

Green Power Control in Hybrid Underlay/Overlay Cognitive Radio Networks

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Abstract

In this paper, Cognitive radio technology is used to improve spectrum utilization and also to address the spectrum scarcity problem in the wireless networks. To fully utilize the primary spectrum and maximize the spectral efficiency, overlay and underlay transmissions, which exploits the white and gray spaces respectively, should be used together. Interference mitigation is a major issue in underlay networks and spectrum sensing is a crucial function in overlay networks. In the proposed work the entire spectrum is used for underlay transmission to minimize the PU interference and the spectrum holes are used for overlay transmission to maximize the data rate. An efficient green power control algorithm for hybrid overlay/underlay cognitive radio network is proposed. The performance (total achievable Bit error rate and throughput) of the proposed algorithm will be analyzed using MATLAB.

Keywords: Cognitive radio; Green communication; Power control; Underlay/overlay

Introduction

Cognitive radio (CR), introduced by Mitola, Maguire [1] and Haykin [2], is a promising method to solve the spectrum efficiency problem, in which all radio devices are able to explore the usage of all frequencies and find final all which are free. Then alone can change its frequency to send or receive data. In general, the CR device is a technique that allows the use of all unused time in the radio frequency, which greatly increases the use of the spectrum. This is possible through the use of artificial intelligence techniques in the radio devices. They can automatically find free frequencies and change the band, so that the user is not able to notice it.

The CR networks are built with cognitive radio devices. Thanks to them it is possible to obtain two kind of wireless communication systems. The first is based solely on the device CR, that uses licensed frequencies. The second is formed by the CR equipments which work by using the unlicensed bands. All CR radios belonging to the first group are defined as primary users (PUs) and are accessing the licensed bands. The CR devices occupied the unlicensed bands are called secondary users (SUs). These devices can use the free licensed frequency bands without causing a harmful interference to the licensed primary users (PUs). It overcomes the pressing problem of lack of bandwidth or use the unused band (also called spectrum hole).

Energy-efficient green communication techniques are of special importance in the design process of the future wireless networks. The CR networks are identified as a very important technology which can overcome of carbon dioxide gas emission. In such a context, the selected performance metrics for a transmitter are derived from the energy-efficient definition for wireless data [3]. The problem of green power control in the CR networks has been studied by Le Treust et al. [4]. The authors proposed a sensing game where all the transmitters are assumed to take the decision whether to sense or not.

Existing System

The hybrid MC-CDMA system model is shown in Figure 1 where the primary OFDMA-based system and the Cognitive Radio Network (CRN) coexist in the same band B. The total bandwidth is divided into M equi-bandwidth subcarriers. It has been assumed that the spectrum

sensing is performed and the available bands and the interference threshold for the occupied bands are known to the CRN. Overlay is transmission through the spectrum trap while underlay exploiter are overloading the system utilizing the entire spectrum aiming to achieve more variety gain and interference suppression with maintaining orthogonality with the overlay users as much as possible as shown in Figure 1. The number of subcarriers occupied by the plutonium system is represented by M_{pu} and the number of subcarriers to be used by the overlay CR is shown by M_{su} which are known from the spectrum sensing results. The subcarrier handiness for the CR system is shown by an availability vector \mathbf{a} in which $a_i \in \{0,1\}$ with 1 indicating the i -th component to be available, and 0 not available for the overlay [5].

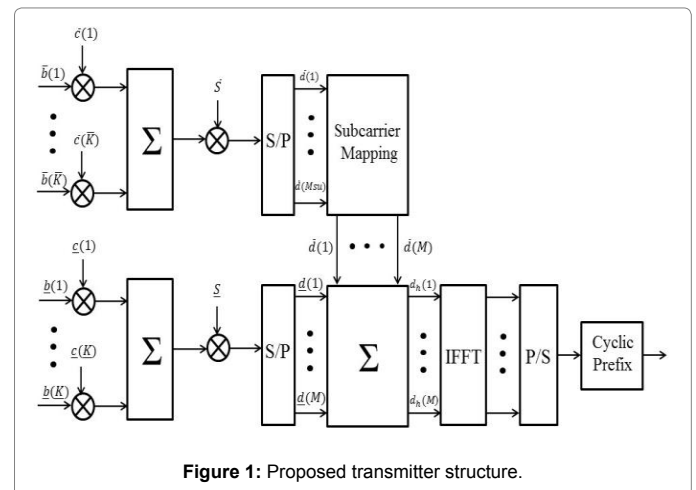


Figure 1: Proposed transmitter structure.

