The Overview of Dynamic Frequency Spectrum Access Based on Some Advanced Techniques

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Abstract

The paper introduced the present insufficient situation of the frequency spectrum resource. Several effective techniques to raise the utilization efficiency of the spectrum and corresponding developments of their applications, such as the Cognitive Radios, the Ultra-Wide Band radio, the Water Filling Principle and the Detection & Avoidance Mechanism, are analyzed and compared, which are increasingly significant to the spectrum regulation and management research.

1. Introduction

Frequency spectrum is a precious and scarce natural resource. With the rapid development of science and economy, the need for the spectrum resources has been dramatically increasing. To resolve this contradiction, both managers and users focus on the allocated spectrum resources. Based on the statistics of the time occupancy ratio, large amount of spectrum resources are standing idle. For instance, 70% allocated spectrum are not effectively utilized in the US, and some frequencies are even only occupied for several milliseconds. It is similar with the situation in China, according to an experimental test conducted by the authors in the mobile communication frequency band between 800MHz and 1GHz in Beijing 2006. The waste of the idle resources not only brings inequality in resource utilization but also greatly cumber the rapid development of our information society. This fact urges us to increase the efficiency of spectrum utilization.

2. Engineering techniques to increase the efficiency of spectrum utilization

According to the analysis of lots of references relevant to efficiency of spectrum utilization, the authors focus on the following techniques that can improve spectrum efficiency, such as Cognitive Radio, Ultra-wide bandwidth, Soft Spectrum characteristics of Software Defined Radio, Detection and Avoidance Mechanism, Water Filling Principle, Sharing Spectrum, Frequency Spectrum Character Memory Database.

2.1 Cognitive Radio

The concept of Cognitive Radio was firstly raised in IEEE Person Communications in August 1999, by the consultant of MITRE Co., Dr. Joseph Mitola, from Swedish Royal Institute of Technology. In common sense, Cognitive Radio is a radio network and an intellectual wireless communication technique with

software radio as the extending platform. It could perceive the existence of users with high priority and electromagnetic environmental characteristics and cognize the types of their communication by analyzing the stimulus from surroundings. Then the best solution would be selected to realize coexistence with the primary users without any harmful intervention. CR is also capable of switching the transmitted waveforms quickly and conduct electromagnetic environment inspection within broadband to get the signal parameters in order to cognize the occupying situation within the band. Even if without the license, it is still feasible to operate in certain bands once they are not occupied. In fact, Cognitive Radio has the ability to control and utilize spectrums dynamically.

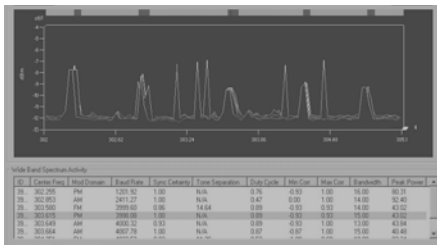

Figure 1: The inspect and apperception of electromagnetic environment

Cognitive Radio demands intellectual facilities which have the abilities of perception, study, prediction and analysis and could automatically fit different electromagnetic environments with the characteristics of software radio. It could cognize frequency spectrum in multi-dimensions (time, frequency, space and waveform). Once an available band is detected, CR would respectively control the transmitting power to make sure that it does not exceed the interfering threshold of any important users. From the aspect of spectrum resources utilization, CR shows highly-effective, friendly, compatible, equal and technically negotiation.

Generally speaking, CR realizes effective utilization of spectrum resources by precisely perceiving and automatically fitting the local electromagnetic environment while avoiding intervention. The significance of CR is that it improves the efficiency of spectrum utilization while increases the number of users, and solves the problem of how to utilize spectrum equally. The new technique provides possibilities for the applications of new services especially for the demands in the national security.

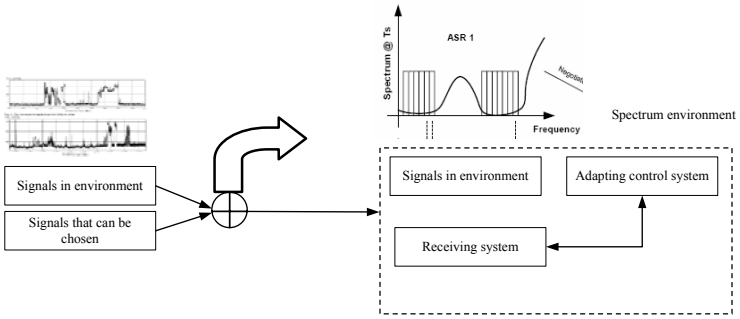

Figure 2: the system flow of Cognitive Radio

2.2 Ultra-wide bandwidth

The technology closely related to Cognitive Radio is UWB (ultra wideband) wireless communication. Different from traditional communication systems, UWB utilizes spectrum in an underlay way sharing with the traditional licensed systems. The transmitting power of UWB system is much lower than the traditional

cases. Metaphorically speaking, UWB is like “spectrum grass” while traditional systems are like “spectrum trees”. The latter ones apply to all kinds of applications in communication, and the former one only applies to short or middle-term range communication systems due to the limitation of transmitted power in civil applications.

