Overlay Cognitive Radio OFDM System for MIMO Operation

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Abstract— *The performance of cognitive radio systems is mainly governed by the wireless channel environment. As opposed to the typically static and predictable characteristics of a wired channel, the wireless channel is rather dynamic and unpredictable, which makes an exact analysis of the wireless communication system often difficult. For a multi-antenna communication system, referred to as the MIMO (Multiple Input Multiple Output) system, have been recently developed by the various research and standardization activities, aiming at high-speed wireless transmission and diversity gain. In this work for the receiver diversity in overlay we have used different diversity technique, out of which we used three techniques selection diversity (SC), maximal ratio combining (MRC) and equal gain combining (EGC) for overlay cognitive. QAM modulation technique and Rayleigh fading is used for checking the performance of these techniques.*

Keywords— MIMO, BFO, OSTBC, BER

I. Introduction

The entire spectrum has been fully allocated, leaving very little space for additional wireless services. In addition, the current spectrum policy makes it difficult for the rapid deployment of new services, which is particularly crucial for emergency services. Moreover, it has been found that the spectrum is underutilized temporally, spatially and spectrally. This has lead to the creation of large portions of underutilized and vacant spectrum, which are termed as spectrum white spaces or spectrum holes. For instance, the dynamic nature of the spectrum utilization by mobile telephony services has resulted in an inefficient usage of the spectrum temporally. In the television and FM broadcast bands, buffer spaces have been created in order to maintain safe distances between broadcasting stations operating on the same frequency channel. In addition, guard bands have been assigned between adjacent station frequency channels in order to avoid adjacent channel interference.

Furthermore, the demand for wireless services has been steadily increasing due to the growing need for wireless broadband connectivity. There has been an increase in the number of users of wireless services, as well as new wireless services that are constantly evolving. Moreover, the requirements of federal agencies and emergency services place high and uncompromising constraints on the spectrum. The current regulatory structure does not possess the flexibility to allow the dynamic reuse of the licensed spectrum even when it is idle as well as fast deployment of new wireless services. This rigid spectrum management system is the main cause for a potential spectrum scarcity in the near future. Cognitive wireless [1] is an a promising technology that can be utilized to enhance the utilization efficiency of the wireless spectrum, by permitting secondary user (SU) webs to co-exist alongside Primary user (PU) webs across spectrum sharing. A key necessity is that SU transmission will not adversely alter the PUs' performance. To accomplish this, a public method involves the SUs early noticing if at least one PU is sending, that is usually denoted to as "spectrum sensing". If no signals are noticed, the SUs are allowed to transmit. The significance of gesture detection can be perceived by its inclusion in the IEEE 802.22 [2] standard; a average crafted on cognitive wireless methods.

The organization of present paper is as follow. Section II presents the literature survey which highlights the facts of various researchers. Section III describes the methodology used for proposed work as in this paper cognitive radio is used. Result analysis is presented in section IV following the concluding remarks in section V.

II. Literature review

This section will provide the brief description and highlights the contribution, remarks and factors of the work done by the researchers. Many attempts have been made in the past to achieve the minimum bit error rate while the transfer of optimum amount of energy from source to destination.

Tragos, E.Z. et al, in 2013 [7] Cognitive radio (Cognitive Radio) has emerged as a promising technology to exploit the unused portions of spectrum in an opportunistic manner. The fixed spectrum allocation of governmental agencies results in unused portions of spectrum, which are called "spectrum holes" or "white spaces". Cognitive Radio technology overcomes this issue, allowing devices to sense the spectrum for unused portions and use the most suitable ones, according to some pre-defined criteria.

Beibei Wang et al, 2011 [8] The concept of cognitive radio is proposed to address the issue of spectrum efficiency and has been receiving an increasing attention in recent years, since it equips wireless users the capability to optimally adapt their operating parameters according to the interactions with the surrounding radio environment. There have been many significant developments in the past few years on cognitive radios. This paper surveys recent advances in research related to cognitive radios.

Yucek, T. et al., 2009 [9] The spectrum sensing problem has gained new aspects with cognitive radio and opportunistic spectrum access concepts. It is one of the most challenging issues in cognitive radio systems. In this paper, a survey of spectrum sensing methodologies for cognitive radio is presented. Various aspects of spectrum sensing problem are studied from a cognitive radio perspective and multi-dimensional spectrum sensing concept is introduced.

