

Research Article

Cognitive Radio

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Abstract

The growing demand of wireless applications has put a lot of constraints on the usage of available radio spectrum, a limited and precious resource. However, a fixed spectrum assignment has led to underutilization of the spectrum as a great portion of licensed spectrum is not effectively utilized. Cognitive radio is an immensely promising technology that provides an effective way to improve utilization efficiency of available electromagnetic spectrum. Spectrum sensing helps to detect the spectrum hole, underutilized bands of the spectrum, providing high spectral resolution. In this paper, the cognitive radio technology is implemented to achieve better spectrum utilization. It is simulated using MATLAB and the results are shown.

Keywords: Cognitive radio, Dynamic spectrum access, Electromagnetic spectrum, Power spectral density.

1. Introduction

The electromagnetic spectrum is a not a scarce resource but investigations reveal that major part of the spectrum is underutilized. The reason for this is the inefficient usage of this very important resource. The licensed bands are under-utilized but unlicensed bands are crowded resulting on spectrum scarcity. In order to improve this situation, there has to be some means through which we can better utilize the spectrum without having to trespass the primary user bands. Primary user is one who is allocated a licensed band for exclusive use. Only few and small numbers of unlicensed bands are left open for unlicensed users like ISM bands 900MHz and 2.4 GHz. Technological advancement has resulted in wireless technologies like -Wi-Fi, Bluetooth, digital cordless phones, 3G, and so on which operate on unlicensed band. Thus we need some technology that can utilize the temporarily-unused spectrum without causing excessive interference to primary licensed users. A cognitive radio is a transceiver that is designed to intelligently detect whether a particular segment of the spectrum is currently in use and utilize the temporarily-unused licensed bands. The moment any primary user wants to use this band, the cognitive radio then puts the secondary user in some other spectrum hole. Secondary user is one who occupies these primary bands temporarily. A spectrum hole is the unallocated spectrum band. This can be clearly understood from the following figures.

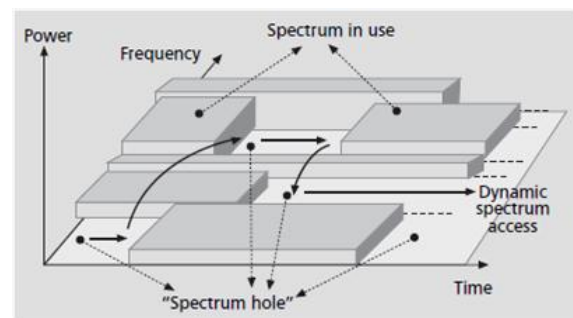


Fig. 1: Spectrum hole

2. Literature Survey

Joseph Mitola (J. Mitola *et al*, 2000) was the first person to bring the concept of cognitive radio. He proposed it by designing a prototype, analyzed its architecture and performance in a simulated environment. Thus cognitive radio is also called as “Mitola radio”. Haddad *et al* (Haddad M *et al*, 2007) gave the concept of implementing cognitive radio to increase the total system capacity by reusing locally unused spectrum. Simon Haykin (Simon Haykin *et al*, 2005), in his paper, presents the potential of Cognitive radio that can make an immense difference in wireless communications but stressed on the fact that the key factor to this kind of technology to evolve over time be it for military or civil purpose is, trust. Q. Zhao and A. Swami (Q. Zhao *et al*, 2007), in their paper discuss different dynamic spectrum access strategies broadly categorized under three models. Study of these models gives the idea on how to use “Opportunistic spectrum access (OSA)” which involves spectrum opportunity identification,

spectrum opportunity exploitation, and regulatory policy.

3. Cognitive Radio

As explained before, a cognitive radio is a transceiver that is fully aware of its surroundings and adapts intelligently with its signal processing capabilities in all 7 layers of ISO model. Combining the facets of radio flexibility, intelligence and spectral awareness, cognitive radio is the amalgamation of software defined radio (SDR) and intelligent signal processing.

