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Wireless Information and Power Transfer in Single - User OFDM System

[1] Ayush Sabat, [2] Abhishek Bhardwaj, [3] Chintapalli Srivatsav [4] Dr Prabu K
[1] [2] [3] B.tech Electronics and Communication Engineering VIT University , Vellore
[4]Associate Professor , VIT University , Vellore

Abstract:-- **In the paper, we are analyzing the efficient design for the (SWIPT) Simultaneous Wireless Information and Power Transfer in Single-User OFDM System. An intense research interest has been focused for finding new algorithms of resource allocation for purpose of efficient utilization of limited transmitted power and frequency resource in Single-User orthogonal frequency division multiplexing systems. Orthogonal Frequency Division Multiplexing (OFDM) provides a promising technique for the nextgen wireless communication systems, where the user harvest energy and decode information that has been received from the same access point.**

In order for the information transfer to take place, Time Division Multiple Access (TDMA) and Orthogonal Frequency Division Multiple Access (OFDMA) schemes are implemented.Rules and algorithm for resource allocation in Single-User OFDM are found in this paper. We propose the algorithm for resource allocation in order to utilize channel bandwidth and also to reach the maximum channel capacity. Due to limitations of circuits the energy harvesting from radio signals are not still able to decode the information carried directly, user applies either time switching or power splitting at the receiver end in order to coordinate between information decoding and energy harvesting processes.

In the given two processes, we underwent maximizing the weighted sum-rateover the user by varying the frequency or time powerallocation and either time switching or power splitting ratio and is made subject to a minimum harvested energy constraint on each user as well as a peak andtotal transmission power constraint.

I. INTRODUCTION

In recent years, Simultaneous Wireless Information and Power Transfer (SWIPT) has received an upsurge of research interest as the signals that carry energy can transport information at the same time thereby providing perpetual energy for the energy-constrained wireless networks. The concept of SWIPT as proposed by varshney suggest a fundamental tradeoff between information and power transmission was implemented over frequency selective channel and flat fading channel where the receiver end was able to harvest the energy and decode the information from the same signal. However, this assumption was not realizable as circuits for harvesting energy from the received radio signals are unable to decode the carried information directly.

When the time switching was applied at the receiver end, the received signal can be processed either by an energy receiver for the purpose of energy harvesting or by an information receiver for the purpose of information decoding. However, when power splitting is applied at the receiving end, the received signal is split into two different streams of signals using a power splitter that has constant power ratio. After this one of the signal stream is flown to the information receiver while second to energy receiver. Multiple Input Single Output multicasts SWIPT technology where a multi-antenna is used to send the same information to many single antenna users simultaneously with wireless energy harvesting. A MISO SWIPT system without channel state information at the transmitter used a method that enforced random beamforming for energy harvesting.

SWIPT exploiting flat fading was analyzed where the receiver performed dynamic power splitting or dynamic time switching. SWIPT with information relaying was studied where energy restrained relay harvests energy is obtained from the signal and is used to move the source information to the destination. A hybrid network that overlays an uplink cellular network was studied with randon deployed power beacons that can charge mobile phone wirelessly. It is followed by research on cognitive radio network that was powered by opportunistic wireless harvesting where mobile in the secondary network can either harvest energy from the surrounding transmitter present in primary network or can transmit information in case the primary transmitter are far away.

Orthogonal Frequency Divison Multiplexing is a powerful tool for high rate wirelesscommunication and has been adopted in many applications like Europeandigital audio broadcasting (DAB), the European Digital VideoBroadcasting (DVB), IEEE802.11 Wireless LAN and IEEE802.16 Wireless MAN.It has been emphasized as the key technique of the future wireless communications for itsadvantages in fighting against inter-symbol interference andfrequency selective characteristic of wireless channel.

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It is observed that a tradeoff exists between the achievable rate and the transferred power by power allocation in the frequency bands. The results suggest that for sufficiently small transferred power, the required optimal power allocation can be given by the waterfilling allocation in order to maximize the information transmission rate, however, as the transferred power increases, more power needs to be allocated for the channels with larger channel gain and hence this approaches the strategy with all power allocated to the channel with largest channel gain.