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In this model, K^- overlay users are using the M_{su} available subcarriers and K^- underlay users will utilize the whole spectrum while maintaining the interference threshold of the PU and at the same time keeping the orthogonality with overlay. In this model, K^- overlay users are using the M_{su} available subcarriers and K^- users. The total number of cognitive users is shown by K . P consecutive symbols are spread with the spreading factor G and are sent in parallel by each overlay user, i.e. $M_{su} = GP$. Since underlay is utilizing the whole spectrum, the underlay code length will be M [6]. The spread data of each overlay user is obtained by underlay users will utilize the whole spectrum while maintaining the interference threshold of the PU and at the same time keeping the orthogonality with overlay multiplying the users symbol by its specific signature sequence of each code has unit energy. The column vector y^k is defined as:

$$y^k = [b_1 c_1, \dots, b_1 c_G, \dots, b_p c_1, \dots, b_p c_G]^T \in C^{Msux1}.$$

Simulation Result

The results show that in spite of a very high interference level from the PU, the underlay maintains good performance, and as the number of available overlay subcarriers increases, the underlay performance enhances. Next, the effect of underlay transmission to the overlay users in the proposed overloaded operation is evaluated. The overlay BER performance is compared with that of an overlay-only system and is shown in Figure 2. In the hybrid case, the overlay occupancy level is 50% (256 subcarriers). It is observed that the overlay performance degradation is very small [7]. Therefore, with the proposed hybrid system, the underlay can enhance the spectral efficiency without degrading the overlay performance (Figure 3). Underlay performance for increasing number of underlay users for two cases when overlay is fully loaded and when there is no overlay user in the system $M=64$. Presents the underlay performance with an increasing number of underlay users for two cases of full-overlay and without-overlay users, using solid and dashed lines, respectively. The number of occupied subcarriers, i.e., M_{pu} , is considered to be 64, i.e., the PU is utilizing one block of subcarriers only, and the rest of the spectrum is being utilized by an overlay cognitive system. The number of underlay users, i.e., K , is shown by K_{un} in the figure. Underlay interference to overlay is assumed to be negligible since the overlay transmission power is considerably higher than the underlay transmission power. On the other hand, the underlay codes have been meticulously chosen according to the number of overlay and underlay overlapping subcarriers to make the

least possible correlation with the overlay system. Green power control in underlaying networks [8].

Let us consider a CR network, as shown in a simplified (Figure 4), which shows a coexistence of primary and secondary networks in CR network. The primary user network consists of M active PUs. We assume that the secondary users (SUs) belong to the secondary network and use orthogonal frequency division multiplexing (OFDM) technique for transmission of data. Let us denote that the total number of SUs is given by K . The SUs divide the acquired bandwidth into N subcarriers. When CR devices and PUs transmit in an underlay manner, mutual interference may arise. Thus, CR nodes have to firmly control their power to avoid any serious interference with active PUs. Spectrum sharing in an underlay CR networks involves the following assumptions.

PUs are licensed users possessing a license to operate in a certain spectrum band with interference-free environment. PU-Tx-primary user transmitter (primary user base station, PUBS) that offers licensed spectrum to PUs. Secondary users (SUs) can take the advantages of unused spectrum band. SUs coexist with PUs in an underlay manner and have no spectrum license.

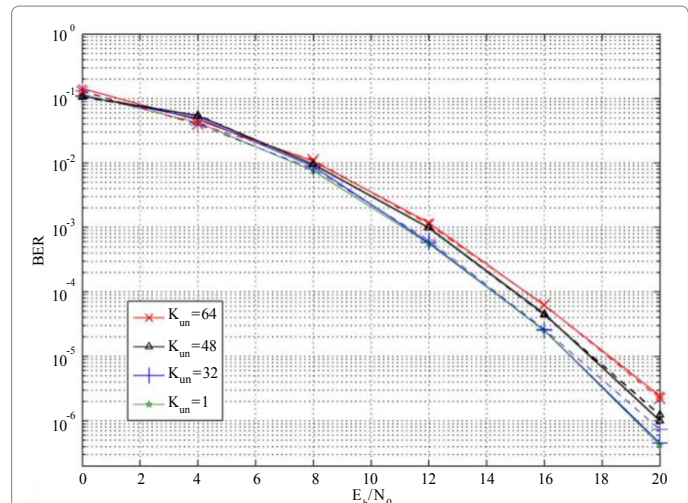


Figure 3: Underlay performance for increasing number of underlay users for two cases when overlay is fully loaded and when there is no overlay user in the system $M=64$.

