Cognitive Ultra Wideband Radio

Soodeh Amiri

M.S student of the communication engineering

The Electrical & Computer Department of Isfahan University of Technology, IUT

E-Mail : s.amiridoomari@ec.iut.ac.ir

July 2009

***Abstract*-This paper introduce the concept of cognitive UWB radio, a wireless system based on UWB transmission able to self adapt to the characteristics of the surrounding environment. UWB is an promising underlying method for coexistence among different systems. However, the performance may not be as good as expected due to the changing spectrum environment. Thus, cognitive UWB radio is proposed by taking the advantage of cognition, which enables the radio to learn the spectrum environment by itself. Cognitive radio techniques enable flexible, efficient and reliable spectrum use.**

***Key words:* Cognitive radio (CR); ultra wideband (UWB); spectrum sensing; spectrum sharing; primary user; secondary users.**

I. INTRODUCTION

UWB technology is a promising physical layer technique for wireless personal area networks. It enables high data rate and low power wireless systems. While UWB technology has lately excited attention as a new physical layer technique, it has been initially developed in radar systems for military applications since the1960s. Currently, it is intended to be used in a wide range of applications, such as positioning, monitoring and multimedia services.

A UWB system is allowed to operate in the US at either below 1 GHz or between 3 GHz and 10 GHz, where the maximum average power spectral density shall be less than -41.3 dBm / MHz [1].

Two definitions of the UWB signal exist. If an absolute bandwidth is more than 500 MHz or fractional bandwidth Bf is larger than 20%, a signal is seen as:

$$\beta_f = 2\frac{f_h - f_l}{f_h + f_l} \qquad (1)$$

Where f_h and f_l are the high and low frequencies, respectively, measured at -10 dB [2],[6]. Here is the classification of signals based on their fractional bandwidth [7]:

Narrowband $\beta_f < 1\%$

Wideband $1\% < \beta_f < 20\%$

Ultra wideband $\beta_f > 20\%$

Since occupying very wide spectrum, UWB system must consider the effect from/to other existing systems within the same band, such as personal communication services (PCS), global positioning system (GPS) and wireless local area network (WLAN). Currently, these systems are protected by limiting the transmission power of UWB radio under its emission mask, which is announced according to the regulations in different countries or regions [2]. However, it is not enough to avoid the possible interference due to different implementation condition, such as different countries. Even UWB system transmits under limited power level, it could cause interference to other systems [1]. Therefore, cognitive UWB which combines UWB with CR technique comes to the frontier. Despite the similarity with spectrum sharing, also some differences between CR and UWB can be found. A CR utilizes only unused spectrum segments or spectrum holes at a given time and location, whereas the UWB signal spectrum may overlap with the PU signal spectrum. In addition, the UWB technology is aimed at short-range communications due to transmission power constraints, but the CR may therefore may be deployed in longer-range communications.

II. Structure of Cognitive UWB System

Conventional UWB occupies wide frequency band where other systems are certain interference to the overlapped systems. On the other hand, UWB transmission is also degraded due to the overlapped systems [1]. However, cognitive UWB system divides the whole band into several sub bands and selects the ones with good channel condition for its transmission. The performance is enhanced not only because better sub-bands system's signal are avoided [2]. Fig. 1 shows the system description of the Cognitive UWB system, which employs the cognitive ability in the conventional UWB system. At the transmitter, the input data passes through the channel coder, where it is encoded to reduce the bit error rate of transmission. This coding is followed by the modulation module, where the data is modulated by pulse position modulation (PPM). We insert the preamble after this step, in order to achieve the synchronization at the receiver. Thereafter, the data are processed in DAC and sent out in the RF part. Contrarily, at the receiver, the received signal is first sampled in RF part, and synchronized with the help of preamble, finally demodulated by PPM. The data is recovered after passing through the decoder. There are two new blocks inserted in cognitive UWB system: one is the pulse mask code (PMC) generator embedded with mask information and spectrum sensing block, are utilized but also due to the sub bands containing other which can adapt in the specific mask regulation and channel information; the other one is Cognitive UWB pulse generator. With the help of PMC generator, the suitable cognitive UWB pulse is generated, which can recognize predefined frequency rule and channel condition. We use this pulse to in PPM modulation and demodulation block and generate the most suitable cognitive UWB radio.

