SCHOOL OF ELECTRICAL ENGINEERING AND TELECOMMUNICATIONS

Max-min Fair Resource Allocation for SWIPT Systems

By

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Abstract

Wireless sensor technology plays an increasingly important role in daily life due to the widespread use of Internet-of-Things (IoT). To solve high-energy consumption of heavy computation cost and communication overhead, battery storage and recharging technology of wireless sensors becomes a research focus. Simultaneous wireless information and power transmission (SWIPT) is proposed to enable the perpetual operation of wireless devices which performs energy harvesting (EH) in communication instead of wired charging. Besides, beamforming technology and power splitting (PS) technology are also considered to achieve a more efficiency SWIPT system. To achieve a balance of fairness among all legitimate users, this paper optimizes the transmit beamforming vector with the constraint of maximum transmit power and minimum harvested energy by maximize the minimum signal-to-interference-plus-noise-ratio (SINR). Using SDP relaxation and KKT condition, the non-convex problem can be changed into a convex problem that can be solved by programming efficiently. Moreover, simulation results show the optimal solution and performance of this SWIPT system.

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1 Introduction

In current years, the quick expansion of wireless communications, 5G technology has also been planned. Gigabit speeds for wireless access have been achieved via many progresses such as multiple-input multiple-output (MIMO), capacity implementation codes, millimeter-wave communications, and small cellular networks. Supporting by the highly boosting speed of wireless and wired access, mobile devices such as smartphones, tablets and laptops have substituted desktop computers and are becoming the leading stages for Internet access [1]. At the same time, many wireless sensors are used accompanied by the fast growing Interest. However, in wireless networks, battery storage of relay or sensor nodes are usually limited thus external charging mechanisms are required for remaining active in the network . On the contrary, advances in battery technology are less developing, therefore mobile device are requested for connection to the grid for battery charging after a period of time. Now Simultaneously Wireless Information and Power Transmission (SWIPT) is providing a key to acceptable action of IoT devices and is going to achieve success hopefully [1].

In the wireless communication networks, the quality of service or security applications may not be satisfied, since traditional energy harvesting technologies are obtaining their energy from natural resources (e.g, solar, wind, and geothermal energy), which is uncontrollable. Based on this stimulation, more and more attention have been paid to the wireless energy harvesting technology that attained energy from radio frequency (RF) signals. Due to that the simultaneous transmission of energy and information can be realized by frequency signals, SWIPT has recently catch broad attention in energy-constrained wireless communications. The information and energy transmitted by the RF signal can be applied simultaneously while the information is the only thing that can be transmitted by the RF signal. That is to say a wireless communication node with SWIPT can collect energy when it is processing information [2] .

For the SWIPT system, more and more interest has been generated [3]–[5] by utilizing RF signals to transmit both information and energy. Even though acting as one of the hopeful substitute for the permanent operation of wireless devices, SWIPT technology combined with the application of wireless devices capable of performing Energy Harvesting (EH) is affected by some basic bottlenecks [6]. At first, the specific goals of signal processing and energy resource allocation for EH are greatly different [7]. Meanwhile, SWIPT performance suffers the affection from the low energy sensitivity and rectification efficiency when getting energy from RF to Direct Current [5]. Another actual issue with SWIPT is the truth that the information cannot be worked out straightly by the existing RF EH circuits, and it's the same thing to the opposite situation [8]. Lastly, the answer [9]-[12] to making practically obtainable SWIPT gains request for high complexity and there is a long way to go for the supply of analytical insights. To break these bottlenecks, the joint resource allocation schemes and MIMO technology have been take into consideration in recent days[7]–[15].

Basing on MIMO technology, a phase array and a technique called retro directive beam control are commonly adopted by power beamforming for MPT, where a beam in the opposite direction of the incident pilot signal received by base station is automatically steered by searching channel reciprocity. In the SWIPT system, Beamforming make it possible for the specific user to send the corresponding signal, which contributes to design desired system [1].

For the receive side. Targeting at the solution to the challenges occurred in the process of designing circuits that carry out information decoding(ID) and EH at the same time, different receiver architectures have been introduced lately in periodicals and journals[8,16] as quoted below.

Time Switching (TS) Receiver [16]: This architecture adopts an antenna switching at a set time between two parts that are ID and EH. By separating the time of signal processing and energy harvesting, two parts can work well in the orthogonal time slots.

