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Cognitive Radio Based on Software Defined Radio

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***Abstract* — It is commonly accepted that the wireless spectrum is the scarce resource in wireless communications. However, more than 95% of the usage is below 3GHz. The static assignment of the spectrum results in inefficient usage of the spectrum. The utilization of the spectrum can be as low as 10%. Dynamic access to the spectrum can be considered as a method for solving spectrum scarcity. Cognitive Radio and Dynamic Spectrum Access represent two complementary developments that will refashion the world of wireless communication. In order to investigate the roles of knowledge representation and reasoning technologies in this domain, we have developed an experimental cognitive radio simulation environment. That is, a conventional radio when operating in a particular communications mode always follows the same procedure and either succeeds or fails at a given task. This paper represent the spectrum sensing of Cognitive radio using matlab software. A cognitive radio, by contrast, can use knowledge of radio technology and policy, representations of goals, and other contextual parameters to reason about a failed attempt to satisfy a goal and attempt alternate courses of action depending upon the circumstances. Finally, the results shows the power spectral density of the channel which can be used cognitively to find out the available gaps those can be assigned to new incoming users thus improving the overall channel's throughput.**

***Keywords* — Cognitive Radio, Spectrum Sensing, Software defined radio,**

I. Introduction

The wireless communication systems are making the transition from wireless telephony to interactive internet data and multi-media type of applications, for desired higher data rate transmission. As more and more devices go wireless, it is not hard to imagine that future technologies will face spectral crowding, and coexistence of wireless devices will be a major issue. Considering the limited bandwidth availability, accommodating the demand for higher capacity and data rates is a challenging task, requiring innovative technologies that can offer new ways of exploiting the available radio spectrum. Cognitive radio is the exciting technologies that offer new approaches to the spectrum usage. Cognitive radio is a novel concept for future wireless communications, and it has been gaining significant interest among the academia, industry, and regulatory bodies. Cognitive Radio provides a tempting solution to spectral crowding problem by introducing the opportunistic usage of frequency bands that are not heavily occupied by their licensed users. Cognitive radio concept proposes to furnish the radio systems with the abilities to measure and be aware of parameters related to the radio channel characteristics, availability of spectrum and power, interference and noise temperature, available networks, nodes, and infrastructures, as well as local policies and other operating restrictions. Most of today's radio systems are not aware of their radio spectrum environment and operate in a specific frequency frequency band using a specific spectrum access system. Investigations of spectrum utilization indicate that not all the spectrum is used in space (geographic location) or time as shown in fig. 1. A radio, therefore, that can sense and understand its local radio spectrum environment, to identify temporarily vacant spectrum and use it, has the potential to provide higher bandwidth services, increase spectrum efficiency and minimize the need for centralized spectrum management.

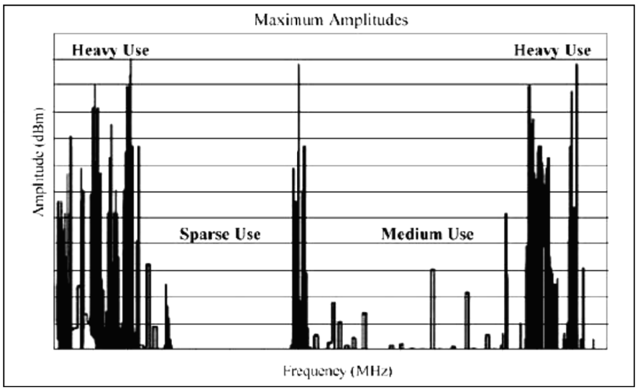

Fig.1.Spectrum Utilization

This could be achieved by a radio that can make autonomous (and rapid) decisions about how it accesses spectrum. Cognitive radios have the potential to do this. Cognitive radios have the potential to jump in and out of un-used spectrum gaps to increase spectrum efficiency and provide wideband services. In some locations and/or at some times of the day, 70 percent of the allocated spectrum may be sitting idle. The FCC has recently recommended that significantly greater spectral efficiency could be realized by deploying wireless devices that can coexist with the licensed users.

