International Journal of Advanced Computer Technology (IJACT)
ISSN: 2319-7900 www.ijact.org Volume IX, Issue IV, August 2020

Energy-Efficient Resource Allotment for OFDM-Based Cognitive Radio Networks

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Abstract— *Orthogonal frequency-division multiplexing (OFDM), is a frequency-division multiplexing (FDM) scheme used as a digital multi-carrier modulation method. Recently, some schemes have proposed to reduce the number of DFT blocks required. OFDM meets the LTE requirement for spectrum flexibility and enables cost-efficient solutions for vast carriers with high peak rates. Ultra-wideband characteristics are well-suited to short-distance applications, such as PC peripherals. Adaptive resource allocation (RA) for the OFDM systems has been studied extensively for more than a decade. A survey can be found in and references therein. For the arising OFDM-based CR, a system, adaptive RA has also attracted much attention starting from the surfacing of the CR and with the references therein provides a comprehensive survey. For single SU case, RA in an OFDM-based CR system degenerates into power distribution. Due to low emission levels permitted by regulatory agencies, UWB systems tend to be short-range indoor applications. We studied the energy-efficient resource allocation in an OFDM-based CR network, which is an urgent task for green communication design.*

Keywords—Digital Image, Lossless Image, Cryptography, Watermarking.

1. INTRODUCTION

Multiple receive antennas can be employed with orthogonal frequency-division multiplexing (OFDM) to improve system performance, where space diversity achieved using subcarrier-based space combining. However, in subcarrier-based space combining, it required that multiple discrete Fourier transform (DFT) processing, each per receive antenna, be used. As a result, such systems are quite complicated because the complexity of DFT is a significant concern for system implementation. Recently, some schemes have proposed to reduce the number of DFT blocks required. In the principle of orthogonal designs, the number of DFT blocks reduced to half with 3 dB performance degradation. In the received time-domain OFDM symbols from each antenna are first weighted and then combined before the DFT processing. By doing so, the number of DFT blocks required reduced to one. In OFDM with multiple transmit and multiple receive antennas (MIMO) is investigated, and a reduced- complexity algorithm proposed to reduce the number of DFT blocks required to one. Motivated by the work in, and based upon Eigen analysis, we offer a receive space-diversity scheme to effectively trade-off system performance and complexity. The method regarded as a particular case of our proposed scheme. However, we will show that excellent performance is only applicable when the number of distinct paths in the channel is minimal. When the number of separate paths is large, it demonstrated that more DFT blocks are needed. Our proposed scheme, the received signals are weighted and combined both before and after the DFT processing, and the margin of the performance improvement decreases along with the increase of the number of DFT blocks. As a result, system complexity and performance can be effectively traded-off. When the weighting coefficients obtained assuming perfect channel information, we will show that the maximum number of DFT blocks required is the minimum of the number of receive antennas and the number of distinct paths in the channel. Such an achievement obtained without performance loss, compared with subcarrier-based space combining.

1.1 Orthogonality

In OFDM, the sub-carrier frequencies chosen so that the sub-carriers are orthogonal to each other, meaning that cross-talk between the sub-channels eliminated and inter-carrier guard bands are not required. This dramatically simplifies the design of both the transmitter and the receiver; unlike conventional FDM, a separate filter for each sub-channel not needed. The orthogonality requires that the sub-carrier spacing is

$$\Delta f = \frac{k}{T_U}\,\text{Hertz},$$

where T_U seconds is the useful symbol duration (the receiver side window size), and k is a positive integer, typically equal to 1.

Therefore, with N sub-carriers, the total passband bandwidth will be $B \approx N \cdot \Delta f$ (Hz). The orthogonality also allows high spectral efficiency, with a total symbol rate near the Nyquist rate for the equivalent baseband signal (i.e. near half the Nyquist rate for the double-sideband physical passband signal). Almost the whole available frequency band can be utilized. OFDM generally has a nearly 'white' spectrum, giving it benign electromagnetic interference properties for other co-channel users. A simple example: A useful symbol duration T_U = 1 ms would require a sub-carrier spacing of

$$\Delta f = \frac{1}{1\,\text{ms}} = 1\,\text{kHz}$$

(or an integer multiple of that) for orthogonality. N = 1,000 sub-carriers would result in a total passband bandwidth of $N\Delta f$ = 1 MHz For this symbol time, the required bandwidth in theory according to Nyquist is $N/2T_U$ = 0.5 MHz (i.e., half of the achieved bandwidth required by our scheme). If a guard interval is applied (see below), the Nyquist bandwidth requirement would be even lower. The FFT would result in N = 1,000 samples per symbol. If no guard interval were applied, this would result in a baseband complex-valued signal with a sample rate of 1 MHz, which would require a baseband bandwidth of 0.5 MHz according to Nyquist. However, the passband RF signal produced by multiplying the baseband signal with a carrier waveform (i.e., double-sideband quadrature amplitude-modulation) resulting in a passband bandwidth of 1 MHz. A single-sideband (SSB) or vestigial sideband (VSB) modulation scheme would achieve almost half that bandwidth for the same symbol rate (i.e., twice as high spectral efficiency for the same symbol alphabet length). It is, however, more sensitive to multipath interference. OFDM requires very accurate frequency synchronization between the receiver and the transmitter; with frequency deviation, the sub-carriers will no longer be orthogonal, causing inter-carrier interference (ICI) (i.e., cross-talk between the sub-carriers). Frequency offsets are typically caused by mismatched transmitter and receiver oscillators, or by Doppler shift due to movement. While Doppler shift alone may be compensated for by the receiver, the situation worsened when combined with multipath, as reflections will appear at various frequency offsets, which is much harder to correct. This effect typically worsens as speed increases and is an important factor limiting the use of OFDM in high-speed vehicles. Several techniques for ICI suppression suggested, but they may increase the receiver complexity.