There are significant differences between the resourceallocation scheme for single-user system and that for multiuser system. In case of Single-user system, all sub-carriers of a particular user are available simultaneously. While undergoing research on the issue of resource allocation, there are basically two kinds of optimization methods corresponding to two optimization criteria: rate adaptive (RA) and margin adaptive (MA).

Rate adaptive primary objective is to maximize every user's error-free capacity or to maximize spectrum utilization with a total transmit power constraint. This criterion is applicablefor the users that are having variable data rate. Margin Adaptive objective is to achieve the minimum overall transmit power given the constraints on the users' data rate or bit error rate (BER). This criterion is applicable for the users that are having fixed data rate. In compliance to the requirements of different techniques of communication systems, there are other optimization criteria. For eg, in the case of given total transmit power and users' rate, the BER adaptive (BA) criterion can achieve the best BER performance. These optimization problems are therefore comparativelynonlinear and hence computationally intensive to solve.

In this paper, we are undergoing joint optimization of the power allocation strategy as well as the subcarrier allocation strategy. SWIPT in a single-user single-antenna OFDM system is implemented, where PS is applied at the receiver end to coordinate between Energy Harvesting and Information Decodingand it is assumed that the splitting ratio could be different for different subcarriers. However, in case of practical circuits, analog power splitting is performed before (digital) OFDM demodulation. Thus, for an OFDM-based SWIPT system, allsubcarriers are required to be power split with the same power ratio atthe receiver even though only a subset of the subcarriers contain information for the receiver. In contrast, for the case of a single-carrier system, a receiver simply harvests energy from all signals that do not contain information for this receiver.

Time Switching (TDMA)

Considering case of TDMA oriented info. Transmission we find that Time Switching is applied at receiver end . It is nothing It is noting that for a single-user SWIPT system with Time switching applied at the receiver end, the transmission time has to be divided into couple of time slots to coordinate the Energy Harvesting & Info. Decoding at the receiver end. Therefore , in "SWIPT" system with K users, we consider K + 1 time slots , where the additional time slot +1 is called as the Power slot, which is allocated for all users to perform Energy Harvesting only at a time. In orthodox TDMA systems without Energy Harvesting, the power slot is not necessary .Assuming that slot k, k = 1, . . . ,K is assigned to user k for information transmission, while slot K + 1 is termed as power slot. The transmitted power with boundary conditions is:

$$\sum_{k=1}^{K+1} \alpha_k \sum_{n=1}^{N} p_{k,n} \le P$$

Considering user k decodes the information at time slot k & harvest energy during other time slot, i not equal to k . The noise at receiver for every user is said to be independent over Sub Carriers & is framed as a Circularly Symmetric Complex Gaussian (CSCG) random variable with mean zero and variance . The gap for rate from the channel capacity to a practical Modulation Coding Scheme is denoted by Γ ≥1.Therefore, the rate is given by

$$R_k = \frac{\alpha_k}{N} \sum_{n=1}^{N} \log_2\left(1 + \frac{h_{k,n} p_{k,n}}{\Gamma \sigma^2}\right)$$

Where ,

Γ= gap in achievable rate due to MCS
σ= Variance at sub carriers

The energy harvested at receiver end is framed as :

$$E_k = \zeta \sum_{i \neq k}^{K+1} \alpha_i \sum_{n=1}^{N} h_{k,n} p_{i,n}$$

Where , 'ζ' is conversion efficiency .

The main objective is to enhance and maximize the weighted sum-rate of different users by changing the power transmitted in frequency & time s a joint venture with time

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splitting ratios, subject to Energy Harvesting initial conditions & the transmission power constraints. Therefore, the optimization problem is formulated and we get a fair idea .

(P-TS) is denoted by

$$\max_{\{p_{k,n}\},\{\alpha_k\}} \frac{1}{N}\sum_{k=1}^{K}\sum_{n=1}^{N}\omega_k\alpha_k \log_2\left(1+\frac{h_{k,n}p_{k,n}}{\Gamma\sigma^2}\right)$$

s.t $\zeta\sum_{i\neq k}^{K+1}\alpha_i\sum_{n=1}^{N}h_{k,n}p_{i,n} \geq \overline{E_k}$

$$\sum_{k=1}^{K+1}\alpha_k\sum_{n=1}^{N}p_{k,n} \leq P$$

$0 \leq p_{k,n} \leq P_{peak}$, p=1,2,3

$\sum_{k=1}^{K+1}\alpha_k \leq 1,\quad 0 \leq \alpha_{k,n} \leq 1$,k=1, 2,3,……….,K+1

Where , ωk ≥0 denotes non negative rate .

