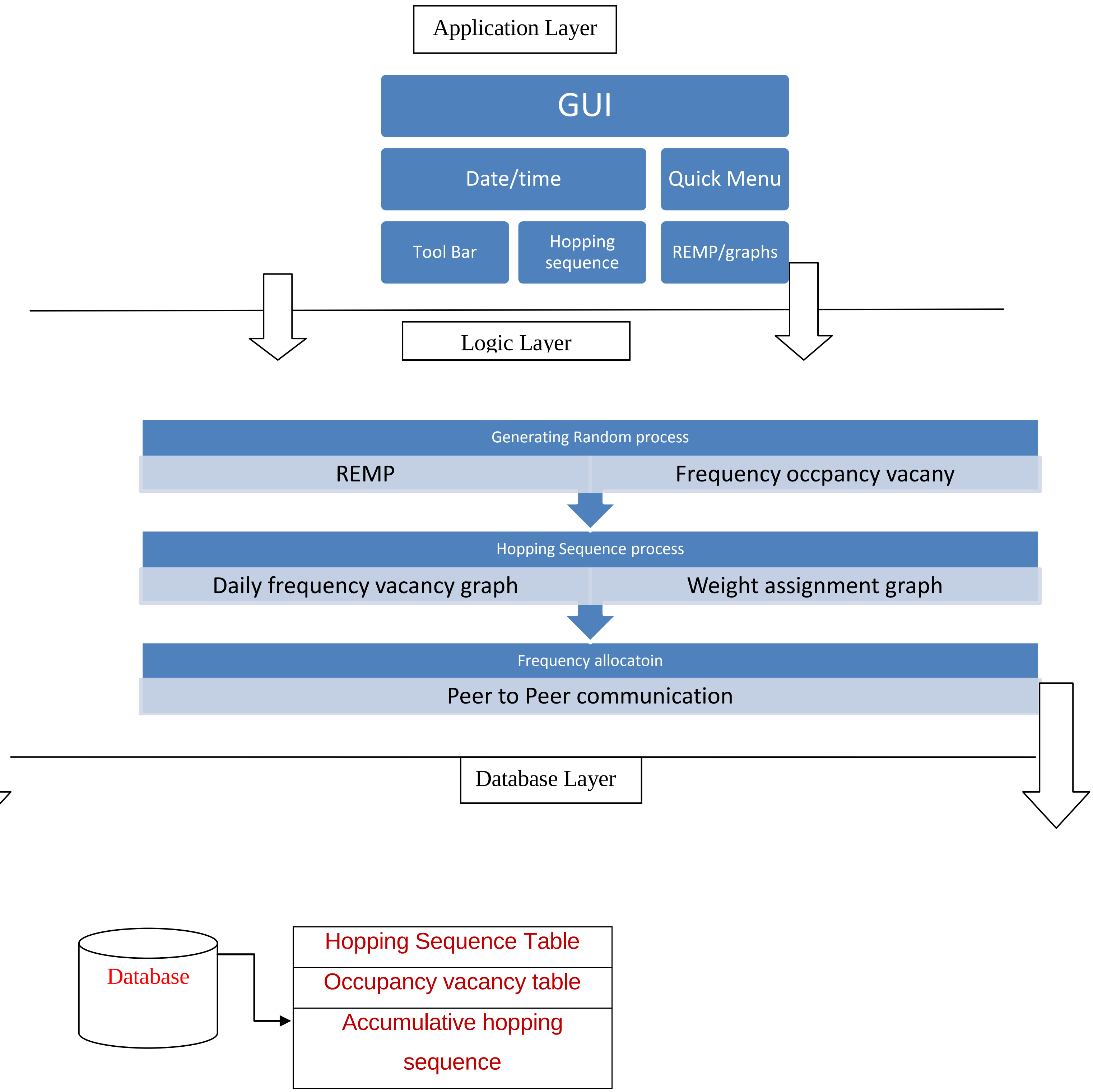

Application Layer
GUI
Date/time
Quick Menu
Tool Bar
Hopping sequence
REMP/graphs
Logic Layer
Generating Random process
REMP
Frequency occpancy vacany
Hopping Sequence process
Daily frequency vacancy graph
Weight assignment graph
Frequency allocatoin
Peer to Peer communication
Database Layer
Database
Hopping Sequence Table
Occupancy vacancy table
Accumulative hopping sequence

Figure 4.1 System High Level Design

4.3 System Overview

The system is developed keeping in mind the following aspects shown in the figure.