Power Splitting (PS) Receiver [16]: This architecture involves a power splitter device. It can allocate the resource from the received signal. By changing the power splitter ratios, ID and EH can get the corresponding power. An ideal power splitter ratio is planned [17].

However, in order to make the TS efficient, the ratio for the TS must be the same adopted by all users in EH mode. For multiple or various TS ratios and variability in duration of EH mode, acceptance of TS method can be applied as well. For multi-cell MISO frameworks, different streamlining problems were tended to where both the data rate and the energy harvesting could be broadened simultaneously [18].

The design of power splitter in the SWIPT system is worked out in [19]. For enlarging the minimum harvested energy of all the EH as much as it can be, while meeting signal-to-interference-plus-noise ratio (SINR) requirement at the information decoding part at the receiver and the constraint of total transmission power at the transmitter. The initial problem will be a hard issue with many restrictions, which is non-convex. Via exploring the semi-definite relaxation (SDR) technique, a relaxed semi-definite programming (SDP) can solve the problem efficiently, which can be worked out successful by adopting interior point methods. Finally, [19] shows the accomplishment of the planned robust beam forming design based on imitation.

2 Literature Review

The difference between PS and TS receiver will be discussed is worth studying. The author of [18] has conducted research about the energy efficiency of SWIPT. This was done in MIMO for two way networks. Power splitting scheme is used for SWIPT in two way amplified networks [18]. The research done by simulation shows effectiveness of the scheme. The proposed SWIPT system can decode data and harvest energy autonomously controlled by a similar flag. The two schemes proposed here are mainly TS and PS scheme [18]. TS stands for time switching and PS is Power splitting [8]. In sensor networks, there are many relay and sensor nodes. They often have very limited battery storage. Therefore, in order to remain active in the network, they require some external charging mechanisms [8]. Along these lines, SWIPT for these systems is particularly vital in light of the fact that the constrained power grouping can gather energy from sources with a settled power source, and afterward utilize the packaged energy to convey the data from the source to the goal [20].

The design on SWIPT using TS scheme is proposed in [21]. Although research materials are available on PS scheme but the TS scheme has been very less utilized. For the plan of TS-based SWIPT conventions in multi-client frameworks, a noteworthy test is the means by which to deal with non-concurrent circumstances for numerous clients coming about because of various TS arrangements for clients [21]. What's more, in TS techniques, clients can powerfully alter their modes to enhance framework execution. In SWIPT systems that are based on TS scheme, the beamforming remains same for different modes applied by the transmitters [22]. By utilizing the path following algorithms, the problems of minimum rate maximization can be solved and as well as the transmit power minimization. The author of this research article has also found that the TS scheme for SWIPT is more effective in solving minimum rate and as well as transmit power than that of the PS scheme [22].

This rather contrasting from that of author who found effectiveness in both the schemes [18]. But for the TS to become effective, the ratio for the TS must be same employed by all users in EH mode. For multi-cell MISO frameworks, various streamlining issues were tended to where both the data rate and the energy harvesting could be expanded in the meantime [18]. A proposal for New Joint TS protocol has been provided in this article, which can be used for MISO BC systems [9].

There are many indicators in SWIPT system, but fairness cannot be ignored. A research of the design for transmission of SWIPT in MISO is proposed [19]. They proposed the transmit beamforming design with imperfect CSI .Its plan objective was to find maximization of the energy efficiency for each receivers using jointly optimizing the transmit beamforming vectors and changing ratios of the power splitter devices with a high level of theSINR and the constraint of total transmit power. [19]. However, the problem is non-convex due to the coupled beamforming vector and PS ratios. To counter it, they transformed it into a basic issue, not solve the problem directly .At that point, with the assistance of SDR innovation, we likewise get a relaxed SDP problem. In this article, they likewise contemplated the arrangement of basic transmission and the plan of the power segment of the multi-client SWIPT framework with an imperfect CSI [19].The deficit of CSI is composed utilizing an Euclidean ball. In view of the most exceedingly awful deterministic model, we expect to expand the harvested energy by all EHs while we guarantee the base SINR to the ID device and the aggregate transmission energy to the sender's constraints. The underlying plan issue is the non-convex quadratically constrained quadratic programming problem, which is hard to solve it. To fathom it, we initially reformulate the underlying issue, transform it into a relaxed SDP problem that satisfies the constraints. Utilizing SDR innovation, they transfer the non-convex issue to a raised SDP issue, which can be proficiently settled utilizing interior point techniques. They endeavored to boost the harvested energy reaped in the most pessimistic scenario due to certain SINR confinements and the transmitter's aggregate transmission control constraints [8].

