International Journal of Scientific & Engineering Research, Volume 5, Issue 4, April-2014
ISSN 2229-5518

Efficient Channel Allocation Schemes for Cognitive Radio Networks

Sitadevi Bharatula

Abstract - In today's wireless scenario, most of the spectrums (licensed bands) are already allocated for license users for exclusive use. Few unlicensed bands are left open for unlicensed users, i.e. ISM bands 900MHz and 2.4GHz. Licensed bands are under-utilized but unlicensed bands are crowded resulting on spectrum scarcity. Solution is to let unlicensed users use the license frequencies, provided they can guarantee interference perceived by the primary license holder will be minimal which the concept of Cognitive Radio (CR). With the fast growing of multimedia communication applications, Cognitive Radio Networks (CRNs) have gained the popularity as they can provide high wireless bandwidth and support quality driven wireless multimedia services. This paper deals with efficient channel allocation scheme for Secondary Users (SUs) in CRNs based on their priority. In the proposed system, the frequencies (spectrum resources) are allocated efficiently by using Greedy Algorithm. The main advantages of this proposed system are; it allocates spectrum resources with less interference thereby increasing the throughput. The results obtained show that this algorithm makes better utilization of unutilized licensed bands.

Index Terms – Channel State Information, Cognitive Radio Base Station, Cognitive Radio Networks, Dynamic Spectrum Allocation, Primary Users, Quality of Experience, Secondary Users, Signal to Noise Ratio

---

1 INTRODUCTION

Today's static spectrum allocation policy results in a situation where the available spectrum is being exhausted while many licensed spectrum bands are under-utilized. A Cognitive Radio (CR) system allows the unlicensed users to dynamically and opportunistically access the "under-utilized" licensed bands. CR was first termed by Joseph Mitola in 1991. It is a radio that includes a transmitter in which operating parameter such as frequency range, modulation type or maximum output power can be altered by software. This is also known as "dynamic spectrum allocation".

1.1 Existing System

Cognitive radio networks gained the popularity as they can provide high wireless bandwidth and support quality driven wireless multimedia services. The Quality of Experience (QoE) that directly measures the satisfaction of the end users cannot be easily realized due to the limited spectrum resources. The unstable channels allocated to the multimedia secondary users (SUs) can be re-occupied by the primary users (PUs) at any time, which causes traffic while allocating the channel for secondary users (SUs). The opportunistic spectrum access cognitive radio (CR) is an efficient technology to address this issue. However, the unstable channels allocated to the multimedia secondary users (SUs) can be re-occupied by the primary users (PUs) at any time and it is important to study how to allocate frequency or spectrum resources with less traffic. The data under different primary channels (PCs) are collected by the SUs and delivered to a Cognitive Radio Base Station (CRBS). The CRBS will allocate available channel resources to the SUs based on their priority.

1.2 Proposed System

In the proposed system, frequency or spectrum resources is allocated to SUs with trafficless model. The opportunistic spectrum access cognitive radio (CR) is a new efficient technology to improve the frequency/spectrum utilization by detecting unoccupied spectrum holes and assigning them to SUs. In this paper, new algorithm is proposed to allocate efficient channel to the secondary users with trafficless mechanism and to reduce the interference between the primary users (PUs) and the secondary users (SUs). Greedy algorithm works in phases. At each phase the optimized value is taken, without regard for future consequences. Using greedy algorithm high efficiency throughput mechanism is achieved. Using greedy algorithm the optimized value is taken based on the priority at each phase. The optimal (efficient) channel allocation for trafficless mechanism is attained using greedy algorithm.

The distributed algorithm is used to allocate the active channels to the secondary users from the priority queue and the performance of signal to noise ratio (SNR) is achieved between the number of secondary users and the channel capacity of active secondary users. The novel idea in this paper is to allocate the optimal channel to the secondary users even in the occurrence of interference and thereby increasing the throughput. The throughput for the multimedia applications such as video conference over

• *Sitadevi Bharatula is currently working as Asst Prof in Tagore College of Engineering, Chennai. She is pursuing her PhD in Cognitive Radio Networks from Anna University, Chennai, India. E-mail: sita_bharatula@yahoo.co.in*

the cognitive radio (CR) for the increased number of primary users (PUs) has been analyzed using Markov model.

2 COGNITIVE RADIO SYSTEM

A cognitive radio system allows the unlicensed users to dynamically and opportunistically access the “under-utilized” licensed bands. It was first termed by Joseph Mitola in 1991. It is a radio that includes a transmitter in which operating parameter such as frequency range, modulation type or maximum output power can be altered by software and also known as “dynamic spectrum allocation”. CR technology has the potential to exploit the inefficiently utilized licensed bands without causing interference to incumbent users.