The output of PMC is based on the specific spectrum emission mask information and the channel state information from detection. With the help of cognitive ability, we can identify whether the channel is occupied during the observation period. This occupation may due to the existence of narrowband interference signal or primary user signal. If it is occupied, cognitive UWB system has to avoid using this band to guarantee its transmission quality. Meanwhile, the spectrum emission mask information is stored in the payload and shared by the cognitive UWB system. Due to different policies, mask regulation in each country is different, as indicated in Fig. 2. Even in the same country, the regulation for indoor environment is different from that of outdoor, which increases the difficulty in product development. Therefore, adding the spectrum emission mask information in the Cognitive UWB system is able to solve this problem.

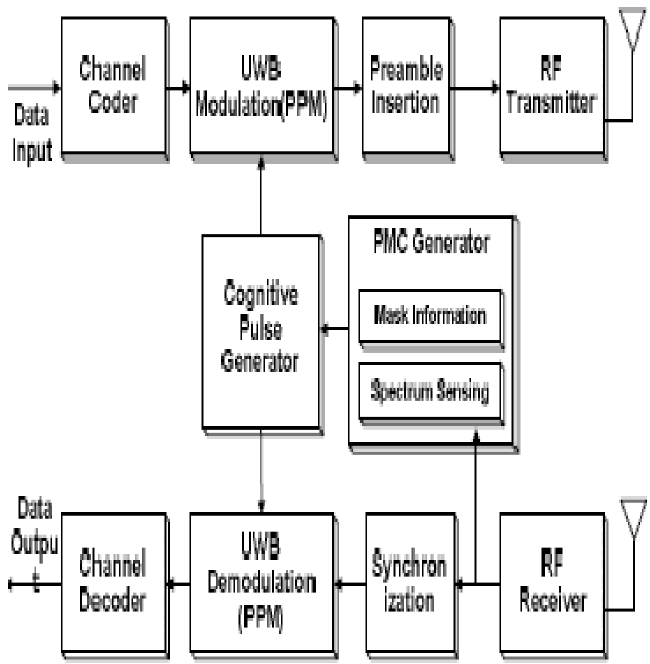

Figure 1.The structure of cognitive UWB system.

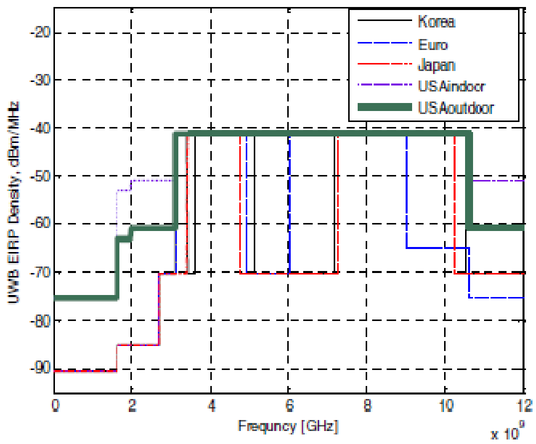

Figure2. Spectrum emission mask of different countries

III.Spectrum sharing in Cognitive UWB Radio

As cognitive radios coordinate radio resources autonomously while operating, fair and efficient resource sharing between radio systems is a big challenge. It is difficult to guarantee that some radio systems do not dominate the spectrum usage and thus prevent other radio systems from operating at the same time. This is a challenge for cognitive radio as well as for traditional radio systems operating in unlicensed frequency bands.