1.2 Cognitive Radio Network

Cognitive radio is an intelligent radio that can be programmed and configured dynamically. Its transceiver designed to use the best wireless channels in its vicinity. Such a radio automatically detects available channels in wireless spectrum, then accordingly changes its transmission or reception parameters to allow more concurrent wireless communications in a given spectrum band at one location. This process is a form of dynamic spectrum management.

3. Problem Statement

We assume that AP in the CR system has perfect knowledge of the channel state information between the transmitter of the AP and the receivers of the SUs, as well as ideal CSI between the transmitters of the AP and the receivers of the active PUs. The former can be approximated by assuming channel reciprocity. The latter can be periodically measured by a band manager and sent to the CR AP via a common control channel, or estimated by listening to a beacon signal and then fed-back to the CR AP. The CSI can also be calculated by using the statistical information of channel gains, which may yield a chance-constrained optimization model that emphasizes the long-term energy efficiency of the CR system. In this paper, we consider instantaneous energy efficiency with perfect CSI. Hence the results obtained by our proposed scheme can serve as an upper bound on the achievable EE with channel estimation errors. To prohibit the unacceptable performance degradation of the PUs, the interference introduced to the PUs must be carefully controlled in a tolerable range. Some promising methods can be employed by the CR system to eliminate the interference to the PUs, such as sub-carrier weighting and non-continuous OFDM scheme.

4. Proposed Algorithm for Watermarking

The methodology has implemented in this research work is utilizing the basic concept of the CR using the OFDM. Orthogonal frequency-division multiplexing (OFDM), essentially identical to coded OFDM (COFDM) and discrete multi-tone modulation (DMT), is a frequency-division multiplexing (FDM) scheme utilized as a digital multi-carrier modulation method. A large number of closely-spaced orthogonal sub-carriers used to carry data. The data divided into several parallel data streams or channels, one for each sub-carrier. Each sub-carrier is modulated with a conventional modulation scheme (such as quadrature amplitude modulation or phase-shift keying) at a low symbol rate, maintaining total data rates similar to conventional single-carrier modulation schemes in the same bandwidth. OFDM has developed into a popular scheme for wideband digital communication, whether wireless or over copper wires, used in applications such as digital television and audio broadcasting, wireless networking and broadband internet access. The primary advantage of OFDM over single-carrier schemes is its ability to cope with severe channel conditions (for example, attenuation of high frequencies in a long copper wire, narrowband interference and frequency-selective fading due to multipath) without complex equalization filters. Channel equalization is simplified because OFDM may be viewed as using many slowly-modulated narrowband signals rather than one rapidly-modulated wideband signal. The low symbol rate makes the use of a guard interval between symbols affordable, making it possible to handle time-spreading and eliminate inter-symbol interference. This mechanism also facilitates the design of single frequency networks, where several adjacent transmitters send the same signal simultaneously at the same frequency, as the signals from multiple distant transmitters may be combined constructively, rather than interfering as would typically occur in a traditional single-carrier system.

4.1 Block Diagram of Proposed Methodology

We process the signal for communication and save the energy, first take data and convert bit to a symbol or serial to parallel. They modulate data with the help of QAM modulation after modulation applies USB algorithm and calculate the ser and ber and optimize data and remove ber and SNR value with the help of low pass filter and then plot a final result as shown on a figure 1.

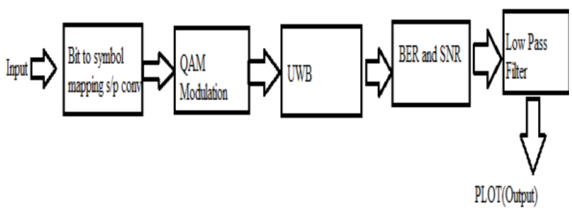

Figure 1 Block Diagram of Proposed Methodology

Conclusion

We studied the energy-efficient resource allocation in an OFDM-based CR network, which is an urgent task for green communication design. Our model is general and covers many practical constraints, leading to an intractable mixed integer programming problem. We perform a series of equivalent transformations by analyzing the formulated problem intensively, converting it into a convex optimization problem which can be solved by a standard optimization technique. Furthermore, we develop an efficient algorithm to work out the (near) optimal solution by exploiting its special structure to update Newton step in an ingenious way, reducing the computation complexity dramatically and making its applications possible. Numerical results show that our resource allocation proposal can achieve near-optimal energy efficiency, while the algorithm developed in this thesis converges quickly and stably. For future work, imperfect channel state information case should be considered. Efficient heuristic methods with lower complexity are also promising for this real-time optimization problem, especially for the sub-channel assignment that introduces intractable integer variables.

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