2.1 Principles of Cognitive Radio

Recent advances in wireless telecommunication technologies have sparked the ever growing wireless applications and services. This condition resulted in a burden which takes form of the spectrum scarcity. The electromagnetic radio spectrum is a natural resource whose usage in transmitting and receiving is controlled by the government. It is concluded that the scarcity of electromagnetic spectrum is more due to inadequate access techniques rather than non-availability. This has resulted in major re-thinking in the regulation of electromagnetic spectrum usage by the government as well as the technology of spectrum access itself. Many research works have been carried out to overcome this problem, and one of the initiatives is the idea of Cognitive Radio (CR). The conditions of the under-utilized spectrum are:

a. Some frequency bands in the spectrum are largely un-occupied most of the time.
b. Some of the frequency bands are partially occupied.
c. The remaining frequency bands are heavily occupied.

So we can say that there are frequency bands which are assigned to primary users, but at a particular time and specific geographical location, the bands are not used by the licensed users. This condition is referred as the spectrum holes. The basic idea of CR is to improve the spectrum utilization by enabling the secondary users (unlicensed) to utilize the spectrum holes which are unoccupied by the primary users in a particular time and location. This is done in a way that the secondary users are invisible to the licensed users. In this scenario the licensed users are the mobile terminals and their associated base stations, which do not possess such intelligence. On the other hand, the secondary users should possess the capability of sensing the spectrum and use whatever available resources when they need them. At the same time, the secondary users must give up the utilized spectrum whenever a licensed user begins transmission.

Haykin described the CR as an intelligent wireless communication system that is aware of its surrounding environment (i.e., outside world), and uses the methodology of understanding-by-building to learn from the environment and adapt its internal states in the incoming RF (radio frequency) stimuli by corresponding changes in certain operating parameters in real-time with two primary objective in mind:

- Highly reliable communications whenever and wherever needed.
- Efficient utilization of the radio spectrum. Modulation scheme, transmit power, channel coding and carrier frequency are examples of the parameters that can be exploited in CR.

2.2 Cognitive Tasks

The basic fundamental tasks of the system are:

(i) Spectrum estimation: is to gauge the radio spectrum scenario and perform radio scene analysis.
(ii) Channel state estimation and predictive modeling: is an accurate and timely channel state information (CSI) at the transmitter, and is important for accurate power control, prediction of channel capacity and scheduling.
(iii) System reconfiguration: based on the radio spectrum scenario and the channel state information, the system adapts the parameter.

2.3 Channel Allocation Schemes

In radio resource management for wireless and cellular network, channel allocation schemes are required to allocate bandwidth and communication channels to base stations, access points and terminal equipment. The objective is to achieve maximum system spectral efficiency in bit/s/Hz/site by means of frequency reuse. There are two types of strategies that are followed.

Fixed:

- FCA, fixed channel allocation. The fixed channel allocation is manually assigned by the network operator.

Dynamic:

- DCA, dynamic channel allocation
- DFS, dynamic frequency selection
- Spread spectrum

2.4 Dynamic Spectrum Allocation (DSA)

Most networks are subject to time and regional variations (traffics may vary with time and location) in the degree to which spectrum is utilized. The waste of spectrum happens when traffic in one place is low while in another place is high. Objective of Dynamic Spectrum Allocation: Manage spectrum in a converged radio system and share it among all participating radio networks over space and time, to increase overall the spectrum efficiency.

2.5 Spectrum Holes

Spectrum Holes represent the potential opportunities for non-interfering (safe) use of spectrum and can be considered as multidimensional regions within frequency, time, and space. The region of space-time-frequency in which a particular secondary use is possible is called a 'spectrum hole.'