II. Cognitive Radios

Cognitive Radio (CR) is a paradigm for wireless communication in which either a network or a wireless node changes its transmission or reception parameters to communicate efficiently avoiding interference with licensed or unlicensed users. This alteration of parameters is based on the active monitoring of several factors in the external and internal radio environment, such as radio frequency spectrum, user behavior, and network state. The idea of CR was first proposed by Joseph Mitola III and Gerald Q. Maguire. It was thought of as an ideal goal towards which a Software-Defined Radio (SDR) platform should evolve a fully reconfigurable wireless black-box that automatically changes its communication variables in response to network and user demands.

Software Defined Radio (SDR) has now reached the level where each radio can perform beneficial tasks that help the user, help the network, and helps to minimize spectral congestion.

CR networks are envisioned to provide high bandwidth to mobile users via heterogeneous wireless architectures and dynamic spectrum access techniques. each CR user in the CR network must:

- Determine which portions of the spectrum are available
- Select the best available channel
- Coordinate access to this channel with other users
- Vacate the channel when a licensed user is detected

These capabilities can be realized through spectrum management functions that address four main challenges: spectrum sensing, spectrum decision, spectrum sharing, and spectrum mobility.

III. Software Defined Radio

An SDR is a radio in which the properties of carrier frequency, signal bandwidth, modulation, and network access are defined by software. SDR is a general-purpose device in which the same radio tuner and processors are used to implement many waveforms at many frequencies. The advantage of this approach is that the equipment is more versatile and cost effective. Additionally, it can be upgraded with new software for new waveforms and new applications after sale, delivery, and installation.

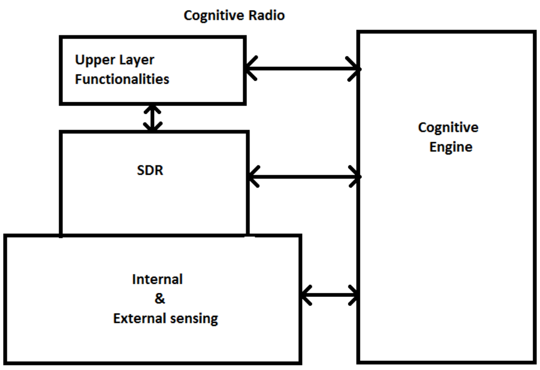

Fig.2. Relationship b/w SDR &CR

IV. Architecture of Cognitive Radio

The main components of a CR transceiver are the radio front-end and the baseband processing unit that were originally proposed for software The novel characteristic of the CR transceiver is the wideband RF front-end that is capable of simultaneous sensing over a wide frequency range. This functionality is related mainly to the RF hardware technologies, such as wideband antenna, power amplifier, and adaptive filter. RF hardware for the CR should be capable of being tuned to any part of a large range of spectrum. However, because the CR transceiver receives signals from various transmitters operating at different power levels, bandwidths, and locations; the RF front-end should have the capability to detect a weak signal in a large dynamic range, which is a major challenge in CR transceiver design-defined radio (SDR), as shown in Figure 4. In the RF front-end the received signal is amplified, mixed, and analog to- digital (A/D) converted. In the baseband processing unit, the signal is modulated/ demodulated. Each component can be reconfigured via a control bus to adapt to the time varying RF environment.