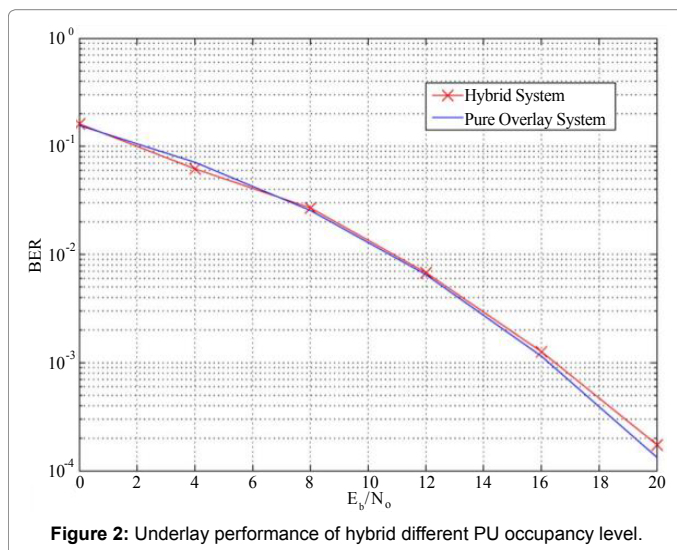


Figure 2: Underlay performance of hybrid different PU occupancy level.

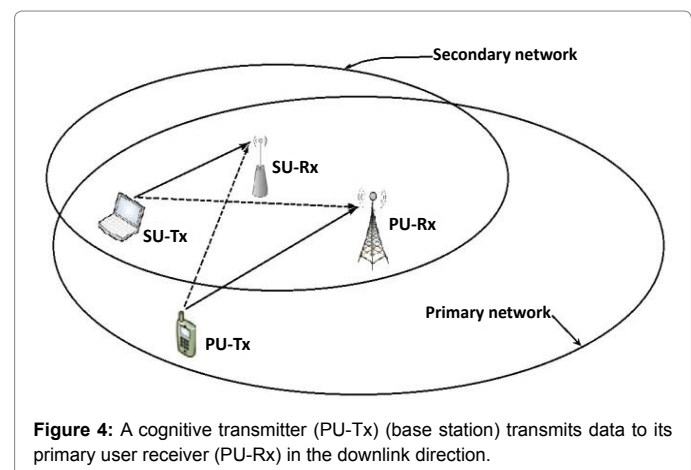


Figure 4: A cognitive transmitter (PU-Tx) (base station) transmits data to its primary user receiver (PU-Rx) in the downlink direction.

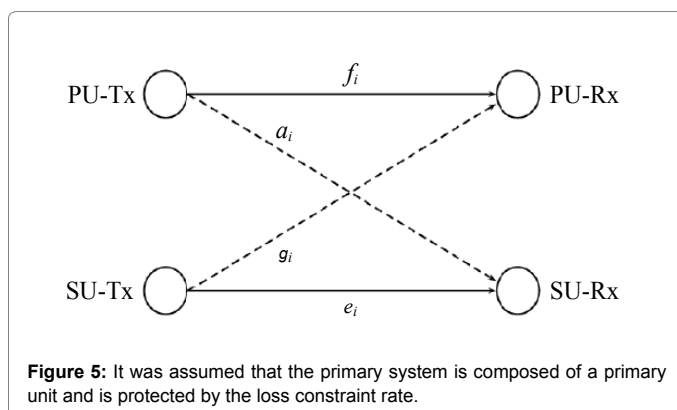
In presented channel model, as shown in Figure 4, a cognitive transmitter (PU-Tx) (base station) transmits data to its primary user receiver (PU-Rx) in the downlink direction. The primary users are the licensed owners of the spectrum. The SUs have the possibility to use the unused spectrum. When the secondary user transmitter (SU-Tx) transmits data to their secondary user receiver (SU-Rx), it inherently causes the mutual interference to the PUs. Analogous, the PUs cause mutual interference to the SUs as well. The relationship between the rate loss constraint and the interference power constraint is required to implement this scenario of wireless communication. In practice, by use the channel state information [9] (CSI) of the primary link and the interference links is needed to find a free and good channel as quickly as possible.