2.6 Functions of CR

The main functions of cognitive radio are:

- Spectrum sensing: Detecting unused spectrum and sharing it, without harmful interference to other users; an important requirement of the cognitive-radio network to sense empty spectrum. Detecting primary users is the most efficient way to detect empty spectrum. Spectrum-sensing techniques may be grouped into three categories:
  - Transmitter detection: Cognitive radios must have the capability to determine if a signal from a primary transmitter is locally present in a certain spectrum.
  - Cooperative detection: Refers to spectrum-sensing methods where information from multiple cognitive-radio users is incorporated for primary-user detection.
  - Interference-based detection
- Power Control: Power control is used for both opportunistic spectrum access and spectrum sharing CR systems for finding the cut-off level in SNR supporting the channel allocation and imposing interference power constraints for the primary user's protection respectively. In a joint power control and spectrum sensing is proposed for capacity maximization.
- 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 (of all bands available) to meet quality of service requirements; therefore, spectrum-management functions are required for cognitive radios. Spectrum-management functions are classified as:
  - Spectrum analysis
  - Spectrum decision

The practical implementation of spectrum-management functions is a complex and multifaceted issue, since it must address a variety of technical and legal requirements. An example of the former is choosing an appropriate sensing threshold to detect other users, while the latter is exemplified by the need to meet the rules and regulations set out for radio spectrum access in international (ITU radio regulations) and national (telecommunications law) legislation.

2.7 Advantages of CR

- CR can sense its environment and, without the intervention of the user, can adapt to the user's communications needs.
- 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.
- Fully utilize multi-channel.
- Cognitive abilities include determining its location, sensing spectrum use by neighboring devices, changing frequency, adjusting output power or even altering transmission parameters and characteristics.
- CR has the ability to adapt to real-time spectrum conditions, offering regulators, licenses and the general public flexible, efficient and comprehensive use of the spectrum".

2.8 Applications of CR

(i) Cellular Networks: In the cellular domain, CR could be used in conjunction with software defined radio for enhanced spectrum utilization to promote efficient use of the spectrum by exploiting the existence of spectrum holes. In addition, an adaptive cross-layer design could be implemented and a multi-hop based architecture could be designed for cellular networks. This could be done using intelligent environment-aware nodes that would increase the system capacity.

(ii) Vehicular Communications: In the vehicular domain, the CR could be used to enhance and improve intelligent interactions with the transportation system. Importantly, CR could be the driving force in order to realize real-time cooperative communications between the vehicles. This would eventually result in seamless vehicle-to-vehicle and vehicle-to-infrastructure communications, a gigantic step towards unified and continuous service provision involving variable speed vehicles.

3 SOFTWARE DESCRIPTION

3.1 MATLAB

MATLAB (matrix laboratory) is a numerical computing environment and fourth-generation programming language, developed by MathWorks. MATLAB allows matrix manipulations, plotting of functions and data, implementation of algorithms, creation of user interfaces, and interfacing with programs written in other languages, including C, C++, Java, and Fortran. In 2004, MATLAB had around one million users across industry and academia. MATLAB users come from various backgrounds of engineering, science, and economics. MATLAB is widely used in academic and research institutions as well as industrial enterprises.

3.2 Algorithms Used

1) Greedy Algorithm: A greedy algorithm is an algorithm that follows the problem solving heuristic of making the locally optimal choice at each stage. The choice made by a greedy algorithm may depend on choices made so far but not on future choices or all the solutions to the subproblem. It iteratively makes one greedy choice after another, reducing each given problem into a smaller one. In other words, a greedy algorithm never reconsiders its choices.

The choice made by a greedy algorithm may depend on choices made so far but not on future choices or all the solutions to the subproblem. It iteratively makes one greedy choice after another, reducing each given problem into a smaller one. In other words, a greedy algorithm never reconsiders its choices. A simplified packet data model is the greedy source model. It may be useful in analyzing the maximum throughput for besteffort traffic (without any quality-of-service (QoS) guarantees).

Problems also exhibit the greedy-choice property.

- When we have a choice to make, make the one that looks best right now.
- The choice that seems best at the moment is the one we go with.
- When there is a choice to make, one of the optimal choices is the greedy choice. Therefore, it's always safe to make the greedy choice. An example is shown in Fig 1.

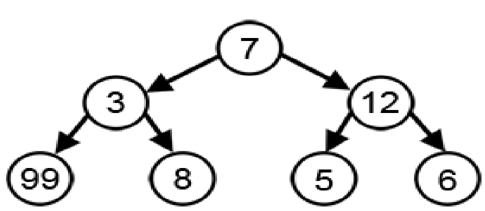

Fig.1 Finding optimal choice

With a goal of reaching the largest-sum, at each step, the greedy algorithm will choose what appears to be the optimal immediate choice, so it will choose 12 instead of 3 at the second step, and will not reach the best solution, which contains 99. While allocating the available channel to the active secondary users by the cognitive radio base station, the optimal path is taken by the greedy algorithm based on the priority.