Spectrum etiquette offers a promising solution to this problem. It is a set of rules for radio resource management to be followed by cognitive radio systems that share the radio spectrum. The rules are based on operations like transmission power control, dynamic channel selection, adaptive duty-cycles and carrier sensing. If all radio systems follow the spectrum etiquette, fairness can be maintained and the use of spectrum is more efficient. However, spectrum etiquette provides only a framework for behaviour. It may restrict the degrees of freedom in radio resource management of individual radio systems, still leaving room for innovations and differentiations.

The equivalent spectrum sharing model of UWB-CR system is showed in Fig. 3. There is no licensing process for equal users, and each user operates in coexistence [3].

However, for primary-secondary users system it should be QoS for primary but opportunistic for secondary. In this case, each user operates in cooperation.

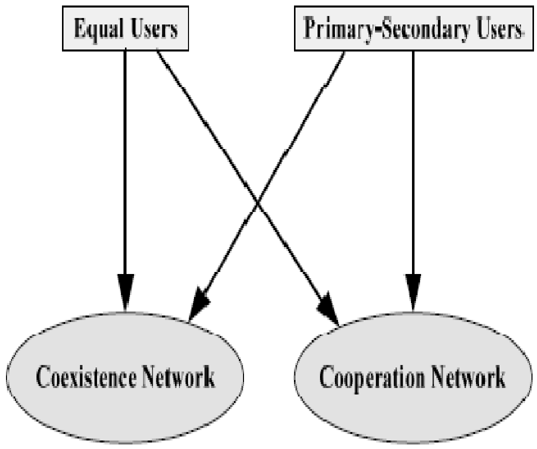

Figure 3. Spectrum sharing model of UWB-CR system

Of course, there should be different spectrum sharing in different bands. It depends on the application, QoS, location, mobility and traffic load.

IV. Spectrum sensing schemes

Spectrum sensing enables SUs to adapt to the environment by detecting the spectrum holes without causing interference to the primary users (PUs).

PU systems have no requirements to change their infrastructure for spectrum sharing with SUs. That is why SUs should be able to detect the existence of PUs through continuous spectrum sensing. The SUs sensitivity should be better than the PU's receiver in order to detect PU transmitters early enough.

Three schemes are commonly used for transmitter detection, namely matched filter detection, energy detection and feature detection.

These schemes can be shortly described as follows:

- **Energy detection:**

When the receiver cannot gather sufficient information about PUs, the optimal detector may be the energy detector. Typically, the signal is squared and integrated over the observation interval and then compared with a threshold, and finally it is decided whether a primary user is present or not. The performance of the energy detector is prone to uncertainty in noise power, and it is not able to distinguish signal types, but can only determine the presence of the signal. This means that the primary user cannot differentiate from secondary users.

- **Feature detection**

Feature detectionis is an alternative detection method, where modulated signals are normally coupled with sine wave carriers, pulse trains, repeating spreading, hopping sequences or cyclic prefixes, which result in built-in periodicity. By analyzing a spectral correlation function, these modulated signals are characterized as cyclostationarity if their mean and autocorrelation display periodicity. Through this method, the number of signals can be found, as well their modulation and the presence of interfering signals.

The main advantage of feature detection is its robustness to uncertainty in noise power. But it is computationally complex and requires significantly long observation times. Moreover, it costs excess bandwidth or guard band, and subject to the radio frequency, spectral leakage of strong signals and timing or frequency jitters.

- **Matched filter detection:**

Matched filter detection is the optimal detector when the information of the primary user signal characteristics is known to the secondary user. Matched filter maximizes the received signal-to-noise ratio (SNR) in an additive white Gaussian noise (AWGN) channel. If a priori knowledge of a primary user signal is available, very fast and reliable coherent detection can be performed. Without this accurate information, the matched filter performs poorly.

From what has been discussed above, we may draw the conclusion that the matched filter detection is the optimal spectrum sensing scheme in the UWB-CR. Because the priori knowledge of the primary user signals in the UWB-CR system is known to the CR user.