Bkassiny, M. et al., 2013 [10] The learning algorithms encountered are categorized as either supervised or unsupervised algorithms. They describe in detail several challenging learning issues that arise in cognitive radio networks (Cognitive Radio Ns), in particular in non-Markovian environments and decentralized networks, and present possible solution methods to address them.

Yuhua Xu et al., in 2013 [11] Opportunistic spectrum access (OSA) has been regarded as the most promising approach to solve the paradox between spectrum scarcity and waste. Intelligent decision making is key to OSA and differentiates it from previous wireless technologies. In this article, a survey of decision-theoretic solutions for channel selection and access strategies for OSA system is presented. They analyze the challenges facing OSA systems globally, which mainly include interactions among multiple users, dynamic spectrum opportunity, tradeoff between sequential sensing cost and expected reward, and tradeoff between exploitation and exploration in the absence of prior statistical information.

Paisana, F. et al., in 2014 [12] drew the conclusion based on a multitude of factors, such as the radar antennas' constant motion, and the absence of a hidden node problems in these bands. The unpredictability of cellular systems, on the other hand, calls for a more coordinated spectrum access approach, namely beacon signaling, that could be implemented using the already established cellular infrastructure and spare bits of its logical channels.

Salami, G. et al., 2011 [13] Centralized Dynamic Spectrum Allocation (DSA) and Distributed Dynamic Spectrum Selection (DSS) are two paradigms that aim to address this problem, whereby they use DSS (distributed) as an umbrella term for a range of terminologies for decentralized access, such as Opportunistic Spectrum Access and Dynamic Spectrum Access. This paper presents a survey on these methods, whereby they introduce, discuss, and classify several proposed architectures, techniques and solutions. Corresponding challenges from a technical point of view are also investigated, as are some of the remaining open issues. The final and perhaps most significant contribution of this work is to provide a baseline for systematically comparing the two approaches, revealing the pros and cons of DSA (centralized) and DSS (distributed) as methods of realizing spectrum sharing.

Gavrilovska, L. et al., 2013 [14] Cognitive radio networks challenge the traditional wireless networking paradigm by introducing concepts firmly stemmed into the Artificial Intelligence (AI) field, i.e., learning and reasoning. This fosters optimal resource usage and management allowing a plethora of potential applications such as secondary spectrum access, cognitive wireless backbones, cognitive machine-to-machine etc. The majority of overview works in the field of cognitive radio networks deal with the notions of observation and adaptations, which are not a distinguished cognitive radio networking aspect. Therefore, this paper provides insight into the mechanisms for obtaining and inferring knowledge that clearly set apart the cognitive radio networks from other wireless solutions.

Changwoo Lee et al, 2010 [15] A cognitive radio (Cognitive Radio) is very significant technology to use a spectrum dynamically in wireless communication networks. However, very little has been done on using the spectrum usage patterns to handle with the problem of spectrum allocation in dynamic spectrum access. They suggest a scheme by exploiting spectrum usage patterns for the efficient spectrum management and reduce the communication cost in cognitive radio networks (Cognitive RadioNs). They propose the following three factors into account: spectrum sensing scheme with a sleep mode, spectrum decision scheme with a probability of spectrum access and spectrum handoff scheme with back-off time. All factors make use of spectrum usage patterns based on the statistical information. The first factor reduces the number of spectrum sensing. The second increases the opportunity of spectrum access and the last decreases the number of spectrum handoff. First of all, their proposed spectrum management scheme considers the analysis of the spectrum usage patterns and various factors obtained from the analysis is applied to lessen the communication cost in Cognitive RadioNs. The simulation results show that their proposed scheme improve the efficiency of spectrum management in dynamic spectrum access.

Poston, Jeffrey D. et al. (2005) [16] In this paper, sharing spectrum with systems that employ frequency reuse over large geographical areas (e.g., TV stations) provides an opportunity to improve spectrum utilization. The Federal Communications Commission (FCC) is considering such sharing in the TV hands (2004). This technical and regulatory opportunity prompted the IEEE to create a new committee, 802.22, that will develop a wireless regional area network (WRAN) standard for operating on vacant TV channels. This paper quantifies the idle bandwidth in the current TV band assignments; although the TV station information incorporated here is specific to the United States, the methodology and findings should be relevant to a global audience. The methodology for this analysis is distinct from prior literature on spectrum use measurements and offers a complementary perspective. Furthermore, the statistics from the analysis point to the value of systems that can operate on discontiguous portions of the radio spectrum. One approach, a modified form of OFDM here termed Discontiguous OFDM (DOFDM), could be well-suited to this dynamic spectrum access application. This paper provides a preliminary description of a DOFDM prototype and describes special considerations for its implementation

