
An Improved Semi-Definite Programming Algorithm for Radio Frequency Energy Harvesting for Mobile Devices

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ABSTRACT

Energy harvesting (EH) is an attractive solution for enabling self-sustainable wireless devices in communication networks and Radio-frequency (RF) signals radiated by ambient transmitters becomes a sustainable new source for wireless energy harvesting. It is therefore important to maximize the total harvested RF energy in order to sustain and charge mobile devices without the use of external sources. In this paper, an improved Semi-definite programming algorithm (ISPA) for radio frequency energy harvesting for mobile devices is presented. A dynamic weight adaptive technique will be used to solve the Semi-definite programming (SDP) algorithm to obtain short convergence time for optimal solution that maximize the amount of RF energy harvested at the receiver and guarantee quality of service of information transfer. Different number of transmitting antennas were considered and the results show an improvement of 24.24%, 12.11% and 56.05% for ISPA over Semi-definite Programming Algorithm (SPA) with number of transmitting antennas $N_T=4$, $N_T=3$, and $N_T=2$ respectively. This shows that the developed ISPA performed more than the SPA which translate to more RF energy harvested at the receiver.

Key words: SDP Algorithm, Energy harvesting, Radio frequency, ISPA

INTRODUCTION

Energy harvesting (EH) is an attractive solution for enabling self-sustainable wireless devices in communication networks. Thus, the inconvenience of recharging and replacing batteries can be avoided by harvesting energy from different energy sources, such as solar and wind. Recently, wireless power transfer (WPT) via radio frequency signals has received considerable attention as it provides a ubiquitous, relatively stable, and controllable source of energy (Grover and Sahai, 2010; Krikidis *et al.*, 2014). Furthermore, other benefits can be reaped by

employing information carrying signals for WPT, which enables simultaneous wireless information and power transfer (Varshney, 2008).

In this research paper, emphasis will be placed on maximizing the total average harvested power in simultaneous wireless information and power transfer (SWIPT) systems while guaranteeing the quality of service.

A semi-definite programming algorithm would be improved using dynamic weight adaptive technique in order to obtain short convergence speed for optimal solution

that maximize the amount of RF energy harvested at the receiver

A lot of research has been carried out on maximizing the amount of RF energy harvested in SWIPT system but few are reviewed and presented

Leng *et al.*, (2016) studied the resource allocation algorithm design for energy efficient simultaneous wireless information and power transfer (SWIPT) systems. However, the alternative approach to harvest as much energy as possible adversely affects information transfer, leading to the degradation of system quality of service (QoS). Zhang & Ho (2013) studied the simultaneous wireless information and power transfer (SWIPT) system for a multiple-input multiple-output (MIMO) wireless broadcast system. However, results obtained were based on the overly optimistic assumption of perfect channel state information. Ng *et al.*, (2014) studied the robust beamforming for secure communication in systems with wireless information and power transfer. But assumption of linear harvesting model makes it imprecise and not capable of capturing the nonlinear behavior of the energy harvesting system. Krikidis *et al.*, (2014) proposed a simultaneous wireless information and power transfer in modern communication systems. However, the RF model did not considered some aspects of nonlinearities of the model. Boshkovska *et al.*, (2016) Studied power allocation and scheduling for SWIPT systems with non-linear energy harvesting model. However, the optimal multiuser power allocation and scheduling policies depend only on the current time, which is not dynamic.

It can be seen from the literatures reviewed that maximizing the amount of RF energy harvested in WSNs in important as it

provides a way of sustaining and charging mobile devices. This paper presents an improved technique for maximizing the total harvested energy harvested at the RF receiver

METHODOLOGY

The maximum number of iteration, L_{max} , and the iteration index are first initialized. The inner loop problem is solved via the SDP relaxation for vectors Υ and α . The optimal solution to the optimization problem is updated until iteration index, $n = L_{max}$,

In each iteration the inner loop non-convex optimization problem in equation (1) was solved.

$$\underset{X, Z \in \mathbb{H}^N, T, \dagger}{\text{maximize}} \quad \sum_{j=1}^J x_j^* [M_j - \Gamma_j^* (1 + \exp(-a_j(\dagger_j - b_j)))]$$

$$C_1 : T_r(X + Z) \leq P_{\max}$$

$$C_2 : \min_{h \in \Lambda} \frac{T_r(XH)}{T_r(ZH) + u_s^2} \geq \Gamma_{req}$$

$$C_4 : \min_{G_j \in \Xi_j} T_r((X + Z)G_j G_j^H) \geq \dagger_j, \forall_j$$

$$C_3 : Z \succeq 0, C_5 : Rank(X) = 1, C_6 : X \succeq 0 \quad (1)$$

$X = xx^H$ is a new optimization variables matrix and $\tau = \tau_1, \tau_2, \dots, \tau_j$ is a vector of auxiliary optimization variable.

where:

M_j = Maximum harvested power at energy harvested receiver

$P_{r_{\max}}$ = Maximum radiated power at one time slot

T_r = Transmitter section

Γ_j and x_j = Vectors

a_j = Non-linear changing rate with respect to the input power

b_j = Minimum turn on voltage of an energy harvesting circuit

Z = Constrain matrix

$X = xx^H$ is a new optimization variables matrix and

$\dagger = [\dagger_1, \dagger_2, \dots, \dagger_j]$ is a vector of auxiliary optimization variables