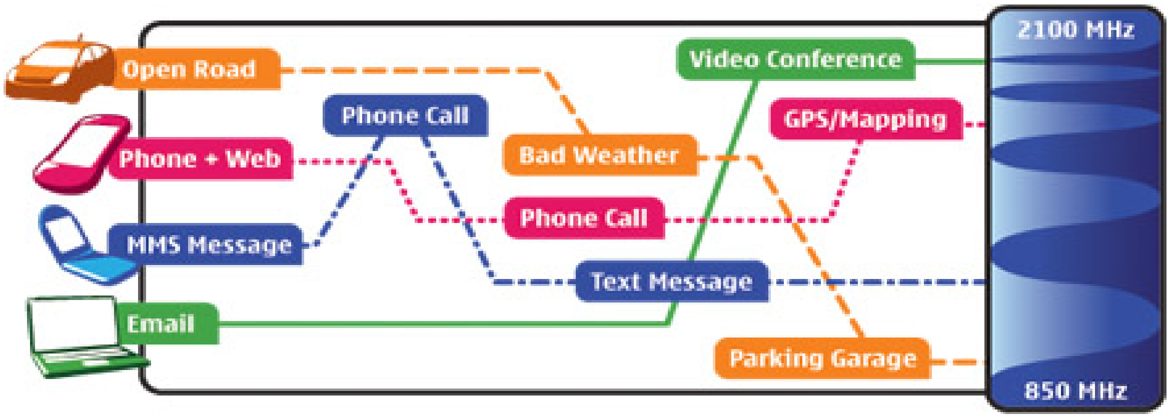


Figure 4.2 System overview

4.4 System Architecture

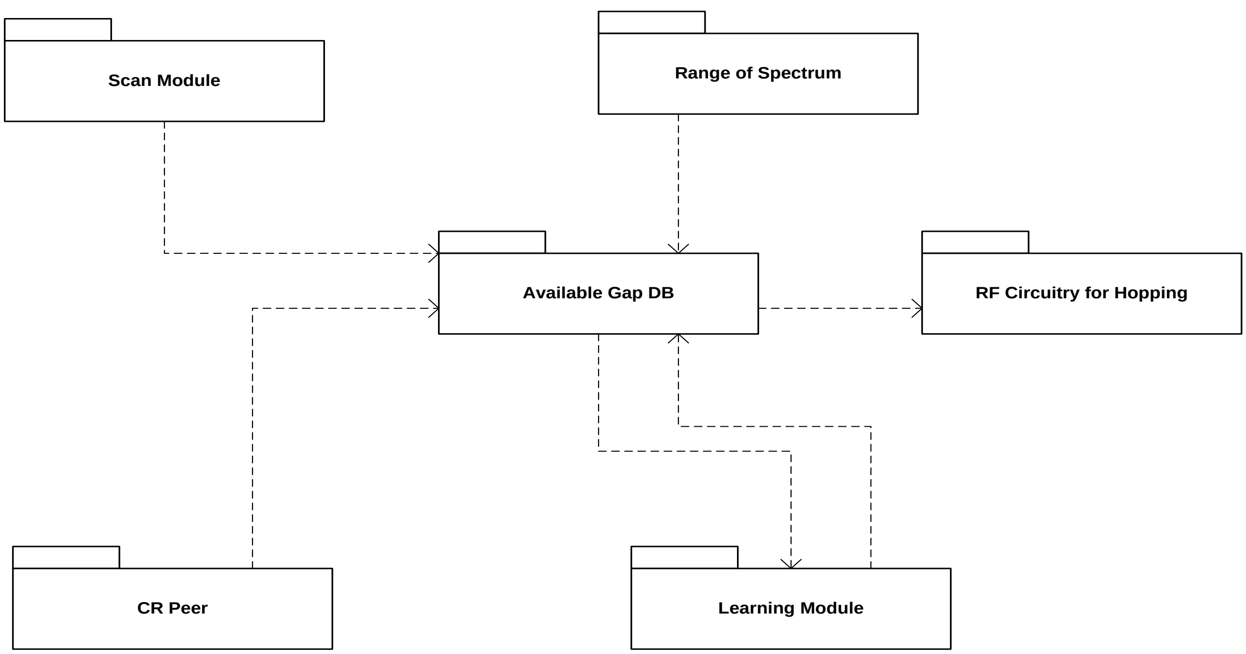


Fig 4.3 System Architecture

4.5 Low Level Design

4.5.1 Use Case Diagram

The use case diagram of the system has been given below. This diagram describes the interaction of user and the system

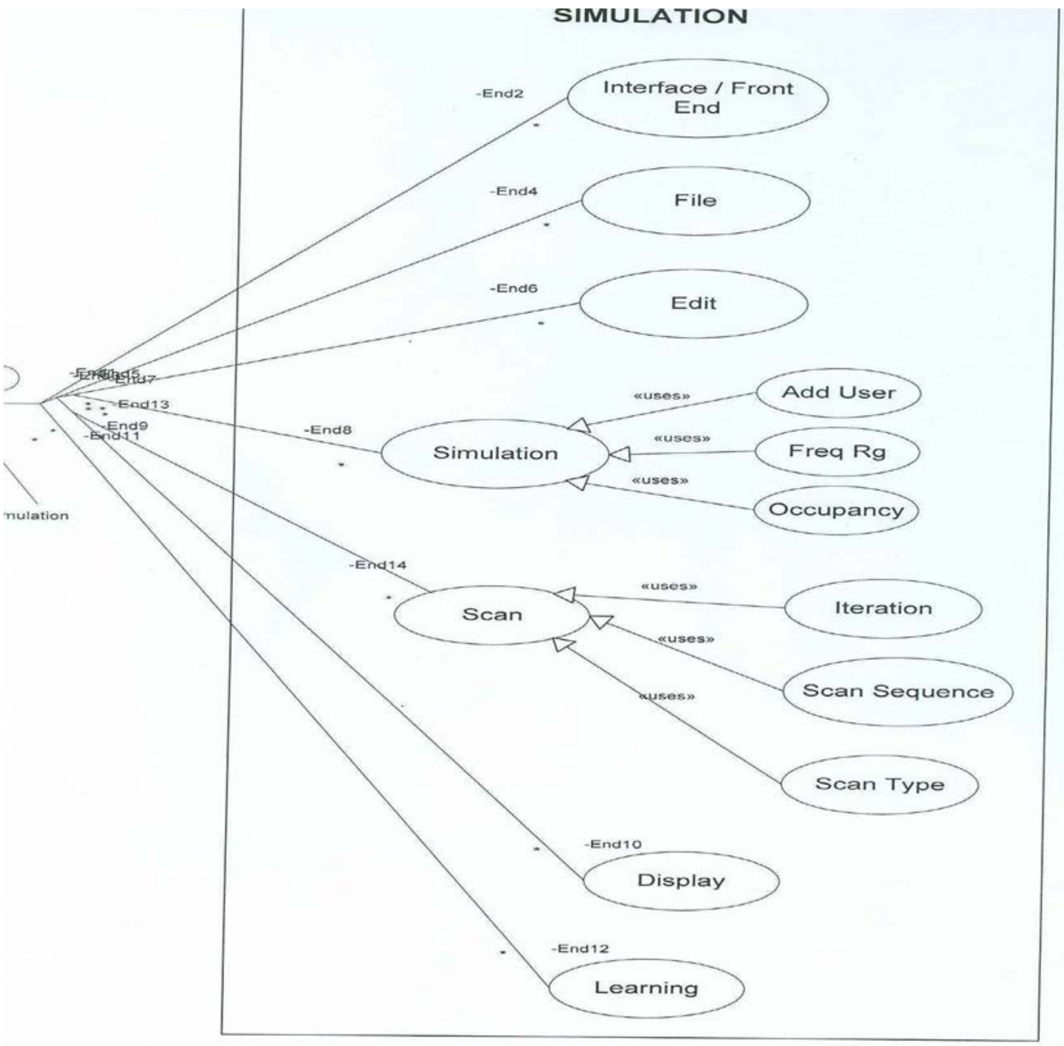


Fig 4.4 Use Case Diagram

4.5.1.1 Basic Flow of System

User registers him into the system. The administrator verifies the user. Now the user can view the main menu. The user can also select the frequency range request for hopping sequence, knowledge score, occupancy/ vacancy graphs. The data base stores the above mentioned graphs in tabular form.

4.5.1.2 Post Conditions:

System has performed the action which was requested by user i.e. making of hopping sequence, knowledge score, occupancy /vacancy graphs etc.

4.5.1.3 Alternate Scenarios:

There is no alternate scenario because the objective is defined and application has been developed by strictly following the requirements.