Optimization is feasible when all boundary conditions are satisfied for {{pk,n}, {αk}}.

From energy harvested equation above, harvested energy for users is max when

ωk ≥0 , is non negative rate assigned to user k

(P-TS) is feasible when all the constraints in Problem .(P-TS) can be satisfied by some {{pk,n}, {αk}}. From harvested energy equation , harvested energy at all users is maximized when αK+1 =1, while αk = 0, pk,n = 0 for k = 1, . . . ,K, n = 1, . . . ,N, i.e., all users harvest energy during the transmission. Thus, (P-TS) is feasible if and only if the following Linear Programming is valid .

$$\max_{\{p_{K+1,n}\}} 0$$

s.t $\zeta\sum_{n=1}^{N}h_{k,n}p_{K+1,n} \geq \overline{E_k}$

$$\sum_{n=1}^{N}p_{K+1,n} \leq P$$

$0 \leq p_{K+1,n} \leq P_{peak}$, p=1,2,3

Power Splitting (Orthogonal Frequency Divison Multiplexing Access)

Now considering the case of OFDMA-based knowledge transmission with Power Splitting applied at each receiver end . Standardized OFDMA transmissions each sub carrier is allocated at most one user in each time slot. No sub carrier sharing is allowed. Now we define a sub carrier allocation function π(n) ∈ {1, . . . ,K}, i.e., the sub carrier ‘ n’ is allocated to userπ(n) Power transmission with boundary conditions is denoted by :

$$\sum_{n=1}^{N}p_n \leq P$$

Pk – power ratio split to energy harvest
1-Pk –power ratio split to information decoding
Achievable rate at sub carrier assigned to user Π(n) is given by

$$R_n = \sum_{n=1}^{N}\log_2\left(1+\frac{(1-\rho\pi(\mathrm{n}))h_{\pi(\mathrm{n}),n}p_n}{\Gamma\sigma^2}\right)$$

The amount of harvested energy in joules at receiver end of user k is given by

$$E_k = \rho_k\zeta\sum_{n=1}^{N}h_{k,n}p_n$$

With the objective to maximixe the weight sum rate of all users , satisfies given boundary conditions.

(P-PS):

$$\max_{\{p_n\},\{\pi(\mathrm{n})\},\{\rho_k\}}$$

s.t $\rho_k\zeta\sum_{n=1}^{N}h_{k,n}p_n \geq \overline{E_k}$, $\forall k$

$\sum_{n=1}^{N}p_n \leq P,\quad 0 \leq p_n \leq P_{peak}$, $\forall n$

From harvested energy equation , harvested energy for all users is maximized when ρk=1 . All power is split to energy receiver at every user . P-PS only feasible if and only if ρk=1, is feasible .

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Optimal Performance

For P-PS and P-TS can be obtained by assuming that each receiver is able to do simultaneously energy harvesting and information decoding .

For Single user resource allocation

In this we consider K=1 , one user based .(h1,n) , (E1), and(ρ1)
are replaced with (hn), (E), and (ρ), respectively.
Thus for K=1 (P-TS) is
(P-TS):

$$\max_{\{p_{1,n}\},\{p_{2,n}\},\alpha_1,\alpha_2} \frac{\alpha_1}{N}\sum_{n=1}^{N}\log_2\left(1+\frac{h_n p_{1,n}}{\Gamma\sigma^2}\right)$$

s.t $\zeta\alpha_2\sum_{n=1}^{N} h_n p_{2,n} \geq \overline{E_k}$

$$\alpha_1\sum_{n=1}^{N} p_{1,n} + \alpha_2\sum_{n=1}^{N} p_{2,n} \leq P$$

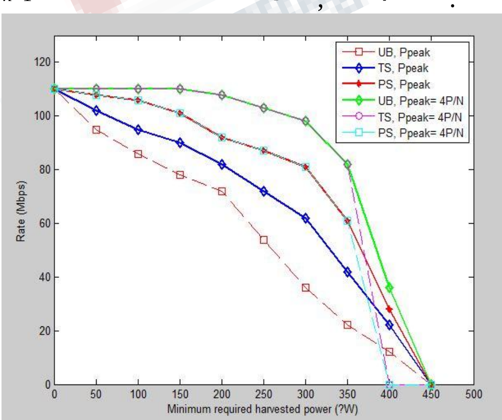
$$0 \leq p_{i,n} \leq P_{peak}, \quad \forall n \quad \text{and } i=1,2$$