In this section, some numerical results to verify the effectiveness of the proposed power allocation schemes are presented. The numerical experiments assumed that all the channels (i.e. primary link, secondary link, interference links) are Rayleigh fading channels. The channel power gains for these channels are exponentially distributed. Additionally, it was assumed that the number of subcarriers N of the primary system is equal to 128 and the transmit power budget of the primary system is equal to 10 dB. The supposed noise level on each subcarrier is identical and equal to 1, namely $N_0=1$. In our approach, all results are compared to the outcome of the 'power decrement water-filling' algorithm recognised by the researcher as the optimal power allocation method in CR networks with OFDM method. This made it possible to check the quality of the method [10].

First, they investigated the effects of loss constraints rate on the SU's transmission rate. It was assumed that the primary system is composed of a primary unit and is protected by the loss constraint rate. The obtained results are shown in Figure 5. The graphs in Figure 6, present the transmission rate of SU depending on the transmit power constraint, P_a , under different PU's constraints rates. We observed that the transmission rate of SU increases with the transmit power constraint and PU's loss constraint rate. Moreover, for a small value of P_a , the transmission rate is also a little. This is due to the dominant constraint when P_a is small. Furthermore, with the increase of P_a , the loss constraint rate becomes the dominant constraint.

Proposed System

Energy-efficient green communication techniques are of special importance in the design process of the future wireless networks. The CR networks are identified as a very important technology which can overcome of carbon dioxide gas emission. In such a context, the selected performance metrics for a transmitter are derived from the energy-efficient definition for wireless data. The paper proposed a sensing game



where all the transmitters are assumed to take the decision whether to sense or not.

The performance of hybrid overlay and underlay cognitive radio networks with green power control algorithm has been presented in this chapter. The performance of hybrid overlay and underlay cognitive radio networks with green power control has been presented in this chapter.

Underlay spectrum sharing

This technique requires sophisticated spread spectrum mechanisms. It allows to co-exist both PUs and SUs on the same geographical area and using the same spectrum band.

This technique achieves two main objectives:

- To maintain the generated interference to PU within an acceptable threshold,
- To ensure the required transmit power of all SUs.

Overlay spectrum sharing

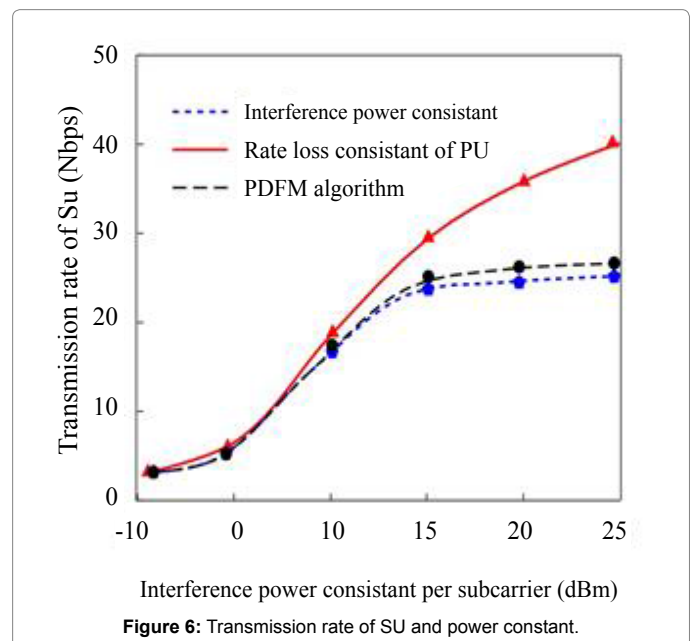
In this technique a spectrum sensing procedure is required to avoid potential collision with the licensed users.

The nodes use the band portion which is not in current use by the licensed users. Thus, the interference to the PUs is minimized.

Underlay transmission and the interference threshold

Underlay is signal with depression business leader spectral density and strict interference concerns. There has been a long regulatory history for carpet pad transmission system since 1938 when FCC allowed the use of certain low-superpower remote controls for radio.

It was for limited applications and only several narrow-bands. Figure 7 shows the spectrum opportunity for underlay transmission. From 1985 underlay was still limited to Industrial, Scientific, and Medical (ISM) bands till in 1989 the general rewrite of unlicensed bands permitted underlay transmission most bands, but the "restricted bands", to level [11].