Hausl, Christoph, et al. (2007) [17]In this paper, they consider a relay communication with distributed channel coding. The source broadcasts channel encoded and modulated information to the relay and to the destination. In a second time slot, the relay sends additional redundancy to the destination. The broadcast from the source leads to the dilemma of adjusting the modulation scheme to the relay or to the destination link. They propose to use hierarchical modulation to solve this dilemma. They show with simulation results that the proposed system achieves a significant gain compared to reference systems.

Vuran, Mehmet C. et al. (2007) [18] In this paper, next generation (NG) wireless networks are envisioned to provide high bandwidth to mobile users via bandwidth aggregation over heterogeneous wireless architectures. NG wireless networks, however, impose challenges due to their architectural heterogeneity in terms of different access schemes, resource allocation techniques as well as diverse quality of service requirements. These heterogeneities must be captured and handled dynamically as mobile terminals roam between different wireless architectures. However, to address these challenges, the existing proposals require either a significant modification in the network structure and in base stations or a completely new architecture, which lead to integration problems in terms of implementation costs, scalability and backward compatibility. Thus, the integration of the existing medium access schemes, e.g., CSMA, TDMA and CDMA, dictates an adaptive and seamless medium access control (MAC) layer that can achieve high network utilization and meet diverse quality of service (QoS) requirements. In this paper, an adaptive medium access control (A-MAC) layer is proposed to address the heterogeneities posed by the NG wireless networks. A-MAC introduces a two-layered MAC framework that accomplishes the adaptivity to both architectural heterogeneities and diverse QoS requirements. A novel virtual cube concept is introduced as a unified metric to model heterogeneous access schemes and capture their behavior. Based on the virtual cube concept, A-MAC provides architecture-independent decision and QoS based scheduling algorithms for efficient multi-network access.

This section has provided the brief review of the work done in past. It also highlighted the factors, contribution and remarks on the achievement.

III. Frame Work for Implementation

The main objectives of research work are To Study and Analyze MIMO in Overlay Cognitive Radio.

To implement overlay cognitive MIMO channel and to select the Secondary User (Tx) based on interference.

To apply various diversity techniques including MRC, SC, and EGC.

To evaluate the performance of proposed work using BER.

Consider a single-user system model wherein the received signal is a sum of the desired signal and noise:

$$x = hu(t) + n$$

Where u(t) is the unit power signal transmitted, h represents the channel (including the signal power) and n the noise. The power in the signal over a single symbol period, T_s, at element n, is

$$P = \frac{1}{T_s}\int_0^{T_s} |h_n(t)|^2 |u(t)|^2 dt = |h_n(t)|^2 \frac{1}{T_s}\int_0^{T_s} |u(t)|^2 dt = |h_n|^2$$

Where, since we are assuming slow fading, the term $|h_n(t)|$ remains constant over a symbol period and can be brought out of the integral and u(t) is assumed to have unit power. Setting $E\{|n_n(t)|^2\} = \sigma^2$ and we get the instantaneous SNR at the n-th element (γ_n) to be

$$\gamma_n = \frac{|h_n|^2}{\sigma^2}$$

This instantaneous SNR is a random variable with a specific realization given the channel realization h_n. The expectation value taken to estimate the noise power is therefore taken over a relatively short time period. Later on we will also find a long-term average SNR.

We are assuming Rayleigh fading, so $h_n = |h_n| e^{j\angle h_n}$, where $\angle h_n$ is uniform in [0, 2π) and $|h_n|$ has a Rayleigh pdf, implying $|h_n|^2$ (and n) has an exponential pdf

$$|h_n| \sim \frac{2|h_n|}{P_0} e^{-|h_n|^2/P_0}$$

$$\gamma_n \sim \frac{1}{\Gamma} e^{-\gamma_n/\Gamma}$$

$$\Gamma = E\{\gamma_n\} = \frac{E\{|h_n|^2\}}{\sigma^2} = \frac{P_0}{\sigma^2}$$

The instantaneous SNR at each element that is an exponentially distributed random variable. Γ represents the average SNR at each element. This is also the SNR of a single element antenna, i.e., the SNR if there were no array. Γ will, therefore, serve as a baseline for the improvement in SNR.