2) Distributed Algorithm: A distributed algorithm is an algorithm designed to run on computer hardware constructed from interconnected processors. Distributed algorithms are used in many varied application areas of distributed computing, such as telecommunications, scientific computing, distributed information processing, and real-time process control. Standard problems solved by distributed algorithms include leader election, consensus, distributed search, spanning tree generation, mutual exclusion.

Distributed algorithms are sub-type of Parallel algorithm, typically executed concurrently, with separate parts of the algorithm being run simultaneously on independent processors, and having limited information about what the other parts of the algorithm are doing. One of the major challenges in developing and implementing distributed algorithms is successfully coordinating the behavior of the independent parts of the algorithm in the face of processor failures and unreliable communications links. The choice of an appropriate distributed algorithm to solve a given problem depends on both the characteristics of the problem, and characteristics of the system the algorithm will run on such as the type and probability of processor or link failures, the kind of inter-process communication that can be performed, and the level of timing synchronization between separate processes. Here the distributed algorithm is used by which the cognitive radio base station will distribute the allocated spectrum resources to the cognitive secondary users which are maintained in the priority queue.

3.3 Traffic Model

We assume that there are two types of radio users: PUs and SUs, and the SUs can be classified as k types of calls. The queue model is shown in Fig 2 below. We have the following assumptions:

- Each SU can use one sub-band for the service.
- PUs always have the priority to use the channels and can occupy any sub-bands used by the SUs.
- The arrivals of type $-\, i(1 \leq i \leq k)$ SUs follow the poisson process with the rate of λsi.

ISSN 2229-5518

- The call holding time of SUs are assumed to follow the exponential distribution with the expectation of 1/usi.
- For example, some are delay-sensitive. Therefore, the stable subbands should be allocated to delay-sensitive multimedia traffic users. In this paper, we assume that type-1 SUs have the highest priority and type-k SUs have the lowest priority in terms of delay-sensitive applications.

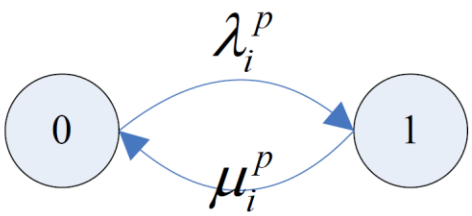

Fig 2. The queue model

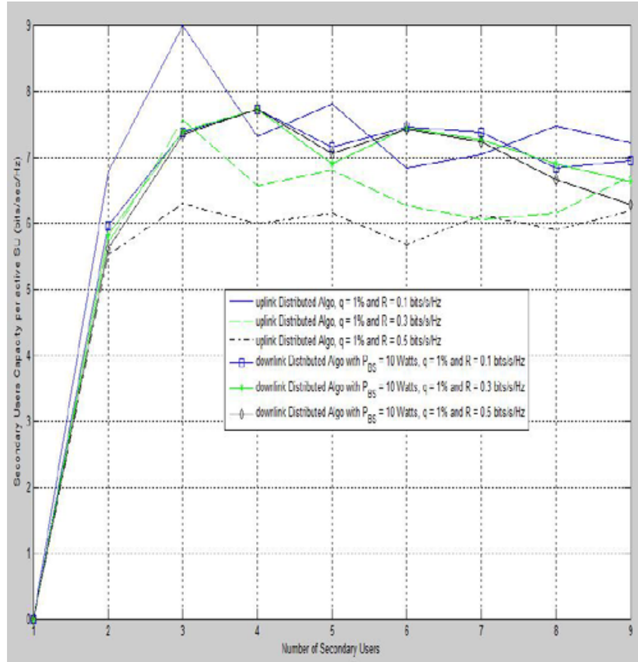

Fig 3. Performance of Secondary User-1

4 SIMULATION AND RESULTS

Parameters taken for Simulation: The outer radius of the primary cell (R) is taken as 1000 meters. The Interference protection radius of primary cell (R_p) is taken as 600 meter sand the Interference protection radius of secondary Transmitter (alpha) is taken as 300 meters. The rate of throughputs say, Rate1, Rate2, Rate3 are .1, .3, .5 respectively. The U_max is the maximum number of users, i.e both the primary and secondary users which is taken as 150. The maximum number of iteration is 100.

- R = 1000 (Outer radius of primary cell in meters)
- R_p = 600 (Interference protection radius of primary cell in meters)
- alpha = 300 (Interference protection radius of secondary Transmitter in meters)
- U_max = 150 (Max number of Users (PU+SUs))
- Rate1 = .1
- Rate2 = .3
- Rate3 = .5

By varying the U_max (Max number of Users (PU+SUs)) and the number of iteration, different performance results of the channel allocation to the secondary users (SUs) is attained. The performance of secondary users are shown in Fig 3 and 4.