3 System Model

As figure 3.1 shown, MISO system is considered in this paper. There are one base station and K users which has single receiving antenna in this system. The number of antennas at base station is N_T ($N_T > 1$), which provides the foundation for beamforming.

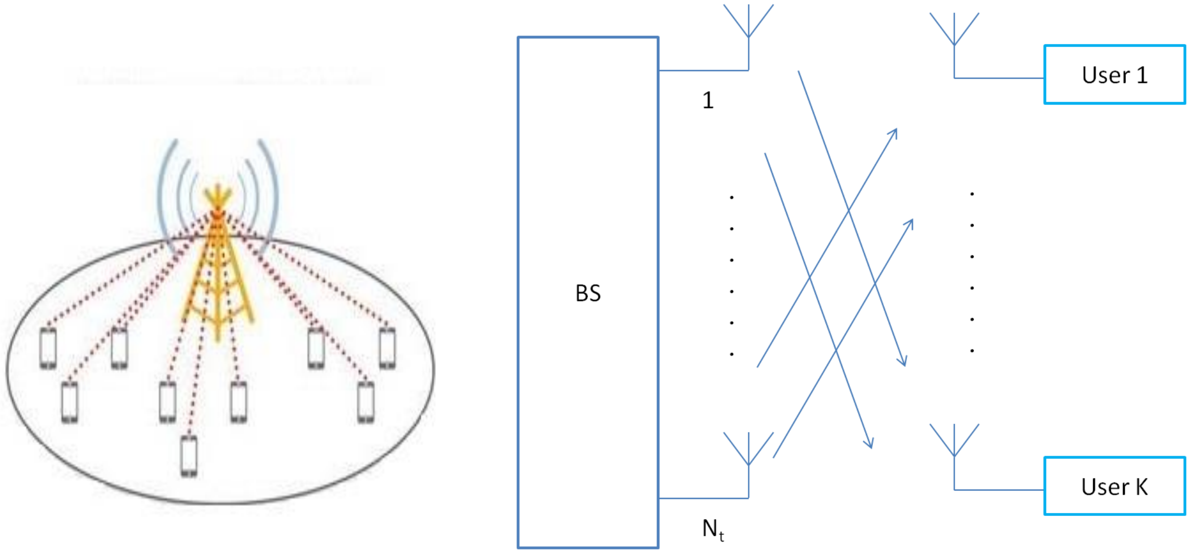

Figure 3.1: The MISO system and its block diagram

3.1 Beamforming model

At the transmitter, beamformed signal carries both information code and energy signal. The transmit signal $\mathbf{x}$ can be expressed as

$$\mathbf{x}=\sum_{k=1}^{k=K}\mathbf{w}_k\mathbf{s}_k \tag{1}$$

$\mathbf{s}_k \in \mathbb{C}^{1\times 1}$ and $\mathbf{w}_k \in \mathbb{C}^{N_t\times 1}$ are the pseudo-random transmit signal and the corresponding beamforming vector for the users. For all users, transmitter will add them up. We assume that the data sequence has a unit power $\mathrm{E}\left\{|\mathbf{s}|^2\right\}=1$

Also, because they are I.I.D., $\mathrm{E}\left\{|s_i s_j|^2\right\}=0 \quad i,j\forall[1,K]\ i\neq j$

Based on the channel model and transmitted signal we proposed, the received signal at the receiver can be modelled as

$$\mathbf{y_k}=\mathbf{h}_k^H\mathbf{x}+\mathbf{n}_k \tag{2}$$

where $\mathbf{h}_k^H \in \mathbb{C}^{N_t\times 1}$ represents the conjugated complex CSI vector between the transmitter and the receiver including the path loss and fading because of multipath, and n_k is the additive Gaussian noise between the transmitter and the receiver with the zero mean and variance σ .

3.2 Power splitter model

Assuming that the power splitter device is equipped for each receiver to coordinate the operation of information decoder and energy harvester. Particularly, the received signal at the receiver is split into $\rho \in [0,1]$ portion of the signal power for the ID and $1-\rho$ portion of the power is fed to the EH of the receiver, as shown in figure3.2 .