The outage probability is defined as the probability that the output SNR,γis below a threshold,γ_s. Since the SNR is exponentially distributed,

$$P_{out} = P(\gamma < \gamma_s) = \int_0^{\gamma_s} \frac{1}{\Gamma} e^{-\gamma/\Gamma} d\gamma$$
$$= \left[1 - e^{-\gamma_s/\Gamma}\right]$$

Note that as $\Gamma \to \infty$, $P_{out} \propto 1/\Gamma$.

The bit error rate of a BPSK system given a SNR ofγ is given by $\mathrm{erfc}(\sqrt{2\gamma}) = Q(|\frac{h}{\sigma}|)$, where,

$$Q(x) = \left(1/\sqrt{2\pi}\right)\int_x^{\infty} e^{-t^2/2} dt$$

The BER averaged over the Rayleigh fading of Eqn. (4) is therefore,

$$BER = \int_0^{\infty} \frac{2|h|}{P_0} e^{-\frac{|h|^2}{P_0}} Q\left(\frac{|h|}{\sigma}\right) d(|h|)$$
$$= \frac{1}{2}\left(1 - \sqrt{\frac{\Gamma}{1+\Gamma}}\right)$$

The final equation uses Eqn. (3.61) of Verdu [3]. Note,

$$\lim_{\Gamma\to\infty} BER = \frac{1}{4\Gamma}$$

Using the BER and P_{out} expressions an important conclusion is that both these error expressions fall as (1/SNR) as SNR → ∞. This extremely slow fall off in error rate is due to the variance in the SNR arising from the random channel.

Within diversity combining (or diversity reception) are three common techniques: Selection Combining, Maximal Ratio Combining (MRC) and Equal Gain Combining (EGC). For all three, the goal is to find a set of weights w, as shown in Fig. above. The structure is similar to what we used in developing interference cancellation.

IV. Result Analysis

In this chapter, main focus on the bit error rate of different modulation technique. A comparison is done between multichannel bacteria forging optimization algorithm and orthogonal space time block codes.

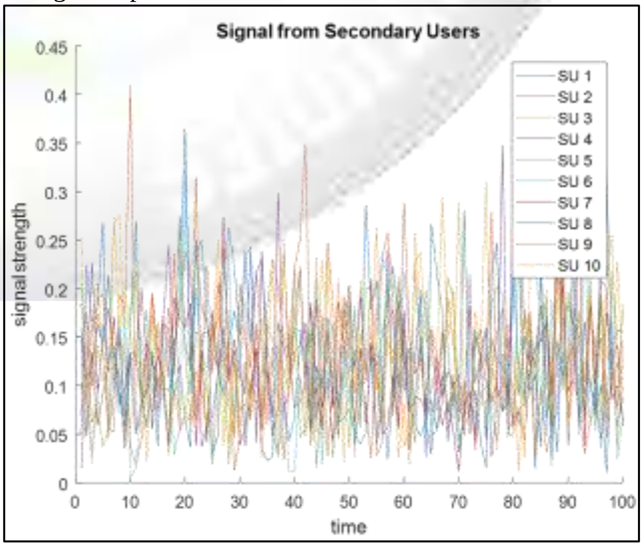

Fig. 1: Signal from 4 Secondary Users (Tx = 10)