V. Spectrum Sensing in Cognitive UWB Radio

Some improvements are still needed because the current UWB system is not able to detect and use the unused part of spectrum. The cognitive UWB system shall be able to sense the spectrum in order to observe the spectrum opportunities and optimally use the vacant spectrum without causing harmful interference to the licensed user. Through opportunistic spectrum use, the operation of the UWB system can be enhanced [3].

Some cognitive radio techniques used in the IEEE 802.22 WRAN, such as distributed spectrum sensing and the use of a spectrum usage database and different sensing processes, can also be applied in the cognitive UWB system. Because of the absence of a base station in the cognitive UWB system, all the functionality in decision making as well as the spectrum sensing must be included in individual devices instead of a base station.

UWB communication systems by definition utilize a wide range of spectrum and could, thus, overlap with many existing and potential future services, Pus must be detected reliably and quickly, and the causing of interference must stop as soon as possible. This is why the key feature of the cognitive UWB system is spectrum sensing. The sensing shall be distributed so that all devices sense the spectrum [3].

Without sensing the channels in advance, it takes a long time to find out a new free channel, and the controlling of devices becomes more difficult in a decentralized system. Devices must have knowledge of the free channel where they can move to quickly when a PU is detected on the current communication channel. For that purpose, a spectrum usage database can be used. The sensing results can be marked on the database during sensing. The database can be checked to see which channels are currently available and which ones are occupied.

Because of shadowing and fading, it is possible that some devices do not receive a primary user’s signal that has faded significantly and whose received power level is significantly low. In order to avoid the hidden PU problem, the spectrum sensing must be distributed among devices[3],[5].

In addition, the device that detects the PU must notify other devices, and then the whole beacon group can move to another channel. Furthermore, by distributing the sensing results to other devices in the beacon group, a device can utilize the sensing results from multiple devices during the selection of a new operation channel. Because devices may be distributed around the network in different locations, where some devices can detect a PU during sensing, while other devices could not. In addition, some other device may also have more recent sensing results to share. In order to use optimally the spectrum opportunities, devices could also have the ability to learn from the past by exploiting the behaviour of primary users.

VI. Conclusion

In this paper, we explain the cognitive UWB radio, which takes advantage of cognitive radio technique to improve the performance of conventional UWB system. Cognitive radio appears to be a promising solution to relieve the problems that appear in UWB systems. This kind of cognitive UWB system can avoid causing interference by using unused spectrum, and the capacity of the UWB system can be improved when using free resources. Furthermore, cognitive radio features may bring flexibility to the transmission power control of the UWB radio.

The sensing schemes are explain and it is conclude that distributed sensing is better than other sensing schemes.

Refrences:

[1].A. Gupta, P. Mohapatra. A survey on ultra wide band medium access control schemes. Department of Computer Science, University of California, Davis, CA 95616, United States. 9 January 2007.

[2].N. H. Choi , J. H. Hwang, G.Zheng, N. Han, J.M. Kim. A Cognitive UWB Testbed Employing Adaptive Pulse Generation.2007

[3].Q. Ji-xin, F.Yong, Z. Shi-bing. Spectrum sensing in ultra-wideband system based on cognitive radio. Journal of Communication and Computer, ISSN1548-7709, USA. Nov. 2008, Volume 5, No.11 (Serial No.48).

[4].H. Zhang, Member, IEEE, X. Zhou, Student Member, IEEE, K. Y. Yazdandoost, Member, IEEE, and I. Multiple Signal Waveforms Adaptation in Cognitive Ultra-Wideband Radio EvolutionIEEE Journal on selected April 2006.

[5].Claudio R. C. M. da Silva, B.Choi , K. Kim. Distributed Spectrum Sensing for Cognitive Radio Systems. Bradley Department of Electrical and Computer Engineering Virginia Polytechnic Institute and State University Blacksburg, VA USA 24061.

[6].F. Granelli, H. Zhang. Cognitive Ultra Wideband Radio: A Research Vision and it's open challenges.

[7] .http://www.iut.ac.ir/~omidi/SDR07/07_UWB/SDR-UWB/Home.html