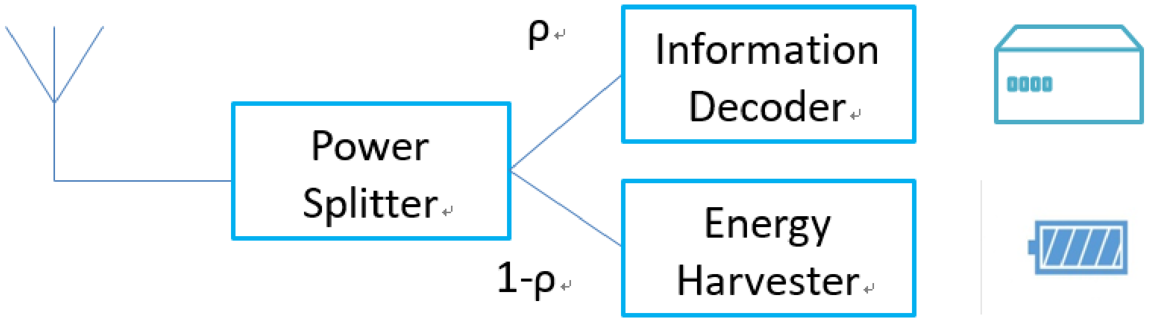

Figure 3.2: diagram of the receiver with power splitter

Several different hardware circuitries are proposed in [8, 23], which can absorb resource and finish RF-to-Direct Current (DC) rectification. However, the circuit is not main consideration for this report. We assume, without loss of generality, energy harvester has a fixed energy conversion efficiency. Thus the receive signal at information decoder and energy harvesting device of the kth receiver is given by, respectively,

$$\mathbf{y}_{ID_k} = \sqrt{\rho}\left(\mathbf{h}_k^H \mathbf{x} + \mathbf{n}_k\right) \tag{3}$$

$$\mathbf{y}_{ER_k} = \sqrt{1-\rho}\left(\mathbf{h}_k{}^H \mathbf{x} + \mathbf{n}_k\right) \tag{4}$$

where $\rho \in [0,1]$ is the split ratio of receive power.

3.3 Energy and SNIR

Figure 3.3 illustrates the block diagram of the whole system. The transmitter send beamformed signal with information and energy simultaneously to the receiver. At receive side, power splitter will split the signal power for information decoder and energy harvester. This part will focus on the receive energy and SINR of system.