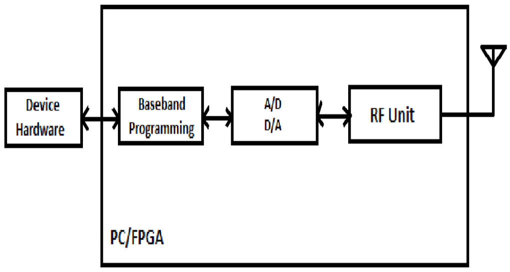

Fig.3.Architecture of Cognitive Radio

V. Simulation

Simulation platform has been developed for the Cognitive Radio using MATLAB. The performance of this network has been studied and compared by previous work. We have simulated the basics of a simple cognitive radio system in MATLAB R2008b. There was no previous technique available, or we couldn't find one, to simulate cognitive radio systems. But we've tried our best to make our code and findings as simpler as possible. The performance of the Cognitive radio using SDR technique has been studied. A cognitive ad-hoc radio network was considered, in this network some users are licensed and some are unlicensed. More specifically a dynamic spectrum allocation situation was simulated. The action selection was optimized using two algorithms, load balancing algorithm and genetic algorithm. This scenario was simulated as competitive or non-cooperative game due to the competitive and the selfish behaviours of the communication users when trying to access the radio spectrum. MATLAB is a programming environment for algorithm development, data analysis, visualization, and numerical computation. Using MATLAB, we can solve technical computing problems faster than with traditional programming languages, such as C, C++, and Fortran. We can use MATLAB in a wide range of applications, including signal and image processing, communications, control design, test and measurement, financial modeling and analysis, and computational biology. For a million engineers and scientists in industry and academia, MATLAB is the language of technical computing. We can use another software for implementing the cognitive radio such as labview or opnet software but using this software implementation is complex so we use matlab which is simpler technique and easy to implement. Firstly we generate the spectrum using wi-max technology and then this spectrum is accessed by software and assign it to the primary user which has licensed to use that spectrum. If

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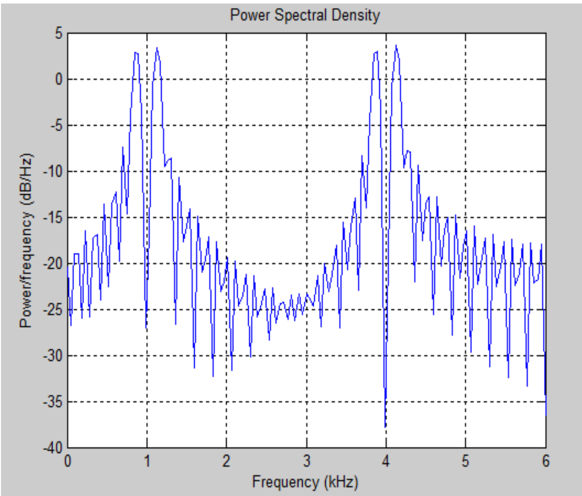
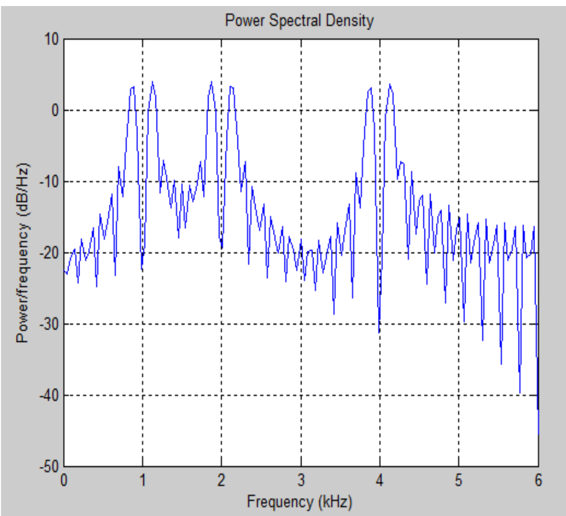
some another secondary user which is unlicensed user want to use that spectrum then it will take the permission of primary user and access that sectrum. This all process is shows in our programming and in result which increase the capacity as well as the throughput of the system and at the same time number of users access the same spectrum according to their need.

VI. Results

We've designed our system to have 5 different frequency channels and each User is assigned a particular frequency band. Once we run our program it'll ask to add a User and assign it a particular band in ascending order.
Here we haven't entered User 2, 3 & 5, thus their respective bands are still un-allocated. We can see them below in the power spectral density graph of our carrier signal.

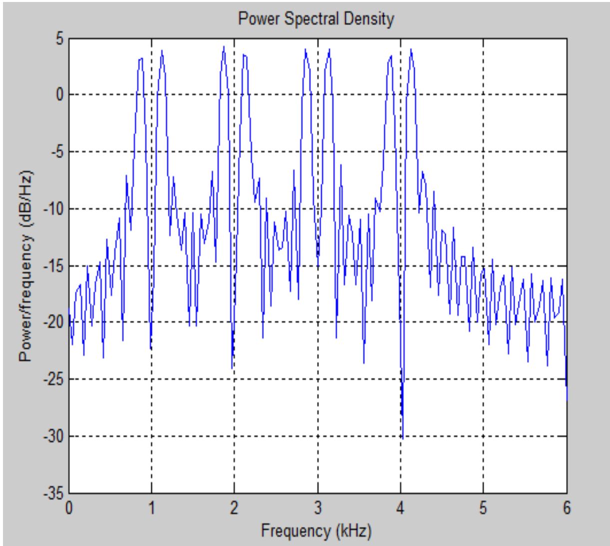


Now we're adding another User, the system will search the first available gap in the spectrum and automatically assign it to the new user. As the first available gap was after User 1 as User 2 was not sending any data so the band reserved for User 2 at start is now assigned to this new User.