4.5.2 Sequence Diagram

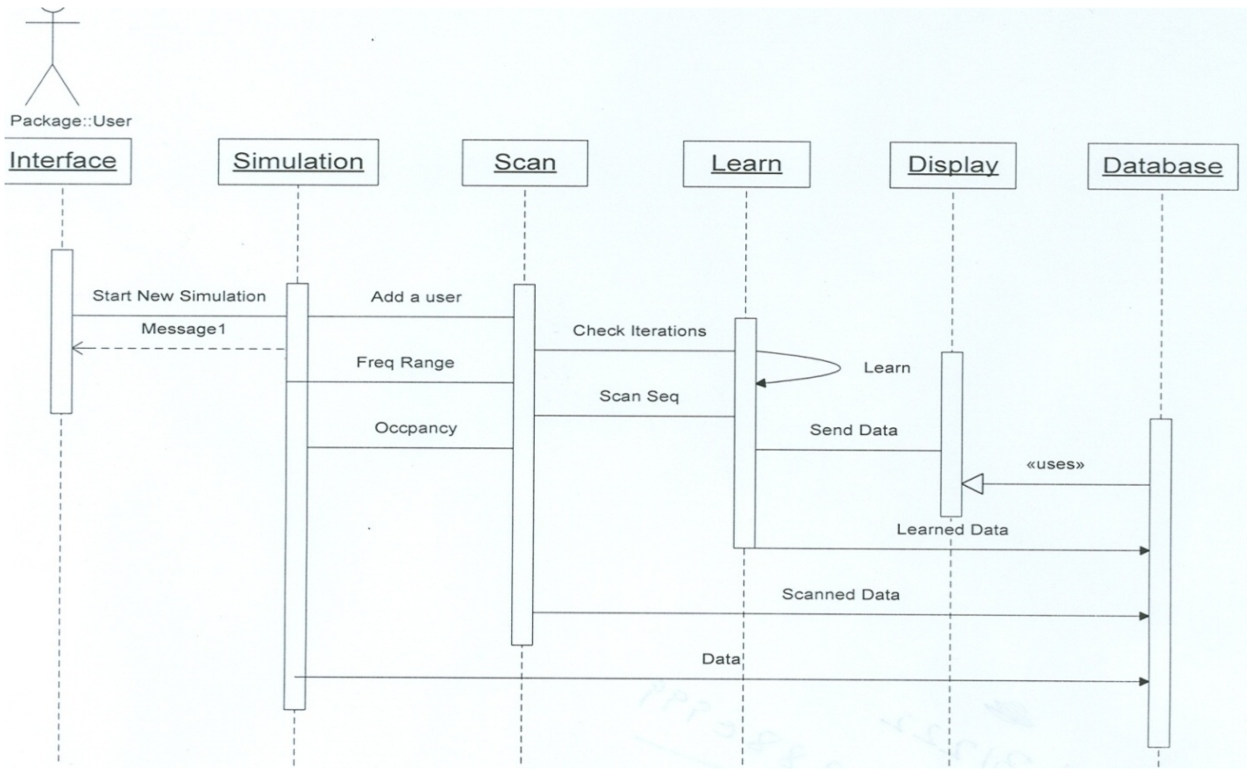


Fig 4.5 Sequence Diagram

4.5.3 System Presentation Model – Home Page

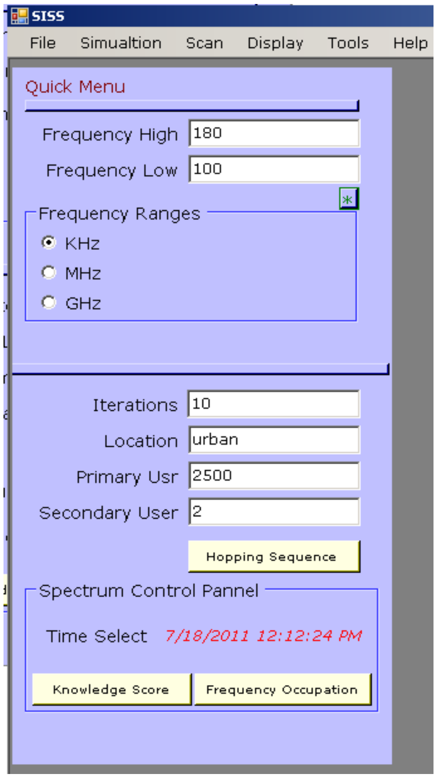


Fig 4.6 System Presentation Model – Home Page

4.5.4 System Class Diagram

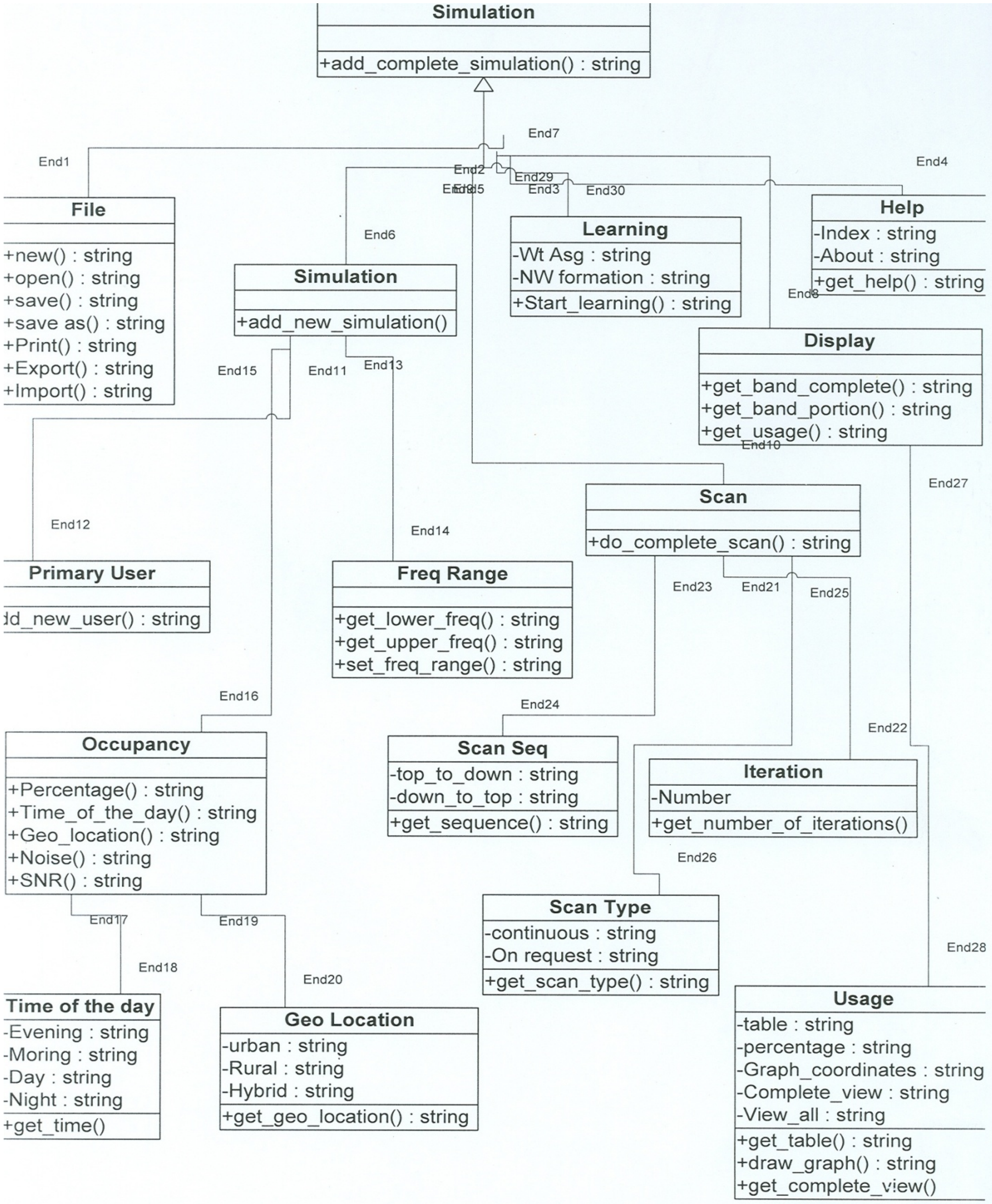


Fig 4.7 System Class diagram

4.6 Modules

4.6.1 Application Level Design

It comprises of four main modules.