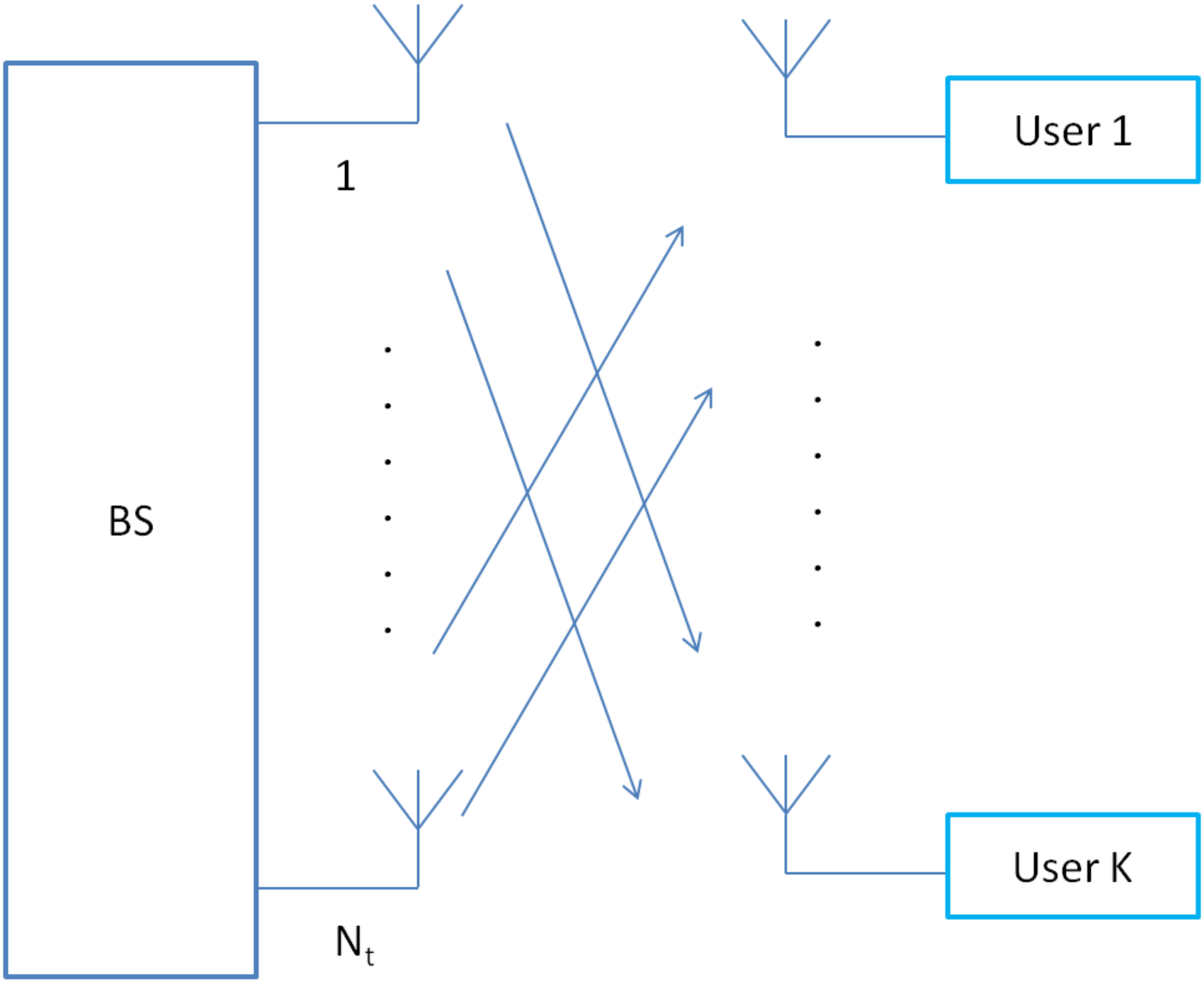

Figure 3.3 – Block diagram of SWIPT system

Accordingly, the power of information signal and harvested RF power at receiver are, respectively,

$$\begin{aligned}\mathrm{P}_{I_k} &= \mathrm{E}\left\{\left|\sqrt{\rho}\mathbf{h}_k^H\mathbf{w}_k\mathbf{s}_k\right|^2\right\} \\ &= \rho\left|\mathbf{h}_k^H\mathbf{w}_k\right|^2 \\ &= \rho\mathrm{Tr}\left(\mathbf{h}_k^H\mathbf{w}_k\mathbf{w}_k^H\mathbf{h}_k\right)\end{aligned} \tag{5}$$

$$
\begin{aligned}
\mathrm{P}_{E_k} &= \eta \mathrm{E}\left\{ \left| \sqrt{1-\rho_k}\, \mathbf{h}_k^H \mathbf{x} \right|^2 \right\} \\
&= \eta\left(1-\rho\right) \sum_{t=1}^{t=K} \left| \mathbf{h}_k^H \mathbf{w}_t \right| \\
&= \eta\left(1-\rho\right) \sum_{t=1}^{t=K} \mathrm{Tr}\left(\mathbf{h}_k^H \mathbf{w}_t \mathbf{w}_t^H \mathbf{h}_k \right)
\end{aligned} \tag{6}
$$

where $0 \leq \eta \leq 1$ is a constant. It represents energy conversion efficiency of the EH at the receiver.

SINR at receive, Signal-to-interference-plus-noise ratio, is modeled as,

$$
SINR_k = \frac{\rho \left| \mathbf{h}_k^H \mathbf{w}_k \right|^2}{\rho \sum_{t \neq k} \left| \mathbf{h}_k^H \mathbf{w}_t \right|^2 + \sigma_k^2} \tag{7}
$$