Here we can see that the first spectral gap has been filled by assigning it the new incoming User's data. The first spectral gap belonged was that of User 2.

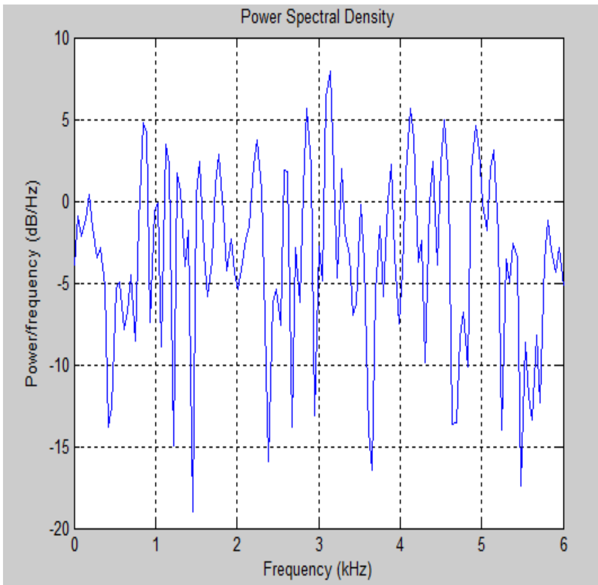
As User 3's data was not present so the Spectral gap of User 3 has been filled by the next incoming User that is another secondary user .Once all the slots are being



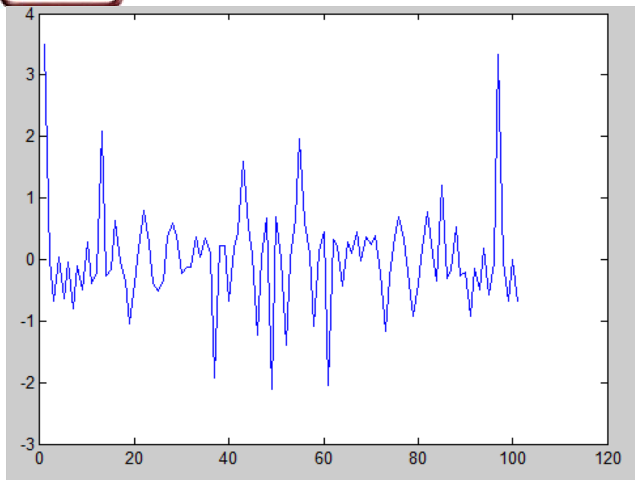
assigned our system will entertain no other User and will be able to free up the slots one by one .

Similarly we can add noise and attenuation parameter to analyze the channel characteristics.

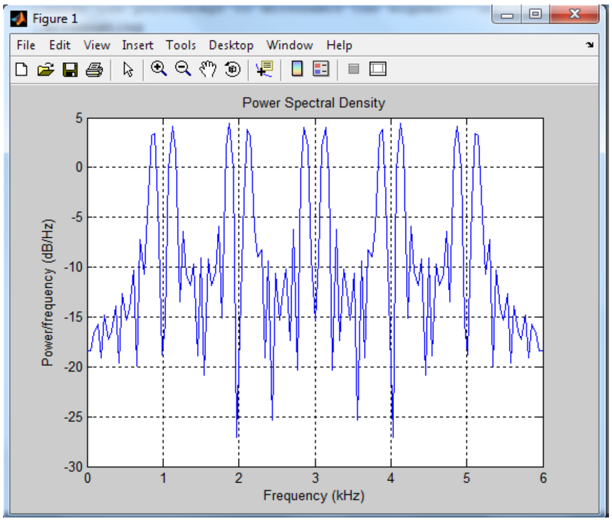
Here we've added noise to our signal. The resulting noisy carrier's power spectral graph is given below