3.1 Spectrum hole

- In time domain it is the period of time that the primary is not transmitting.
- In frequency domain it is a frequency band in which a secondary can transmit without interfering with any primary users (across all frequencies).
- 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 main challenge for secondary radio systems is to be able to robustly sense when they are within such a spectrum hole.

3.2 Cognitive cycle

The basic cognitive cycle of cognitive radio operation as secondary radio system is as shown below

- Spectrum sensing: senses the radio environment and geographical surroundings detect usage statistics of other primary and secondary users and determine possible spectrum space holes.
- Spectrum decision: based on the spectrum sensing information cognitive radio selects when to start its operation, its operating frequency and its corresponding technical parameters.
- Spectrum sharing: Since there is number of secondary users participating in usage of available spectrum holes, cognitive radio has to achieve balance between its self-goal of transferring information in efficient way and altruistic goal to share the available resources with other cognitive and non-cognitive users. This is done with policy rules determining cognitive radio behavior in radio environment.
- Spectrum mobility: when the primary user starts to operate, cognitive radio has to stop its operation or to vacate currently used radio spectrum and change radio frequency. In order to avoid interference to primary licensed user this function has to be performed in real time, therefore cognitive radio has to constantly investigate possible alternative spectrum holes.

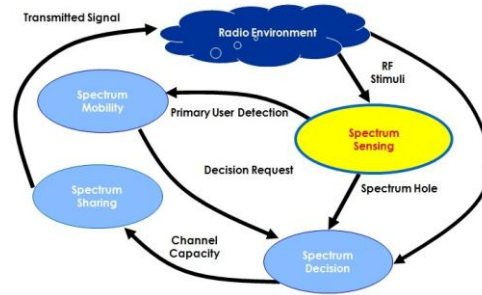


Fig. 2: Cognitive cycle

4. Implementation and Simulation Results

The Power Spectral Density (PSD) is intended for continuous spectra. The integral of the PSD over a given frequency band computes the average power in the signal over that frequency band. It is often simply called the spectrum of the signal. Intuitively, the spectral density measures the frequency content of a stochastic process and helps identify periodicities.

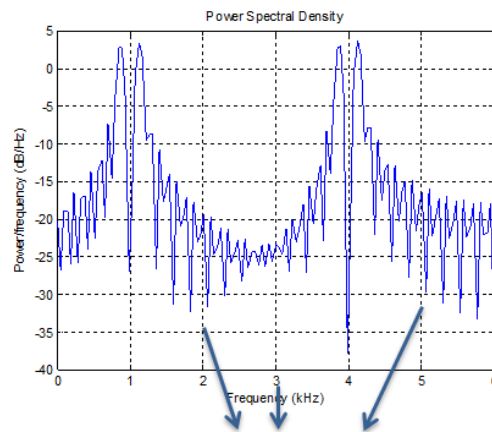


Fig. 3: PSD with 2 Primary users and other unused bands

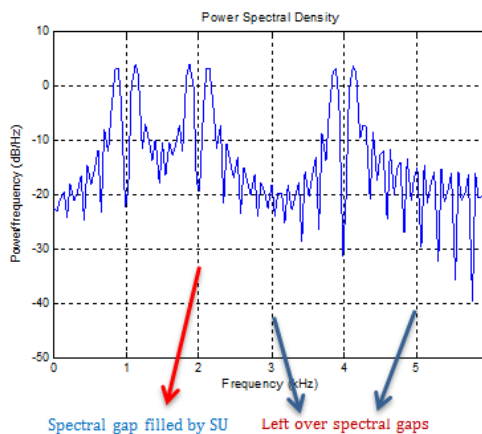


Fig. 4: PSD with 2 Primary users and 1 Secondary user

The MATLAB program is so designed to accommodate 5 users and each one is assigned a particular frequency band. When primary users ask for channel for

communication, they are allocated the frequency bands. In the allocated bands, secondary users can be accommodated. In the figure shown below, the primary user occupies bands 1 and 4, the frequency bands 2, 3 and 5 are unallocated.