FOR K=1 , P-PS is
(P-PS):

$$\max_{\{p_n\},\rho} \frac{1}{N}\sum_{n=1}^{N}\log_2\left(1+\frac{(1-\rho)h_n p_n}{\Gamma\sigma^2}\right)$$

s.t $\rho\,\zeta\sum_{n=1}^{N} h_n p_n \geq \overline{E_k}, \quad \forall k$

$$\sum_{n=1}^{N} p_n \leq P, \quad 0 \leq p_n \leq P_{peak}, \quad 0 \leq \rho \leq 1.$$



In the given figure we see graph is plotted for different schemes .

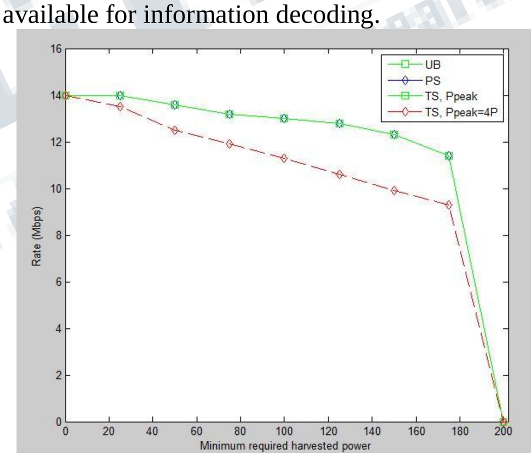
Performances of Time Switching , Power splitting and optimal performance is depicted. Graph is divided into Time Switching , Power splitting and optimal aspects for finite and infinite powers .

In this we have assumed N=64 (number of users), Bandwidth =10MHz, Ptx= 30 dBm

Fading has a path channel that is frequency selective channel which divides bandwidth by number of users , thus frequency for each sub carrier comes to roughly around 0.156 MHz.

In this graph, we have taken 4P/N in order to have higher available power(finite). for the TS ,PS and Upper bound and comparision is made with its infinite counterpart .

For time switching and power splitting their corresponding rate equation and Harvested energy equations are used .TS is better than PS when Ppeak -∞. At x axis =0 , y axis =max value as total time slot is used only for information decoding .When power required is not very high then the rate of information is almost constant .As energy harvested increases rate of information decreases due to less time available for information decoding.



In this graph , we have assumed number of user as one (K=1). Bandwidth=1MHz , Ptx= 30 dBm.

We find that rate is very less compared to when there were more users . The distance from the transmitter end to the receiver end is 1 meter(m), which causes −30dB path-loss for all the channels. Carrier frequency of 900MHz with path-loss exponent equal to 3. The energy receivers the conversion efficiency is ج= 0.2. For information at receiver the noise spectral density is −112dBm/Hz. The MCS gap is taken Γ = 9dB.

CONCLUSION

In this paper we studied resource allocation optimizationfor a single user Orthogonal Frequency Division Multiplexing-based downlink SWIPT system. Two transmission schemes are investigated, namely, OFDMA-based information transmission with PS applied at each receiver end and the TDMA based information transmission with TS applied at receiver end. In both cases, the weighted sum rate is maximum and subjected to a given set of harvested energy boundary conditions as well as the peak and/or total transmission power initial condition. The work mentions that, for the Time Switching scheme, the system can achieve the rate which is same as the conventional TDMA system also at the same time every user is able to harvest a reasonable amount of energy. When the energy harvested required at different users is sufficiently large, EH≠0 slot may be required. In turn this would degrade the rate of the Time Switching scheme to significant extent .Therefore, the PS scheme may outplay the TS scheme with the energy harvested sufficiently larger. The TS scheme is easier to implement at the receiver end side by simply switching between the two operations of EH and ID.

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