1. Hopping Sequence
2. Knowledge score
3. Networking
4. Occupancy/ vacancy graphs

4.6.1.1 Hopping Sequence

Hopping sequence is achieved through allocating weights to the vacant frequencies on hourly basis. Which is done by user defined iterations on hourly basis, every hour of the day is defined in database and weights are given to the frequencies as per there vacancy percentage. Then every hour is compared to the same of the previous four weeks finally bringing the actual vacancy profile of the RF spectrum through assigning weights as per availability percentage.

4.6.1.2 Knowledge Score

It is achieved by simply inserting the frequency range which returns a graph and a table providing frequency to power ratio.

4.6.2 Networking

After knowing the hopping sequence there are two approaches which can be adopted for networking and field use, that DSL or KBL

4.6.2.1 KBL

This is peer to peer communication in this both PEERs sense the spectrum. PEER 1 passes his vacancy table to PEER 2 and vice versa finally they come on single frequency and start communicating with each other.

4.6.2.2 User Login

A security feature kept to ensure the safety of device this includes user name and pass word.

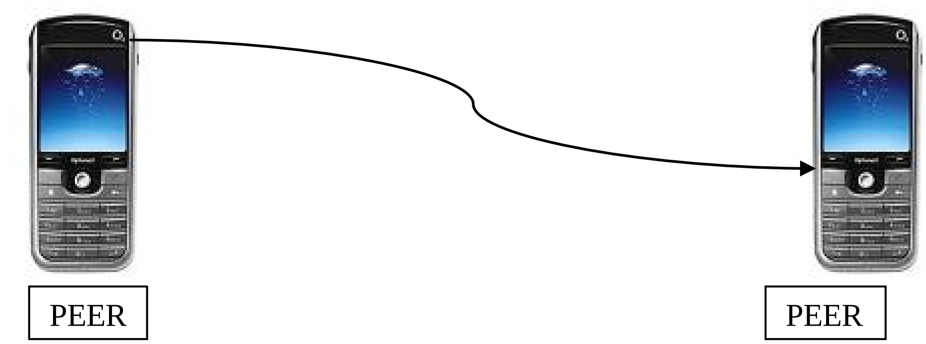


Fig 4.8 Communication Model

CHAPTER 5

IMPLEMENTATION

5.1 Introduction

The application consists of two main parts i.e. front end and back end. Both of these have been implemented separately and are explained below.

5.2 Simulation of intelligent spectrum sensing (SISS)

It is a collection of methods to visualize, manipulate, analyze, and display available spectrum and available spectrum holes. The sources of Simulator are a range of the spectrum data, statistical tables of the spectrum data and other related documents. SISS enable spectrum sensing on a given range, the gapes available are link to SISS databases. These databases keep the available gapes information in freq(Hz)[17] .

SISS relates different information represented in spatial context. For example, a given rang of frequencies are scanned with their energy levels, the avail or free frequencies which are not caring any energy are entered in a table with the time loc and day. The table is maintained every time with new free frequencies after the certain time space, data sharing with other peers or collisions of data/frequencies during data communication.

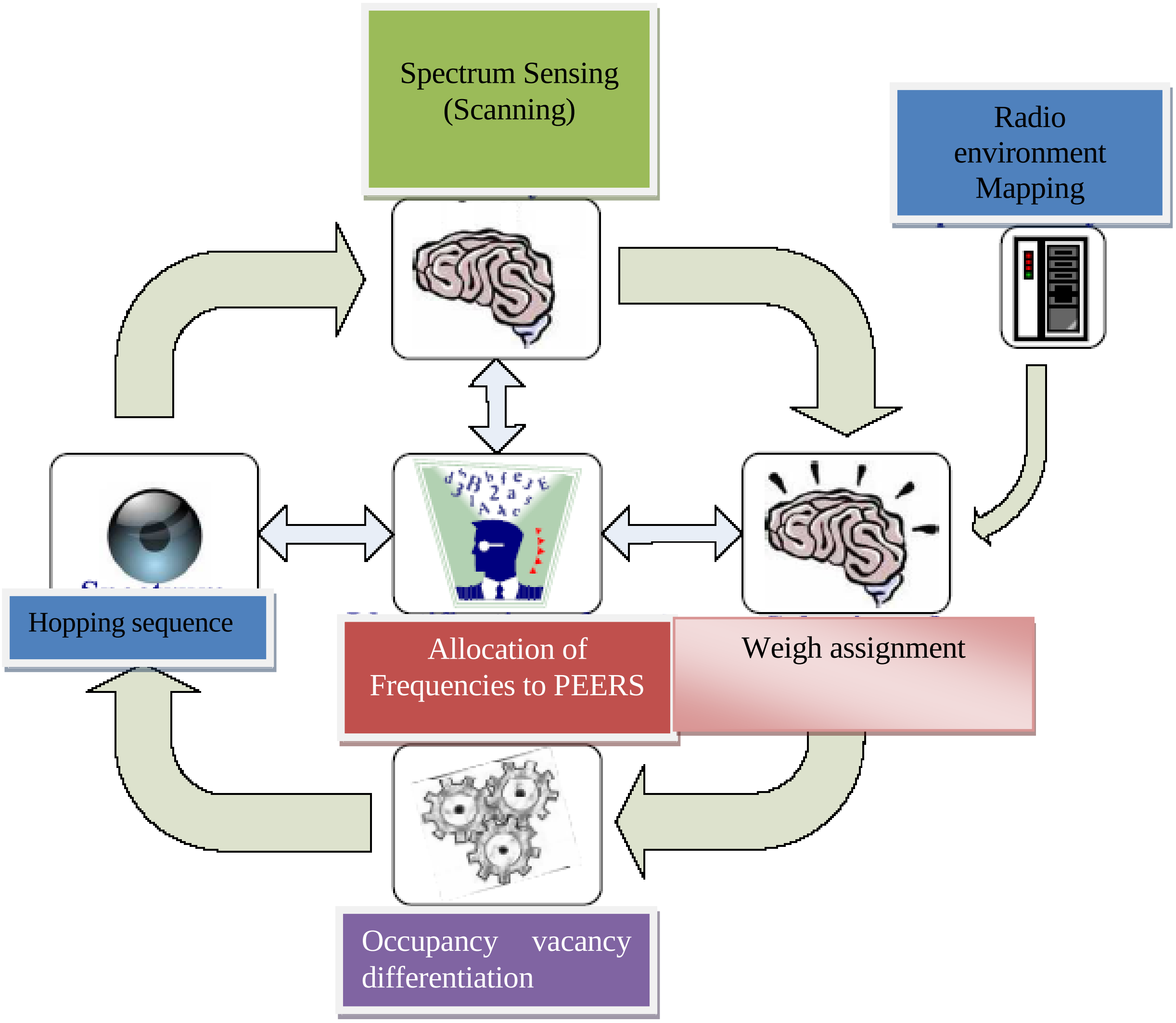
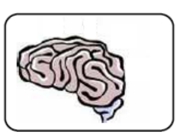


Fig 5.1 Working of SISS

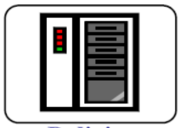


Spectrum Sensing

Task: Reading the spectrum through RF antennas in our case generating random sequences. The processing of data and for further decision making. Finding attractive features, classification of data eg traffic type, filtering out unnecessary information.