To this entered signal, noise can be added and also signal can be attenuated. The original and the noise added signal is easily distinguishable.

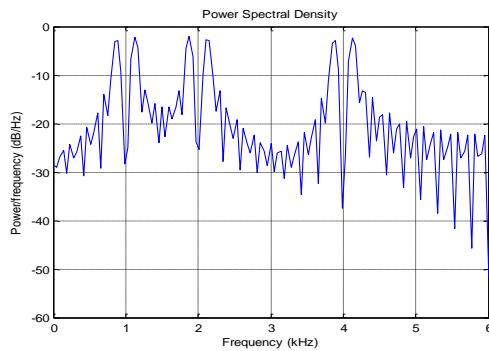


Fig. 5: PSD with 40dB noise added

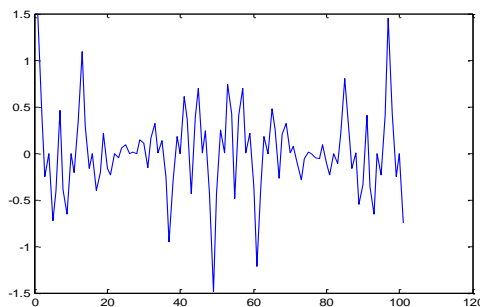


Fig. 6: Signal attenuated by 50%

Now simulating further, the simulating algorithm will ask whether there is another secondary user that requires a spectral band. If yes then the user shall be accommodated in the 3rd slot.

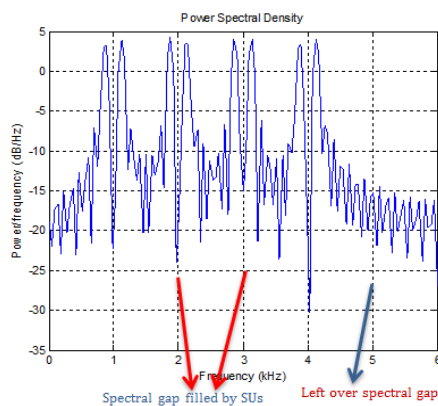


Fig. 7: PSD with 2 Primary users and 2 Secondary users

For every additional secondary user, it will be asked whether or not the signal needs to be added with noise or attenuated.

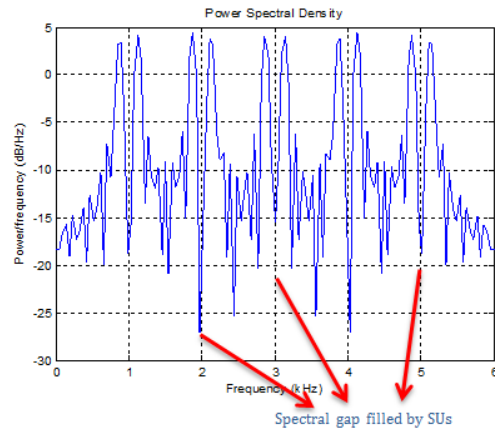


Fig. 8: PSD with 2 Primary users and 3 Secondary users

Conclusions

The Cognitive radio can find its potential and promising applications in the areas such as Mobile multimedia downloads; emergency communications services that require a moderate data rate and localized coverage; Broadband and Multimedia wireless networking services. From a regulator's perspective, dynamic spectrum access techniques using CR could minimize the burden of spectrum management whilst maximizing spectrum efficiency. A cognitive radio-system is 'aware' of its operating environment and automatically adjusts itself to maintain desired communications it's like having a trained operator inside the radio making constant adjustments for maximum performance. Operating frequency, power output, antenna orientation/beam width, modulation, and transmitter bandwidth are just a few of the operating parameters that can automatically be adjusted on the fly in a cognitive radio system.

References

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About the author



Mohamed Najmus Saqhib received his Master's degree from VTU, Bangalore. He is a passionate researcher, moving towards his PhD and his main research activities concern areas of wireless communication and cognitive radio network. His work has led to many publications in highly reputed International Journals and Conferences.