4 Problem Formulation

In this section, we focus on the beamforming design for the maximization of the minimum SINR for each receiver to guarantee the fairness of the system. For example, if there is an EH located close to the transmitter compared to the other receiver, then the transmitter has a tendency to steer the beamforming direction towards this EH for the most of resource. However, this lead to resource starvation of the other receivers. In order to guarantee the fairness in SWIPT system, we formulate the following optimization problem:

$$
\underset{\vec{w}_k}{\text{maximize}} \; \min_{k \in [1,K]} \left\{ \frac{\rho \left| \mathbf{h}_k^H \mathbf{w}_k \right|^2}{\rho \sum_{t \neq k} \left| \mathbf{h}_k^H \mathbf{w}_t \right|^2 + \sigma_k^2} \right\}
$$

$$
\text{s.t. } \; \mathrm{C1}: \; \eta\left(1-\rho\right) \sum_{t=1}^{K} \mathrm{Tr}\left(\mathbf{h}_k^H \mathbf{w}_t \mathbf{w}_t^H \mathbf{h}_k \right) \geq P_{\min}
$$

$$
\mathrm{C2}: \; \sum_{k=1}^{K} \left| \mathbf{w}_k \right|^2 \leq P_{\max}
$$

$$
\mathrm{C3}: \; 0 \leq \rho, \eta \leq 1 \tag{8}
$$

We proposes a problem of the jointly transmit beamforming and receive power allocation with a prefect known CSI. The harvested energy of each receiver at EH device should be above a given threshold $P_{\min}$ ensuring that sufficient energy can be harvested. Also, the transmit power, which is smaller than $P_{\max}$, cannot be infinite due to hardware limitation. ρ is the ratio of power splitting must be in the range of [0,1]. Thus, we formulate the transmit beamformeing optimization problem as a maximization of the minimum SINR for each receiver.

5 Optimal Solution

It can be judged as a non-convex problem due to object function and constraint C1. In order to use property that extremum is maximum value or minimum value, the non-convexity of this problem should be overcome. SDP relaxation provide a solution to make considered problem convex. Firstly, $\vec{w}_k \vec{w}_{\mathrm{k}}^H$ can be replaced by W_{k}, but there are two more constraint to guarantee it. After applying SDP, the new optimization problem can be expressed as:

$$\underset{\vec{w}_k}{\text{minimize}}\ -\tau$$

$$\text{s.t.}\quad \text{C1:-}\sum_{t=1}^{K}\mathrm{Tr}\left(\mathbf{H}_k\mathbf{W}_{\mathrm{t}}\right)+\frac{P_{\min}}{\eta\left(1-\rho\right)}\le 0 \quad \forall k\in\left[1,K\right]$$

$$\text{C2: }\sum_{k=1}^{K}\mathrm{Tr}\left(\mathbf{W}_k\right)\text{-}P_{\max}\le 0$$

$$\text{C3: } 0\le \rho,\eta\le 1$$

$$\text{C4: } \rho\tau\sum_{t\ne k}\mathrm{Tr}\left(\mathbf{H}_k\mathbf{W}_t\right)+\sigma\tau-\rho\mathrm{Tr}\left(\mathbf{H}_k\mathbf{W}_k\right)\le 0 \quad \forall k\in\left[1,K\right]$$

$$\text{C5: } -\mathbf{W}_k\le 0 \quad \forall k\in\left[1,K\right]$$

$$\text{C6: } \mathrm{rank}(\mathbf{W}_k)\le 1 \quad \forall k\in\left[1,K\right] \qquad (9)$$

However, the new optimization problem (9) is still non-convex because of constraint 6. Adopting SDP relaxation, we can remove constraint 6 and considered problem becomes a convex problem. Then, convex program solvers can solve the new problem efficiently and optimally. The SDP relaxed problem formulation can be expressed as

$$\underset{\vec{w}_k}{\text{minimize}} \ -\tau$$

$$\text{s.t.} \ \ \text{C1,C2,C3,C4,C5} \tag{10}$$

For verifying the correctness of SDP relaxation, we must consider the dual problem. Here we need to analyze the Karush-Kuhn-Tucker (KKT) SDP relaxation conditions of optimization problem. First, the Lagrange of (10) can be written as

$$\begin{aligned} L = & -\tau - \lambda_1 \sum_{k=1}^{K} \sum_{t=1}^{K} \mathrm{Tr}(\mathbf{H}_k \mathbf{W}_t) + \lambda_2 \sum_{k=1}^{K} \mathrm{Tr}\left(\mathbf{W}_k\right) + \lambda_3 \rho \tau \sum_{k=1}^{K} \sum_{t \neq k} \mathrm{Tr}\left(\mathbf{H}_k \mathbf{W}_t\right) \\ & + \lambda_3 \sigma \tau - \lambda_3 \rho \sum_{k=1}^{K} \mathrm{Tr}\left(\mathbf{H}_k \mathbf{W}_k\right) - \sum_{k=1}^{K} \mathrm{Tr}\left(\mathbf{Y}_k \mathbf{W}_k\right) + \Delta \end{aligned} \tag{11}$$