Method: Random sequence, giving high and low frequency range.

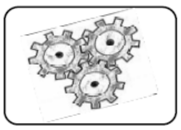
Challenges: Quality of measuring data.

 **Radio Environment Mapping**

Task: Graphing the RF spectrum frequency versus power graph. Determining the range of frequency to read, and processed. Graphical display.

Methods: Access to database.

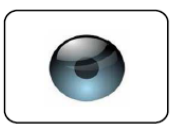
Challenges: How policies are transferred into actions and to ensure those policies met in all situations.

 **Occupancy vacancy differenciation**

Task: After reading the spectrum the graph and tables in data base are split in two as per their power.

Methods: All frequencies below zero or 75% below zero are granred as vacant.

Challenges: High frequency range.

 **Hopping Sequence**

Task: Dividing graph and tables on 24 hourly basis, comparing them with previous weeks.

Method: Same as mentioned above displaying a single day graph

Challenges: Obtaining satisfactory detection probability to protect primary spectrum users, performance and complexity trade off, efficient exchange and optimization of control data.

 **Weight Assignment**

Task: Comparison with previous weeks same time graphs assigning weights as per number of weeks and vacancy. That vacancy divided by total number of weeks in view. Usually four weeks previous only.

Method: Weight assignment with maximum four minimum 1.

Challenges: Volatile and random nature of spectrum either simulated or actual due to higher usage ratio.

Allocation of frequencies to Peers

Task: Both DSL and KBL Methods may be used to recognize users and assign them frequencies here we follow KBL approach.

Method: Hopping sequence tables are swapped and compared by peers one frequency is decided by peer 1 if vacant it is confirmed by peer2 till the time consensus arises.

Challenges: Difficulty to find general solution applicable to versatile network configurations.

5.3 Front end

The front end of the application has been developed in C#(visual studio). The data base attached to the application is in SQL Server. The figure below shows the main page of SISS.

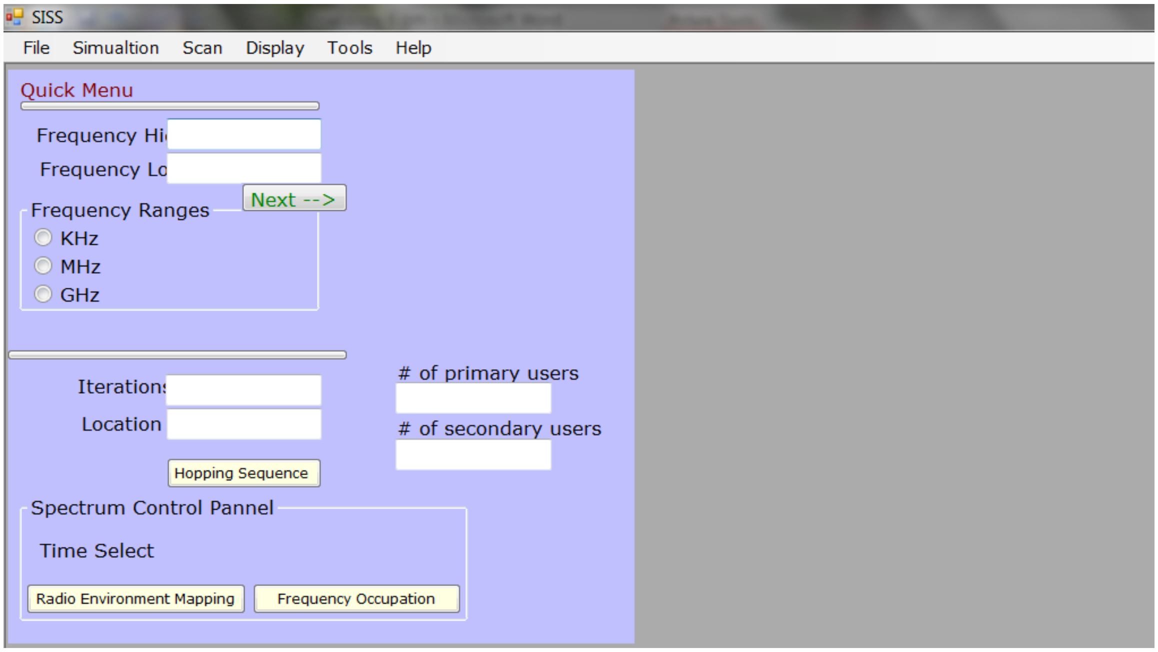


Figure 5.2- Home page (GUI)

The user needs to get registered before using the Simulator for Spectrum scanning and Peer to peer communication .The user name is set as primary key as it is with a password. A random person cannot register himself without name and password and start using the SISS, until administrator has verified the personal information of the individual and if verified authentic allotted the specified rights to an individual.

There are no restriction on password type, it can have alphabets, numbers, special characters or combination of all these but keeping in mind the security issues password of the user has been encrypted by using built in MD5 function to keep the user password save .The administrator is also not given the authority to view the user's password.

The following figure shows the registration page.

Figure 5.3- Registration page

Certain rights have been given to different type of users. Only the administrator has the authority to allocate user rights or user category. The registered user is allowed to view Occupancy vacancy tables. Select frequency for communication with opposite peer.

