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Multiuser Wireless communication Using OFDM System

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Abstract

In this paper, we study the multiuser orthogonal frequency division multiplexing (OFDM) downlink systems with simultaneous wireless information and power transfer for resource allocation algorithm design. The algorithm design for maximizing the energy efficiency of data transmission (bit/Joule delivered to the users) is formulated. We study the design for simultaneous wireless information and power transfer (SWIPT) in downlink multiuser orthogonal frequency division multiplexing (OFDM) systems, where from a fixed access point (AP) the user harvest energy and decode information using the same received signals. we consider orthogonal frequency division multiple access (OFDMA) scheme for information transmission. Due to the practical limitation at receiver side each user apply power splitting (PS) to coordinate the energy harvesting (EH) and information decoding (ID) processes. The main purpose of this paper is to use the MATLAB Simulink of OFDM to analyse the energy harvesting and information decoding processes. Simulation results show that the proposed iterative resource allocation algorithm achieves the maximum energy efficiency of the system and show how system capacity, energy efficiency and wireless power transfer benefit from the presence of multiple users in the system.

Keywords: SWIPT (Simultaneous wireless information and power transfer), energy harvesting, wireless power, OFDM, OFDMA, power splitting.

1. Introduction

Simultaneous wireless information and power transfer (SWIPT) provides energy source for the wireless networks [1]. The SWIPT system offers great advantage to mobile users, thus it understand both uses of radio signals to transfer energy as well as information. In [2] the first proposed idea of transmitting information and energy simultaneously assuming that from the same received signal the receiver is able to decode information and harvest energy simultaneously.

In high-speed communication a common problem found is Inter-Symbol Interference (ISI). ISI occurs when a transmission interferes with itself and the receiver cannot decode the transmission correctly. This project will focus on research and simulation of Orthogonal Frequency Division Multiplexing (OFDM). For high-speed communication OFDM is especially suitable due to its resistance to ISI. By sending many low speed transmissions simultaneously OFDM avoids this problem.

Another advantage to consider OFDM for high-speed systems is the low-complexity implementation than traditional single carrier techniques. For high data rate wireless communications OFDM is a well-established technology and thus it has been used in various standards for example, IEEE 802.11n and 3GPP-LTE. The use of OFDM in wireless communication necessitates due to the combination of high data rate and low bit error rate. Frequency band is divided into number of subcarriers in this OFDM technique. These subcarriers are orthogonal to each other. In [6] the basic principle of OFDM is to split high-rate data stream into number of lower rate streams that are transmitted simultaneously over a number of subcarriers. In OFDM symbol Inter-Symbol Interference is eliminated by using guard time. A number of parameters are used in OFDM system design such as guard time, subcarrier, subcarrier spacing, symbol duration, error correcting code and modulation type. The parameters choice depends on bandwidth, delay and bit rate. The lower multi-path distortion, resiliency of RF interference, and high spectral efficiency are the benefits of OFDM. OFDM is capable of high data rate and is able to eliminate ISI, therefore it is a powerful modulation technique. OFDM can provide large data rates to radio channel impairments with sufficient robustness. A large number of orthogonal, narrow band sub-carriers, overlapping are transmitted in parallel in OFDM scheme. The main attraction of OFDM is its way of handing the multipath interference at the receiver. OFDM has been studied for high speed modems, digital mobile communications [7] and high-density recording in 1980s. OFDM is very useful for multimedia communications as it uses the available spectrum very efficiently. Due to all of the above reasons, OFDM has already been accepted by many future generation systems [8].

Generally wireless power transfer (WPT), or wireless power, refers to the transmission of electrical energy from a power source to one or more electrical loads without any interconnecting wires has been implementation and investigated. WPT is carried out using either "near-field" electromagnetic (EM) induction for short- distance applications [12], or "far-field" EM radiation for long-range applications [13]. On the other hand, in radio frequency (RF) WPT technology enables the receivers to scavenge energy from propagating electromagnetic waves (EM) [7,8,9,10,11,3]. Both information and energy simultaneously carried by the RF signals. The uses of EM waves as a carrier for simultaneous information and power transfer poses many new research challenges for both the source allocation algorithm and receiver design. In [8] and [14] an ideal receiver was assumed such that information decoding and energy harvesting can be performed on the same received signal which is not possible still in practice. In [10], [11], as a solution proposed the power splitting receiver splits the received power into two power streams with a certain power splitting ratio for facilitating simultaneous energy harvesting and information decoding in the receiver. In [10] and [11] the authors investigated the rate energy regions for different types of receivers in point-to-point single carrier systems and two-users. In [3] the authors focused on the resource allocation algorithm design with power splitting receiver in fading channels for point-to-point single user system.

In [4] SWIPT over a single-user OFDM channel has been studied assuming that from the same received signal receiver is able to decode information and harvest energy simultaneously. In this paper, the power allocation strategy as well as the subcarrier allocation strategy is optimized. In [5] considered SWIPT in a multiuser single-antenna OFDM system, where PS is applied at each receiver to coordinate between EH and ID. On the other hand, for a single-carrier system, a receiver simply harvests energy from all signals that do not contain information for this receiver. In this paper, the extension of our previous work in [3] for a single-user narrowband SWIPT system, we study multiuser OFDM- based SWIPT system (see fig.1), where a fixed access point (AP) with constant power supply broadcasts signals to a set of distributed users. In our model, it is considered that each user contains an additional energy receiver to harvest energy from the received signals from the AP, but in conventional wireless network where all the users contain only information receiver and draw energy from their own power supplies. Orthogonal frequency division multiple access scheme is considered for the information transmission. We consider that PS is applied at each receiver and all subcarriers share the same power splitting ratio at each receiver for the OFDMA-based information transmission. We address the problem of maximizing the weighted sum-rate over all users by varying the power allocation in frequency, subcarrier allocation to users and the PS ratios for the OFDMA. It is shown that peak power constraint imposed on each OFDM subcarrier as well as the number of users in the system play key roles in the rate-energy performance comparison by the proposed schemes.