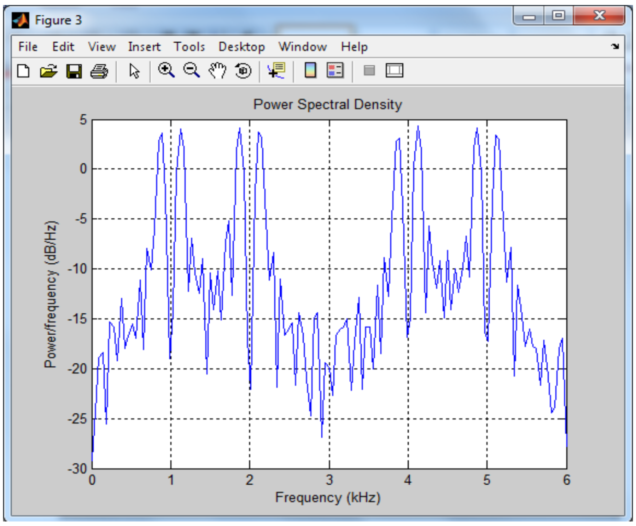
Now we are attenuating our carrier and the system will ask for the percentage of attenuation required. The below fig. shows the amount of attenuated signal



Suppose if all the users are in use i.e. no slots are free and at the same time if some secondary user wants to use the slot then at that time system will ask to fired the slot so that the secondary user perform their operation. We can see in fig. that all slots are filled by their primary user no slots are free for secondary user.

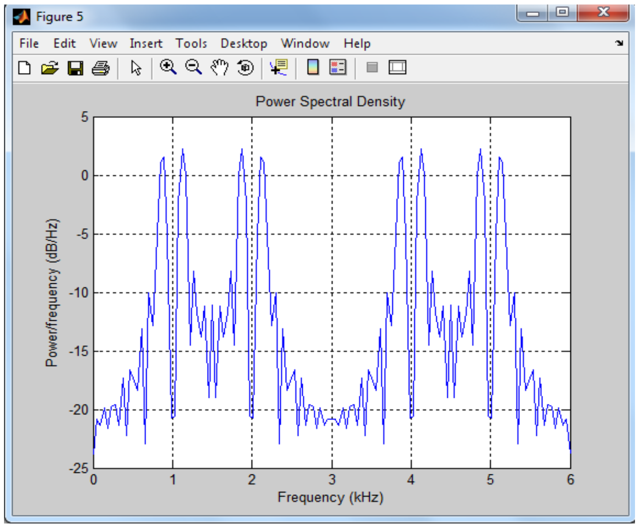


If we fired the slot 3 for secondary user then it will empty



the slot 3 and slot 3 is filled up by the secondary user without any interference.

ZHere we can see that the third spectral gap has been filled by assigning it the new incoming User's data. We add noise 20 db and attenuate the signal by 20%. Finally by adding the noise and attenuate the signal the resulting spectrum is shown below.



Once all the parameter have been applied to the carrier, the system will ask for re-assignments of bands by starting the whole process again infinitely so that all the incoming users at any instant of time are accommodated in the spectral holes left in the channel maximizing the overall throughput of the channel.

VII. Conclusion

We've simulated the basics of a cognitive radio systems enabling dynamic spectrum access at run time. There was no other general simulation method available though we'd tried to dig out all the research papers in this domain but couldn't find any method that could be followed or improved as cognitive radios are still in research pipelines as cognitive science is in its infancy. That's why we've tried to simulate the basics of cognitive radio technology to create awareness among our fellow students regarding the scope and applications of this tremendous new technology. There are very few experimental simulation techniques present regarding cognitive radios, thus we intend to come out with a simpler and efficient simulating technique. The previous results show theoretical approach of cognitive radio. But this paper shows the practical performance of the used spectrum bands in cognitive radio. Fig. shows the primary user which utilize their band and the secondary user occupy the vacant position which is the unlicensed user. This not only increase the users but also increase the spectrum efficiency and spectrum utilization. Our approach was to take the decisions on the basis of power spectral density of the channel which can be used cognitively to find out the available gaps those can be assigned to new incoming users thus improving the overall channel's throughput. Overall the whole project was a success though it took quite a lot of time and research in finding out some generic algorithm for simulating the cognitive radio systems, but in the end we'd to come around with our own idea and implementing it in Matlab. The results are quite accurate and we're still working on improving the code for more presentable results.

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