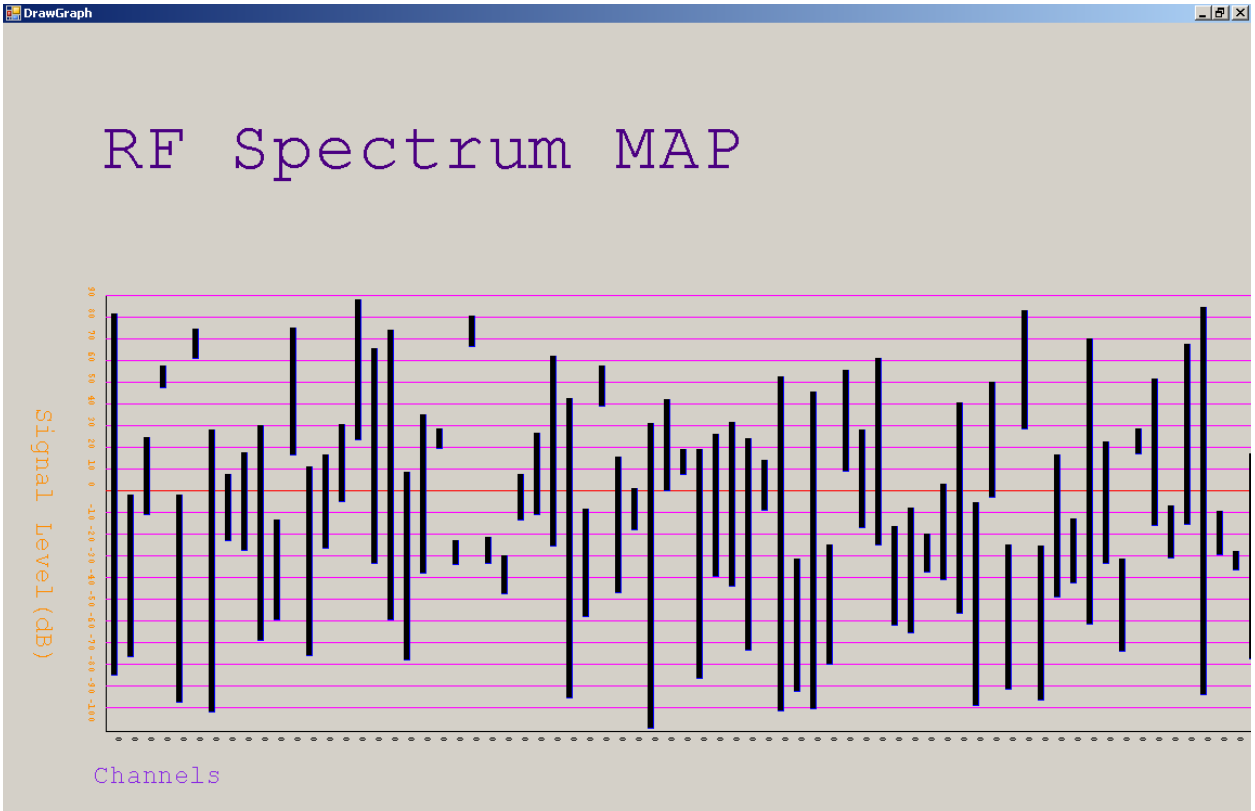


Figure 5.4- Radio environment mapping

Following figure shows the simulation of power to frequency graph.