where, $\mathbf{Y}_k$ is the dual variable matrices of constraint C6 and λ_1, λ_2, λ_3 are the scalar dual variables of constraints C1, C2, and C4, respectively. Δ is the sum of some constants which are independent of $\mathbf{W}_k$. Now, the dual problem can be expressed as

$$\max_{\lambda_1, \lambda_2, \lambda_3, Y_k} \ \min_{\vec{w}_k} L(\lambda_1, \lambda_2, \lambda_3, \mathbf{Y}_k, \mathbf{W}_k) \tag{12}$$

According to KKT conditions, these equations must hold at the optimal solution point $(\lambda_1^*, \lambda_2^*, \lambda_3^*, \mathbf{Y}_k^*, \mathbf{W}_k^*)$ when it is a convex problem.

$$\nabla_{\vec{\mathbf{w}}_k} \mathbf{L}(\lambda_1^*, \lambda_2^*, \lambda_3^*, \mathbf{Y}_k^*, \mathbf{W}_k^*) = 0 \tag{13}$$

$$\lambda_1^*, \lambda_2^*, \lambda_3^* \geq 0 \tag{14}$$

$$\mathbf{Y}_k^* \mathbf{W}_k^* = 0 \tag{15}$$

Moreover, the derivative of the Lagrangian function with respect to $\mathbf{W}_k$ is given by

$$\frac{\partial \mathbf{L}}{\partial \mathbf{W}_k} = -\lambda_1 \sum_{t=1}^{K} \mathbf{H}_t + \lambda_2 \mathbf{I} + \lambda_3 \rho\tau \sum_{t \neq k} \mathbf{H}_t - \lambda_3 \rho \mathbf{H}_k - \mathbf{Y}_k \tag{16}$$

Subsequently, by combining equations (13) and (16), we can get expression of $\mathbf{Y}_k^*$:

$$\mathbf{Y}_k^* = -\mathrm{a}\mathbf{H}_k + \mathbf{B} \tag{17}$$

where $\mathrm{a} = \lambda_3^* \rho + \lambda_1^*$ which is a constant and will not affect the calculation of rank or trace. $\mathbf{B} = \lambda_2^* \mathbf{I} + (\lambda_3^* \rho\tau - \lambda_1^*) \sum_{t \neq k} \mathbf{H}_t$.

It can be observed from (15), the columns of $\vec{\mathbf{w}}_k^*$ will lie in the null space of $\mathbf{Y}_k^*$ because of the complementary slackness condition on $\vec{w}_k^*$ for $\vec{\mathbf{w}}_k^* \neq 0$. Hence, the rank of $\vec{\mathbf{w}}_k^*$ is depend on the rank of $\mathbf{Y}_k^*$. Firstly, we study the property of matrix $\mathbf{B}$. Using contradiction, if matrix B is the a positive semi-definite matrix, then there is at least one zero eigenvalue and we represent the associated eigenvector as $\mathbf{U}$. Without loss of generality, we assume that $\mathbf{U} = \mathbf{u}\mathbf{u}^H$. Multiplying U and find the trace for both sides of (17), we can get

$$\mathrm{Tr}(\mathbf{Y}_k^* \mathbf{U}) \leq -\mathrm{Tr}(\mathbf{H}_k \mathbf{U}) + \mathrm{Tr}(\mathbf{B}\mathbf{U}) = -\mathrm{Tr}(\mathbf{H}_k \mathbf{U}) \tag{18}$$

Because $\mathbf{H}_k$ and $\sum_{t \neq k} \mathbf{H}_t$ are statistically independent, we can obtain $\mathrm{Tr}(\mathbf{H}_k \mathbf{U}) > 0$ and $\mathrm{Tr}(\mathbf{Y}_k^* \mathbf{U}) < 0$. Consequently, $\mathbf{B}$ must be a positive definite matrix and $\mathrm{Rank}(\mathbf{B}) = N_T$.