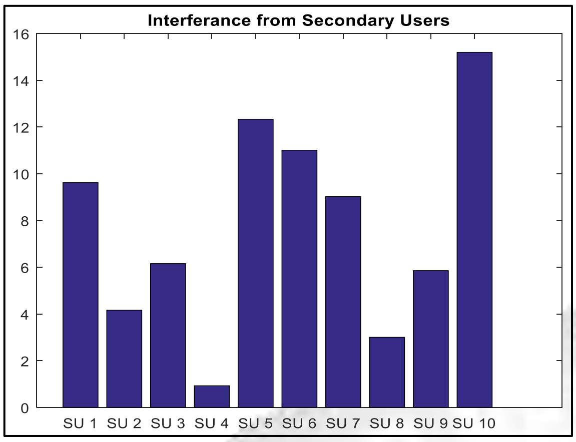

Fig. 2: Detected interference from Secondary Users

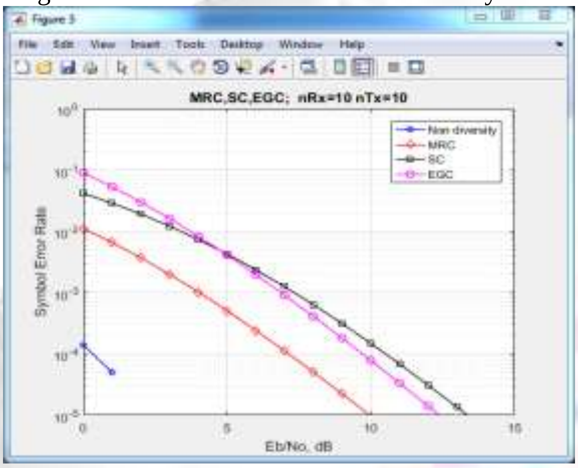

Fig. 3: BER Comparison of various Diversity techniques including MRC, SC and EGC with no diversity

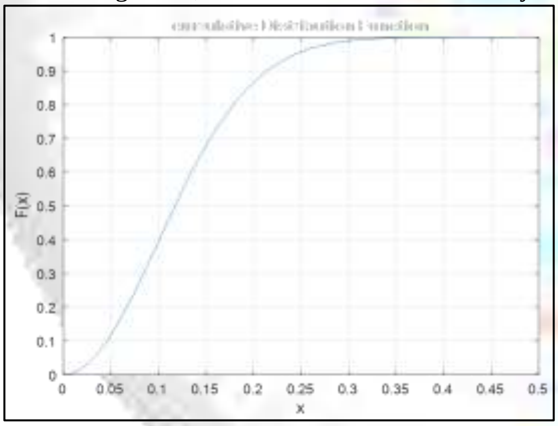

Fig. 4: Cumulative Distribution of the Received Signal

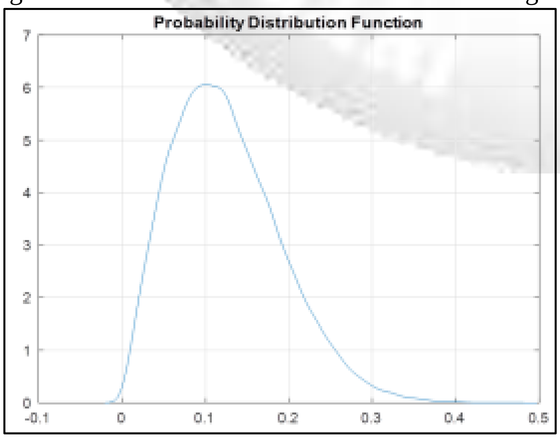

Fig. 5: Probability Distribution of the Received Signal

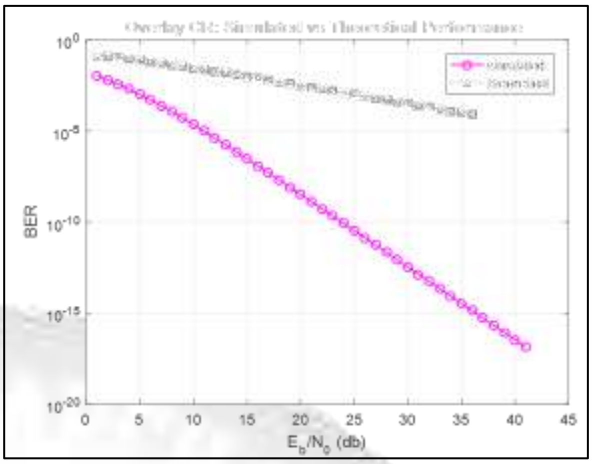

Fig. 6: Comparison of BER performance of overlay CR with theoretical BER

V. Conclusion

We observed that when we calculated the value of SNR with different no. of antenna for these three techniques, maximal ratio combining diversity technique gives the best result as compare to the equal gain combining and selection diversity. For the calculation the bit error rate with respect to the E_b/N_0 then again maximal ratio combining have lesser value as compare to the equal gain combining and selection diversity. So, we can say that the performance of the maximal ratio combining is better as compare to the equal gain combining and selection diversity. In flat fading channels, maximal ratio combining (MRC) diversity is well known to be optimum in the sense of maximizing the output signal-to-noise ratio.

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