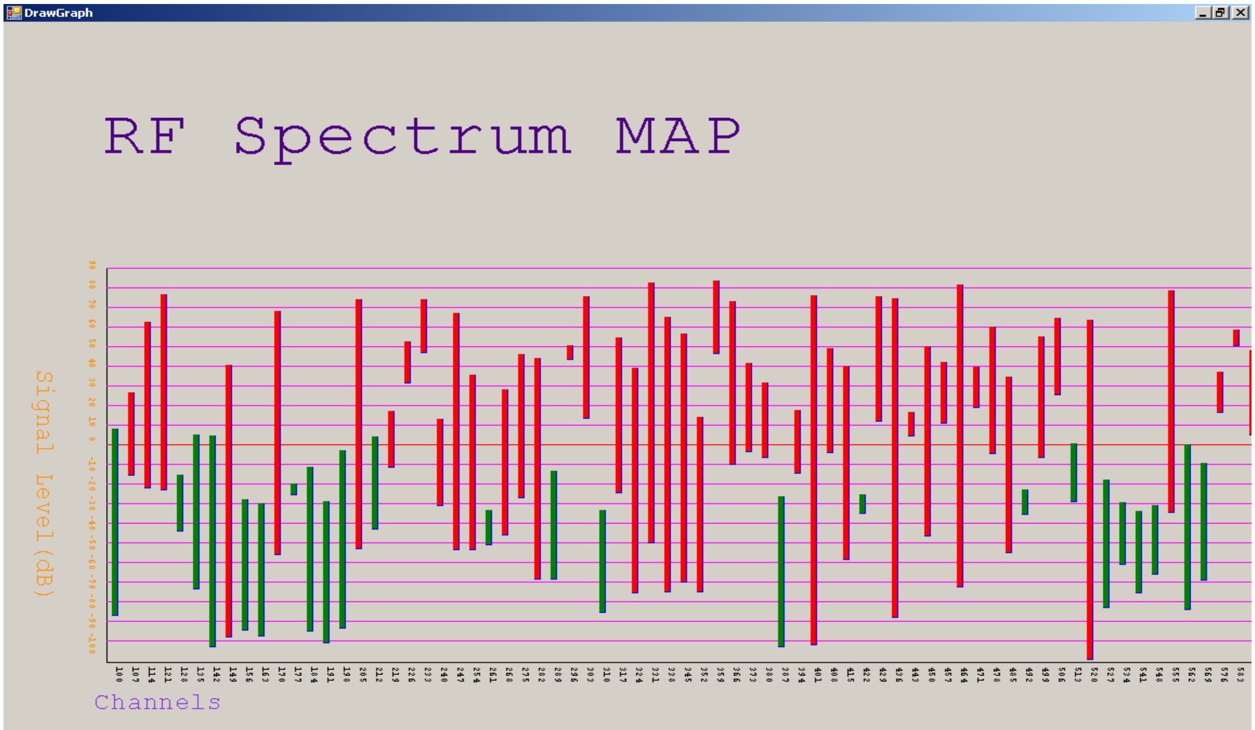


Figure 5.5 – Occupancy/ Vacancy display

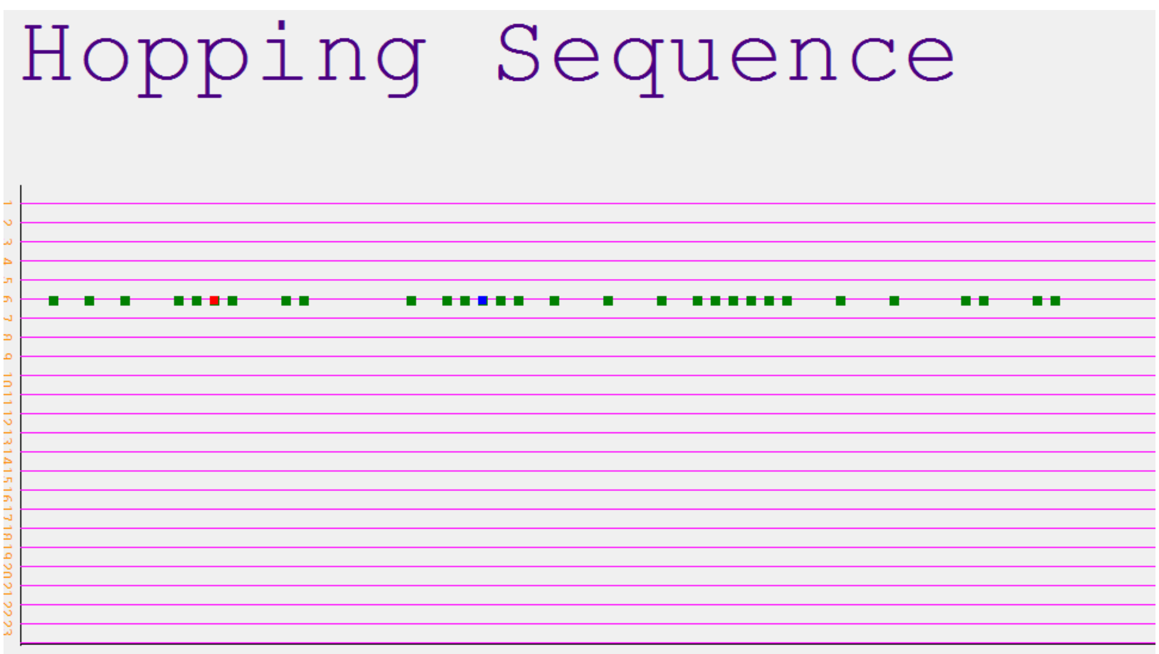


Figure 5.5.1 Hopping Sequence

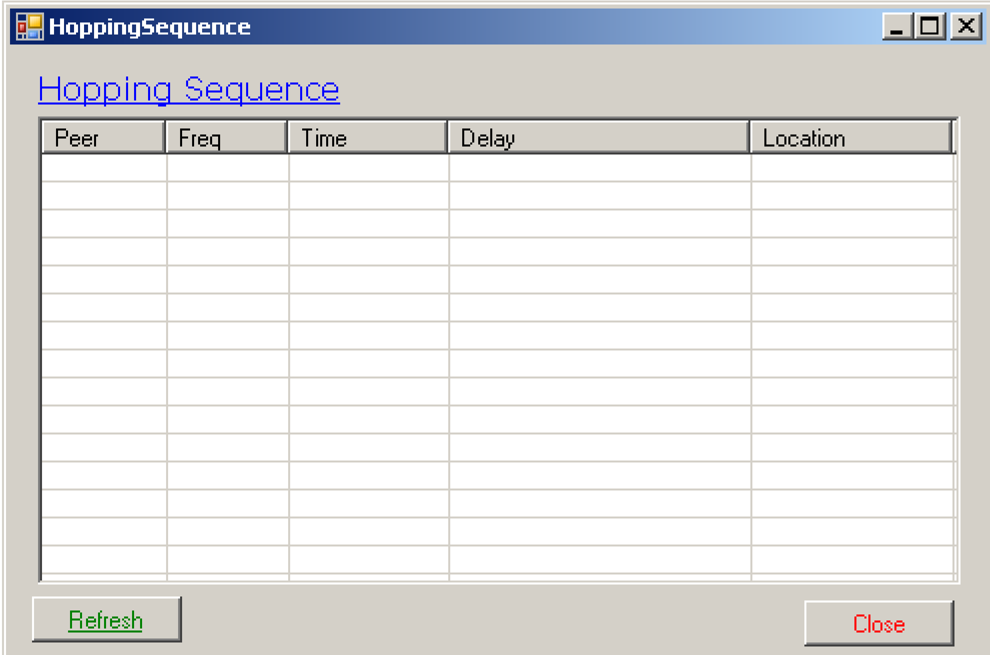


Figure 5.6 – Hopping Sequence Table

5.4 Backend

The backend of the application has been developed jointly using C# and Sql server. The frequency occupancy and vacancy tables are constructed through knowledge base learning which includes 24x7 technique of observing the RF spectrum finding the gaps and holes in it assigning them to vacancy table. The weight of vacancy increases as it approaches the negative value. It is undecided if crossing zero line towards both positive and negative side.

The occupancy is higher as it gains higher positive number.

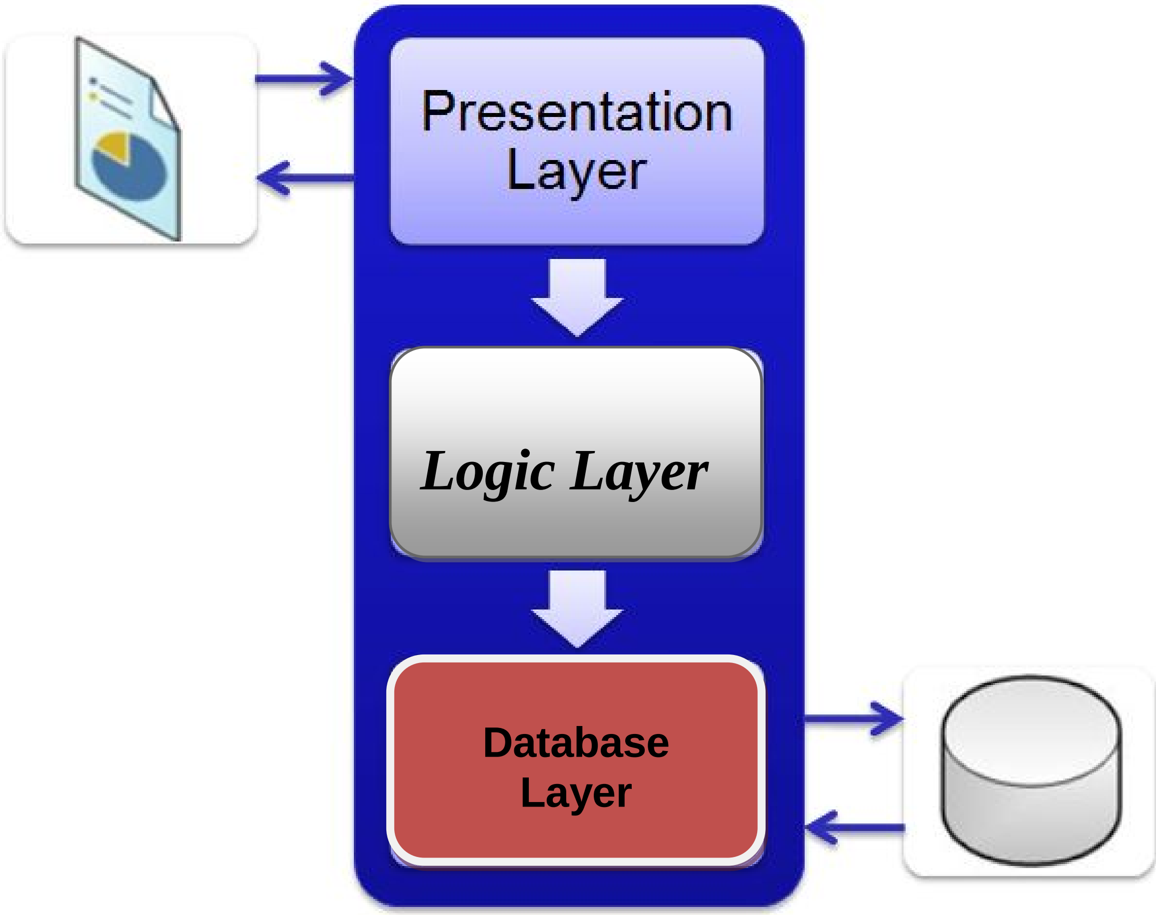


Figure 5.7 – Logic Layers

The Communicating Peer passes the their vacancy tables to each other and then select a group of frequencies among which one is selected as a mean for communication. Further on both the PEERs switch to that frequency and establish a link. Both PEERs maintain a usage time in a table which may be helpful for reference to pay the charges to primary user.

5.5 Future Work

Establishment of an interface with Spectrum Analyzer and Digital Analyzer for getting a real time input in order to make it a complete Cognitive Radio.

DSL or Dynamic Spectrum Leasing may be implemented to make a server client function. Where server will provide runtime data and frequencies to secondary users and charge them accordingly.

Multiple processors and multi threading shall be used by the server in order to increase speed of spectrum sensing.