In UWB technology, due to the use of ultra-wide frequency band, overlapping with the traditional narrow band systems is inevitable. Even if with very low transmitted power, the interference still exists. As a result, the new way to allocate the spectrum resources with “pad” has caused wide-ranged controversy in the industrial field because of the overlapping in spectrum. The advocates emphasize its advantages such as high transmitting speed, strong anti-interference ability and low interception rate, and the skeptics worry about that unexpected interference might bring to the narrow band systems, or that the artificially raised noise level might correspondingly diminish the receiving sensibility. Cognitive Radio just endows intelligence especially the perceiving function to UWB and makes it possible for real-time adjustment of the working spectrum range and transmitted power level of the signals, as a result the coexistence with the traditional narrow band systems could be realized. So the cognitive technique is very crucial in UWB systems.

2.3 Soft Spectrum and Congestion Avoidance Mechanism

The basic principle of soft spectrum is to divide the expected band into several sub-bands, to avoid the interference by closing certain sub-bands when it occurs. Different systems have different strategies to realize soft spectrum. For systems that realized by sub-carriers, the realization and control of soft spectrum is relatively easy. For systems that avoid or close sub-bands by changing shapes of the impulses, it could be focused on the waveform design. As a result, realizing soft spectrum and avoidance mechanism is a process to choose and design the signal waveform. Most of the waveform generation functions are static, scheduled and unchanging, which form “hard spectrum” instead of a soft one. Obviously, using any one of them can not realize the character of soft spectrum. It has been widely accepted that whether the waveform is capable of realizing soft spectrum is the key of study.

Similar to soft spectrum, Congestion Avoidance Mechanism is also based on multi-band theory. Its fundamental idea is: the system detects frequency bands before emission, if the band is not occupied by its legitimate user, then the system can get the permission to use the band with some regulatory limitations. If the band is occupied by its legitimate user some time later, then the system self-perceptively avoids this band, or continues to work in the same band but in much lower PSD level.

2.4 Water Filling Principle

Water Filling Principle originates from the Information Theory. Recently some scholars apply the principle to the field of spectrum engineering for the first time to realize dynamic multi-user sharing of the spectrum resources.

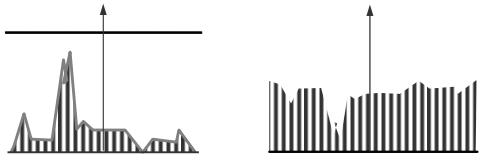

Figure 3: Water Filling Principle Waveform

The principle is that: if a user firstly occupies a vacant band but power spectrum density (PSD) does not reach the limit of the band, then other users could share the same band until the PSD limit is reached. In other words, the total transmitted power on the band should not exceed the allowed redundancy capability. The space between background noise level and the interference level could all be put in utilization.

2.5 Spectrum Sharing

Generally speaking, spectrum sharing is realized by separating radio devices with a reasonable distance in the spectrum space. In demand of more spectrums without authorization, the novel sharing concept is being studied in order to accommodate for secondary users in the same band without interfering with its primary users. Two fundamental methods that are worth being studied have been determined for this purpose. One is an underlay approach with strict restrictions on the transmitted power levels with a requirement to operate in a very wide band; the other one is an overlay approach in which interference with high priority users can be avoided through spectrum detection and adaptive allocation.

In addition, we can also realize spectrum sharing by establishing a spectral character database of different radio devices. As cognitive radio is used as a secondary service, we should study the relationship between the protection distance and possibility of EMI caused by cognitive radio to traditional systems. Also, for certain devices, cognitive radio should detect and respond as quickly as possible, changing its radiation status. Such a spectral character database can have more detailed categorization, or simply make detailed description of each kind of radio devices.

3. Conclusion

In a time when radio spectrum resource is increasingly in shortage, the further improvement of spectrum efficiency is the best solution and it thus has attracted world-wide attention. This paper comprehensively introduces some new theories and approaches to further improve the spectrum efficiency, compares their advantages and depicts the future of spectrum efficiency. It has great significance to the overall planning and institutional study both in present and future spectrum management.

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