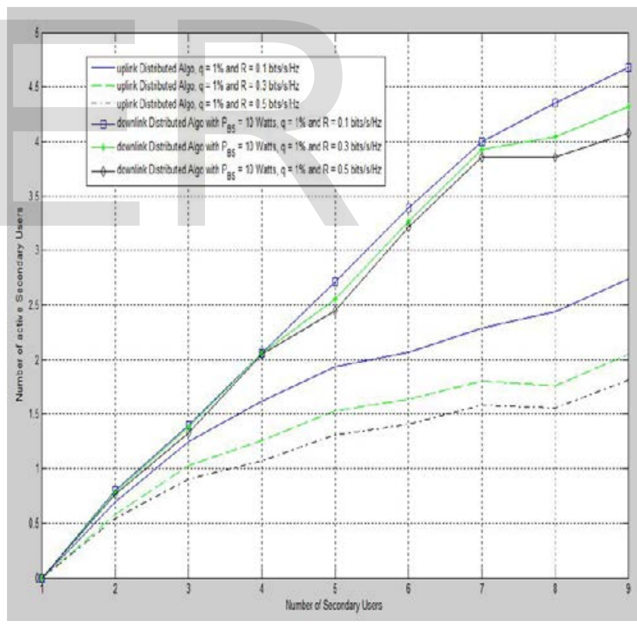

Fig 4. Performance of Secondary User -2

5 SUMMARY AND CONCLUSION

The optimum path allocation for trafficless mechanism is achieved by using greedy algorithm. The simulation results demonstrate that the channel allocation scheme can significantly improve the performance of the priority based secondary users. Also it increases the throughput and thereby decreasing the interference and delay. The channel allocation scheme had been

ISSN 2229-5518

carried out for multimedia transmissions over the cognitive radio network such as video conference using Markov model which improves the efficiency and increases the throughput with less interference.

This paper proposed a novel channel allocation scheme for the multimedia transmission over the cognitive radio networks. Using greedy algorithm high efficiency throughput mechanism is achieved. The simulation results demonstrate that the proposed channel allocation scheme can significantly improve the performance of the priority based secondary users (SUs) over the cognitive radio networks (CRNs).

REFERENCES

[1] Power Control and Channel Allocation in Cognitive Radio Networks with Primary Users' Cooperation, Anh Tuan Hoang, Member, IEEE, Ying-Chang Liang, Senior Member, IEEE, and Md Habibul Islam, Member, IEEE in IEEE TRANSACTIONS ON MOBILE COMPUTING, VOL. 9, NO. 3, MARCH 2010

[2] Distributed Resource Allocation for Cognitive Radio Networks With Spectrum-Sharing Constraints, Duy Trong Ngo, Student Member, IEEE, and Tho Le-Ngoc, Fellow, IEEE in IEEE TRANSACTIONS ON VEHICULAR TECHNOLOGY, VOL. 60, NO. 7, SEPTEMBER 2011

[3] Modeling Channel Allocation for Multimedia Transmission Over Infrastructure Based Cognitive Radio Networks, Tigang Jiang, Honggang Wang, Member, IEEE, and Yan Zhang, Senior Member, IEEE in IEEE SYSTEMS JOURNAL, VOL. 5, NO. 3, SEPTEMBER 2011

[4] Power and Channel Allocation for Cooperative Relay in Cognitive Radio Networks, Guodong Zhao, Student Member, IEEE, Chenyang Yang, Senior Member, IEEE, Geoffrey Ye Li, Fellow, IEEE, Dongdong Li, Member, IEEE, and Anthony C. K. Soong, Senior Member, IEEE in IEEE JOURNAL OF SELECTED TOPICS IN SIGNAL PROCESSING, VOL. 5, NO. 1, FEBRUARY 2011

[5] Joint Connection Admission Control and Packet Scheduling in a Cognitive Radio Network with Spectrum Underlay, Bin Wang, Dongmei Zhao, and Jun Cai in IEEE transactions on wireless communications, vol. 10, no. 11, November 2011

[6] Maximum Channel Throughput via Cooperative Spectrum Sensing in Cognitive Radio Networks, Junyang Shen, Tao Jiang, Siyang Liu, and Zhongshan Zhang in IEEE TRANSACTIONS ON WIRELESS COMMUNICATIONS,VOL.8,NO.10,OCT-2009