CHAPTER 6
SYSTEM TESTING AND VALIDATION

6.1 Introduction

Software testing is one of the most crucial phases of software development life-cycle. This can be termed as an element of a broader topic that is referred to as 'Verification and Validation' (V&V). Verification refers to the set of activities that ensure that software correctly implements a specific function. Validation refers to the different set of activities that ensures that the software that has been built is traceable to customer requirements.

6.2 Validation and Verification

Validation and verification is intended to be a systematic and technical evaluation of the system and its processes. To effectively deal with the increased complexity and functionality, systems need practical techniques that can help improve software quality using the validation and verification process.

SISS was tested for validation by giving it different inputs and getting the desired outputs. User cannot provide uncertain inputs because certain constraints have been imposed on each field. In verification testing it was assured that software meets all functional, behavioral, and performance requirements.

6.3 Unit Testing

In computer programming, unit testing is a procedure to validate that individual units of source code are working properly. A unit is the smallest testable part of an application. Unit testing concentrates on each unit of the software as implemented in source code. The goal of unit testing is to isolate each part of the program and show that the individual parts are correct. In our system each module as developed is individually tested. The each function performed is tested such as frequency occupancy and vacancy states, view layers etc. Each operation and function is individually tested so as to check for possible errors that could occur.

6.4 Integration Testing

Integration testing is the phase of software testing in which individual software modules are combined and tested as a group. It follows unit testing and precedes system testing. In integration testing focus is on design and the construction of software architecture. All the modules have been combined and tested to ensure that they work according to the user requirements.

6.5 System Testing

In software testing phase overall system is tested as a whole. System testing of software or hardware is testing conducted on a complete, integrated system to evaluate the system's compliance with its specified requirements. The purpose of integration testing is to detect any inconsistencies between the software units that are integrated together. System testing is a more limiting type of testing; it seeks to detect defects within the system as a whole.

In SISS user has to login with user name and password. So there is no chance of unauthorized user login.

6.6 Summary

The system is tested thoroughly. It behaves according to the user requirement. The user is not allowed to specify any wrong inputs because have been imposed over input. On entering the required inputs system behaves according to the user requirement and presents the desired results to the user.

CHAPTER 7
RESULTS & ANALYSIS

7.1 Introduction

The world is still relying on fixed and licensed RF Spectrum sharing techniques.

There exists a need to revisit this old fashioned technology, in order to maximize and optimize its use. That is the economy spectrum to avoid congestion and busy network tones during communication. The Cognitive Radios are new emerging technology which will help in reducing the Spectrum scarcity viz a viz the uphill climb of user numbers. That is exponential growth of Mobile industry and wireless internet usage. Our Simulator is first of its kind I the world to give a realistic view of Cognitive Radios.

7.2 Results

SISS has been developed in a way to facilitate secondary users while using the Cognitive Radios. This is a totally new concept taking roots due to over burdening of RF Spectrum and congestion. The idea has been to facilitate the user by allowing them to choose frequency of their choice as per area requirements and suiting .The KBL is a milestone towards emerging cognitive radio concept a first Simulator of its kind covering the entire RF Spectrum in small chunks.

7.2.1 The output

- Communication between two Radio Peers
- Scanning of RF Spectrum
- Usage time calculation
- Multithreading

7.3 Others Developed CR systems

Other CR models and concepts are also in an evolutionary process of development namely Dynamic Spectrum leasing and Dynamic Spectrum sharing models. They are an effort towards optimizing the use of RF spectrum and minimizing the congestion and scarcity which is on rise due to high usage requirements.

7.4 Summary

While developing SISS latest tools have been used to develop the Simulator. Making it a Desktop application, it is now made possible for the user to use the application anywhere where otherwise it was not possible earlier. Now the range and domain of wireless communication can further be developed towards maximum utilization and minimum congestions.

CHAPTER 8
CONCLUSION AND FUTURE WORK

8.1 Achievements

Our project was initiated with the aim of simulating the Cognitive Radio environment through intelligent Spectrum sensing. Bringing a new dimension of research in a programmed atmosphere and we are successful in our efforts by the grace of Almighty Allah. We touched the parameters which were still untouched and now we can say that we are a step short of building a practical and workable model of CRs. While doing so we can claim to be the first one to develop such a simulator in which we successfully created an environment closer to reality.

8.2 Industrial and Commercial Use

This project can be used for finding the gaps in RF spectrum and then utilizing them for use by secondary user's area of interest (AOI) of commercial clients. The project gives detail of entire spectrum. The details include Gaps, holes for further use along with occupied and undecided frequencies in a manner which enables the users to choose the desired frequency for communication.

8.3 Future Work

This project can be further extended as a distributed application where the entire Spectrum can be scanned at selected locations and a data will be kept at central location and users will be able connect and receive frequency for further communication. This technique will be client server based closer Dynamic Spectrum leasing. Being centralized it will not only make it easier to update the databases involved but also give the user a freedom to carry and use it without much of processing power. Some areas where more enhancements can be pursued are indicated below:

8.3.1 Enhancement of Security

Enhancement of security of transferred will make the communication more reliable and trustworthy.

8.3.2 Incorporation of system at all Mobile Towers

Incorporation of database and system at mobile towers will enable to build client server based architecture thus reducing congestions and busy network tones.

8.4 Conclusion

The increase in the numbers of wireless devices and applications has led to a great demand for the sparse capacity of wireless networks, especially in the license-free ISM bands. Cognitive Radios (CR) and Dynamic Spectrum Access (DSA) provide a promising avenues of research to solve the above problem [14], [12]. Unlike classical radio devices, the CR paradigm emphasizes the reconfiguration of radio functionality at a fine-granularity through permitting access to a wide range of spectrum and choice of custom modulation mechanisms that can be exploited to achieving greater spectrum efficiency.

Several factors have contributed to the growth of research in this area. Radio manufacturers have started to create flexible software-defined radios that reveal the low-level radio parameters and functionalities, and support the dynamic reconfiguration of the complete protocol stack [15], [13]. As a result, protocol and application designers have been exploiting this rich set of functionalities to design novel mechanisms that enable cross-layer and cross-technology solutions [12].

Appendix A

Definitions

Following are the definitions of some commonly used terms in the SISS. These terms will be used in the following chapters.

Full Cognitive Radio in which every possible parameter observable by a wireless node or network is taken into account.

Spectrum Sensing Cognitive Radio: in which only the radio frequency spectrum is considered.

Licensed Band Cognitive Radio: in which cognitive radio is capable of using bands assigned to licensed users, apart from unlicensed bands, such as U-NII band or ISM band.

Unlicensed Band Cognitive Radio: This can only utilize unlicensed parts of radio

Spectrum Mobility: is defined as the process when a cognitive radio user exchanges its frequency of operation. Cognitive radio networks target to use the spectrum in a dynamic manner by allowing the radio terminals to operate in the best available frequency band, maintaining seamless communication requirements during the transition to better spectrum.

Spectrum Sharing: providing the fair spectrum scheduling method. One of the major challenges in open spectrum usage is the spectrum sharing. It can be regarded to be similar to generic media access control MAC problems in existing systems

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