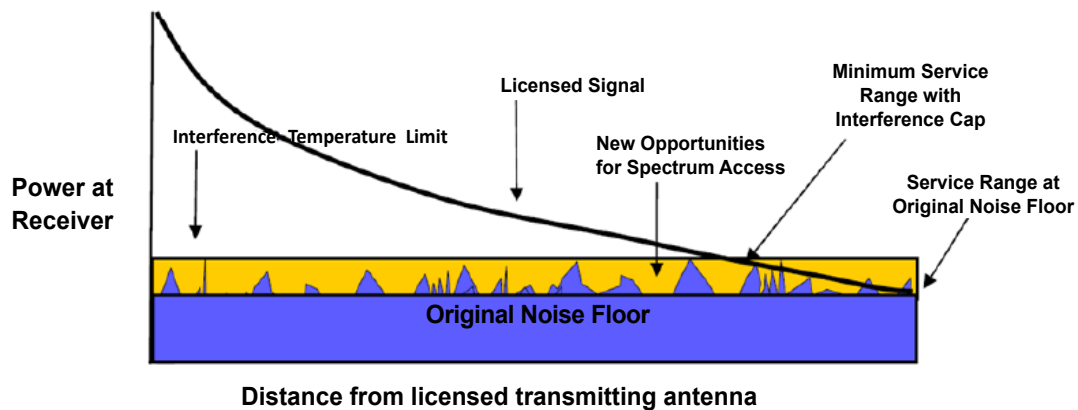


Figure 7: Underlay spectrum opportunity and interference threshold.

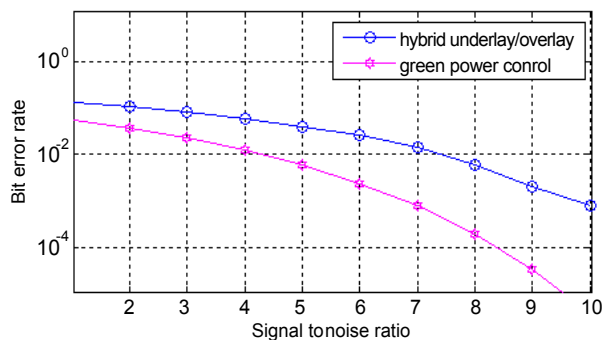


Figure 8: Underlay performance of with and without green power control.

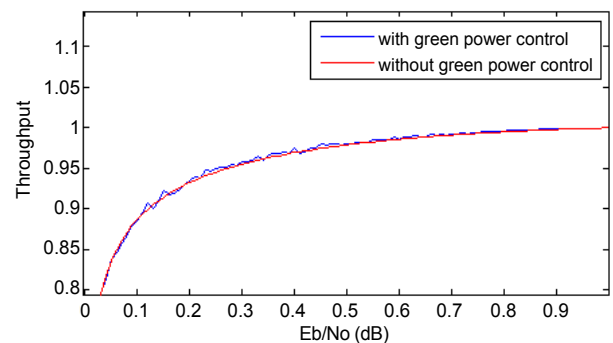


Figure 9: Performance of throughput in with and without power control.

In 1998 with the progress in Ultra-Wide Band (UWB) technology underlay was examined but it had been the area of dispute over time concerning the noise door increase and seriously detecting the licenses. Following the spectrum access issues, a Spectrum Policy Task Force was established in June 2002 to decide on the spectrum policy changes. The report showed that the problem is with the limitations due to the static frequency allocation than the physical scarcity of the spectrum.

Simulation Result

In the hybrid case, the overlay occupancy level is 50% (256subcarriers). It is observed that the overlayer carrying into action degradation is very small. Therefore, with the proposed hybrid organisation, the underlay can enhance the spectral efficiency without degrading the overlay performance. The incorporation of green power control algorithm for hybridoverlay/underlay cognitive radio networks has improved the BER as evidenced in the simulation result. Simulation was carried out using Matlab Version 2017 in Figure 8.

Simulation Parameters

PU signal-QPSK channel-AWGN
No of subcarriers: 256
Noise level on each subcarrier no-1
PU transmit poer-10dB is shown in Figure 9.

Throughput Evaluation

Secondary system throughput is $R_s = (T - T_s) / T * C_s * (1 - P_f) * P(H_0)$

Probability of false alarm $P_f = Q(\sqrt{2\gamma} + 1Q(P_d) + \sqrt{T_s F_s \gamma})$

The channel capacity for the secondary system is $C_s = \log_2(1 + SNR_s)$

The probability that the SU can make data transmission during the time $(T - T_s)$ is $(1 - P_f) * P(H_0)$.

Conclusion

A green power control algorithm was incorporated in a hybrid overlay/underlay cognitive radio network and the performance has been studied in terms of Bit Error Rate by conducting simulation using MATLAB version 2017.

Future Work

Full-Duplex spectrum sensing can be used to identify spectrum holes for overlay networks and performance in terms of achievable transmission rate can be studied.

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