The unique optimal solution (Y, α) is obtain only if

$$\{ (X, r) = [\{ \dagger_1, \{ \dagger_2, \dots, \{ \dagger_{2J}] = o \quad (2)$$

is satisfied

Therefore x^{n+1} and r^{n+1} are updated in the iteration algorithms as:

$$\begin{aligned} x^{n+1} &= x^n + ' \quad q^n_{j+1:2J} \text{ and} \\ r^{n+1} &= r^n + ' \quad q^n_{1:j} \end{aligned} \quad (3)$$

where:

$$q^n = [\{ '(x, r)]^{-1} \{ (x, r) \quad (4)$$

and $\{ '(x, r)$ is Jacobian matrix of $\{ (x, r)$

' n is the largest \in' satisfying

$$\square \{ (x^n + \in' q^n_{j+1:2J}, r^n + \in' q^n_{1:j}) \leq (1 - y \in') \{ (x, r) \quad (5)$$

Improved SDP Algorithm

The SDP algorithm is improved using dynamic weight adaptive technique. An estimated initial weight, $w(t) = o$ is first obtained. The search trajectory $(X(t), \lambda(t), \mu(t))$ is measured periodically. The weight factor, $w(t)$ is adapted dynamically to obtain an efficient convergence time. The optimal solution to the optimization problem is updated until the maximum number of iterations.

Figure 1 show the flowchart of ISPA using dynamic weight adaptive technique

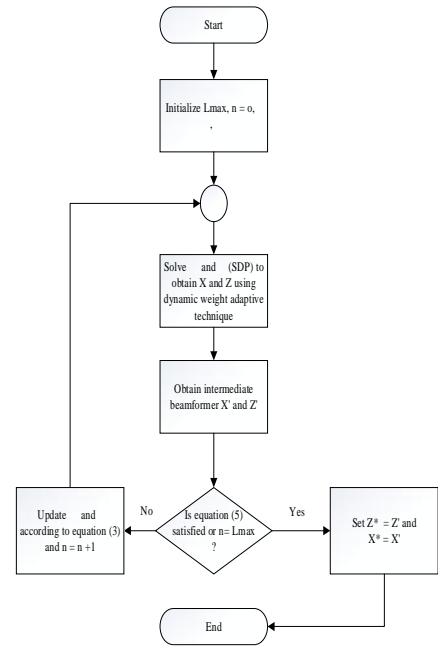


Figure 1: Flow chart of ISPA Algorithm

RESULTS AND DISCUSSION

The improved Semi-definite programming algorithm (ISPA) was simulated and implemented on MATLAB R2016b simulator with the results obtained compared with SPA based on average total harvested power in terms of maximum channel estimation error as performance metric

The results for different numbers of transmitting antennas (N_T) obtained show the relationship between the total harvested power and the normalized channel estimation error. It can be seen from Figure 2 that as the normalized channel estimation error increases, the total harvested power decreases. This is because as the channel estimation error increases the channel state information (CSI) degrade. The degradation of the CSI makes difficult for the transmitting antenna to steer towards the energy harvesting receiver. It can be concluded that with an increase in channel estimation error,

there is a decrease in the total harvested power.

It can also be seen from the result in Figure 2 that with an increase in the number of transmitting antenna the total harvested power increases, this is because additional transmit antenna provides additional degree of freedom for more resource allocation. However the performance of the IS-PA is better than the S-PA by 24.24%, 12.11% and 57.93% which is as a result of proper steering of the transmitting antenna towards the received antenna by IS-PA despite the channel estimation error

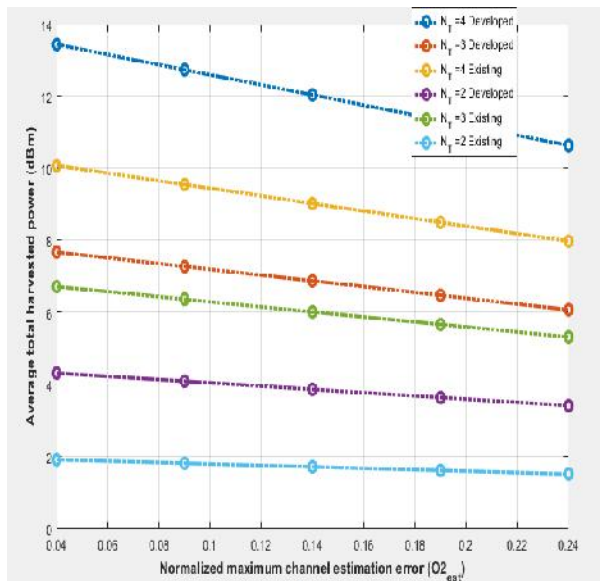


Figure 2: Different Numbers of Transmit Antenna Plot

CONCLUSION

In this paper, an improved semi-definite programming algorithm (ISPA) using dynamic weight adaptive techniques was presented. The developed techniques improved the total average harvested power at the receiver while guarantee the quality of service of the information transfer.

RECOMMENDATIONS

1. Improve the sensitivity of the RF energy harvester by putting into consideration the type of antenna constellation and using a metaheuristic algorithm to select efficient constellations.
2. Developing an algorithm that can optimize the processing time of harvesting this energy. E.g. improving the operation of SDP algorithm.

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