2. System Model

We consider a downlink OFDM-based system with one transmitter and K users as shown in fig.2,. The all users and transmitter are each equipped with one antenna. The systems total bandwidth is equally divided into N subcarriers (SCs). Consider that in a slow-fading environment, where all the channels are considered to be constant within the transmission scheduling period. For understanding, we assume the total transmission time is to be one. It is assumed that for all the users the channel gains on all the SCs are known at the transmitter. Each user performs EH as well as ID at the receiver side.

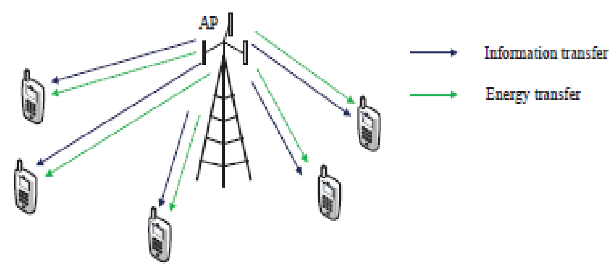

Fig.1 A multiuser downlink SWIPT system.

OFDMA with Power Splitting

We consider the OFDM-based information transmission with PS applied at each receiver. Each SC is allocated to at most one user in each slot, i.e., no SC sharing is allowed in OFDMA transmissions. At the receiver, the received signal at user k is processed by a power splitter, where a ratio of power ρk is split to its energy receiver and the remaining ratio power $1 - \rho k$ is split to its information receiver.

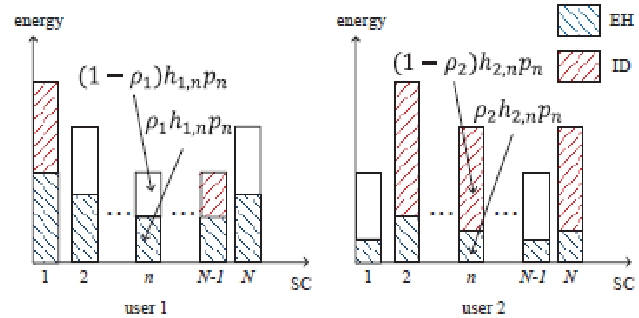

Fig.2 Energy utilization at receivers for a two-user OFDM-based SWIPT system: OFDMA-based information transmission with PS applied at each receiver. The received signals at all SCs share the same splitting ratio ρk at each user k, k = 1, 2.

The example of energy utilization at receiver for the PS case in a two-user OFDM-based SWIPT system is shown in fig.3. As shown in fig.3, the received signals at all SCs share the same splitting ratio ρk at each user k, k = 1, 2. It is noting that only p1 of the power at each of the SCs allocated to user 2 for ID is harvested by user 1, the remaining 1 – ρ1 of power at those SCs is neither utilized for EH nor ID at user 1, similarly for user 2 with PS ratio ρ2. Our objective is to maximize the weighted sum-rate of all users by varying the transmission power in the frequency domain, the SC allocation, jointly with the PS ratios at the receivers to a given set of EH constraints and the transmission power constraints.

3. Advantages

1. OFDM makes efficient use of the spectrum by overlapping. By dividing the channel into narrow band flat fading sub channels, OFDM is resistant to frequency selective fading than single carrier.
2. It reduces ISI and IFI through use of a cyclic prefix.
3. Using sufficient channel coding and interleaving, one can recover the lost symbols.
4. Channel equalization becomes simpler than by using adaptive equalization techniques with single carrier systems.
5. It is possible to use maximum likelihood decoding with reasonable complexity.
6. OFDM is computationally efficient by using FFT techniques to implement the modulation and demodulation function.
7. It is less sensitive to sample timing offset than single carrier systems.
8. It provides good protection against co-channel interference and impulsive parasitic noise.

4. Simulation Flowchart

Figure.3 shows a simplified flowchart of the MATLAB simulink.

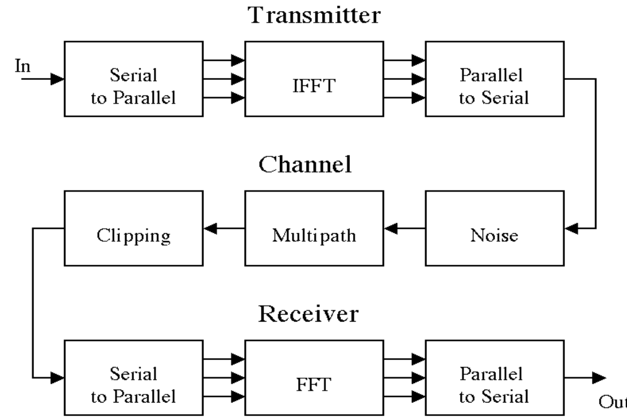

Fig.3 OFDM Simulation Flowchart

5. Conclusions

This paper has studied the resource allocation optimization for a multiuser OFDM-based downlink SWIPT system. The transmission scheme is investigated, i.e. OFDMA-based information transmission with PS applied at each receiver. In this case, the weighted sum-rate is maximized to a given set of harvested energy constraints as well as peak/total transmission power constraint. Hence the PS scheme outperform when the harvested energy is sufficiently large. In practical circuits the power splitter or switcher may introduce insertion loss and degrade the performance of the scheme. This issue is left for future work.

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