According to the basic rule of inequality for the rank of matrix $\mathrm{Rank}(\mathbf{a}) + \mathrm{Rank}(\mathbf{b}) \geq \mathrm{Rank}(\mathbf{a} + \mathbf{b})$, let $\mathbf{a} = \mathbf{Y}_k^*$, $\mathbf{b} = \mathbf{H}_k$, we can obtain

$$\mathrm{Rank}(\mathbf{Y}_k^*) \geq \mathrm{Rank}(\mathbf{B}) - \mathrm{Rank}(\mathbf{H}_k) = N_T - 1 \tag{19}$$

Therefore, (19) and $\mathrm{Rank}(\mathbf{W}_k) \leq 1$ must hold simultaneously. It means that the optimal solution of (10) is the same as that of (9). Now, numerical solvers can solve the convex relaxed problem efficiently.

6 Simulation Results

In this section, we study the performance of proposed optimal resource allocation via simulations. Unless further specified, the contents of Table 6.1 is the important simulation parameters.

Table 6.1**:** System parameters

Small-scale fading distribution	Rician fading with Rician factor 3 dB
Carrier center frequency	915MHZ
Total noise variance, σ^2	-23dBm
Transmit power budget, P_{max}	46dBm
Number of receive antennas at each EH, N_R	2
Receive antenna gain	6dB
Max tolerable channel capacity at $R_{\mathrm{EH}_k,j}$	1bps/Hz
RF energy to electrical energy conversion efficiency for EH_k, η	0.5

Figure 6.1, we consider the average minimum SINR (dB) per information receiver versus the maximum transmit power (dBm) with minimum harvested power of 6 dBm for different numbers of transmitter antennas. In general, with the increase of the maximum transmit power, the average minimum SINR of each information receiver increases as total received energy from the received signals sent by the transmitter increases. In addition, it can be observed that with increasing number of transmit antennas, the average minimum SINR of each information receiver increases due to more transmit antennas can effectively improve energy transmission efficiency with proper beamforming.

Figure 6.2 illustrates the average minimum SINR (dB) per information receiver versus the minimum harvested power (dBm) with maximum transmit power of 46 dBm for different numbers of transmit antennas. Generally, with increasing minimum harvested power, the average minimum SINR of each information

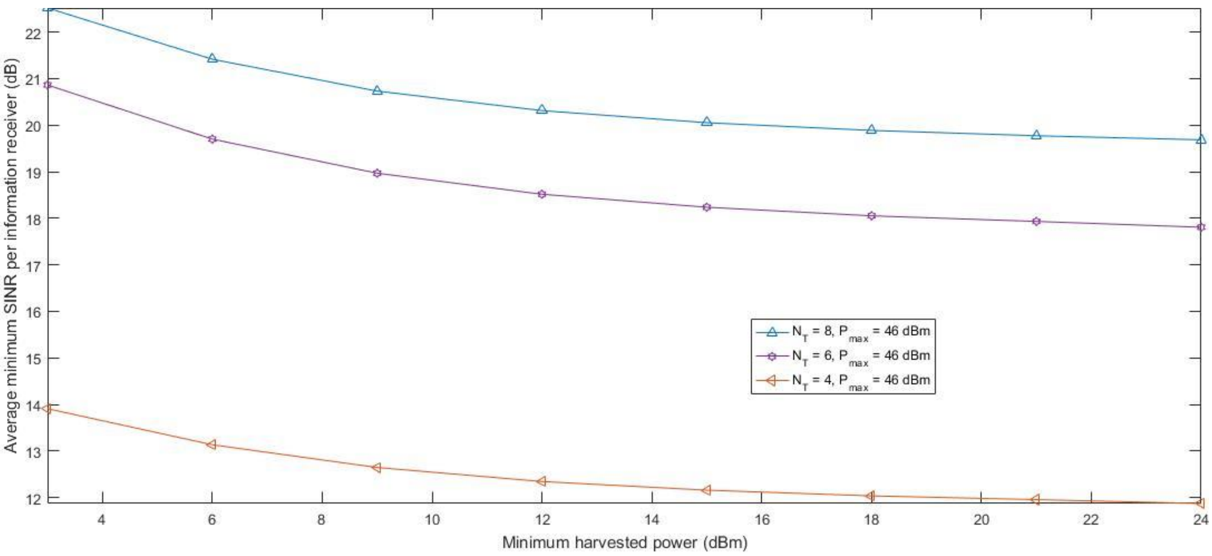

Figure 6.1: Average minimum SINR (dB) per information receiver versus maximum transmit power (dBm), for $N_T = 8,10,12$, $P_{max} = 46dBm$

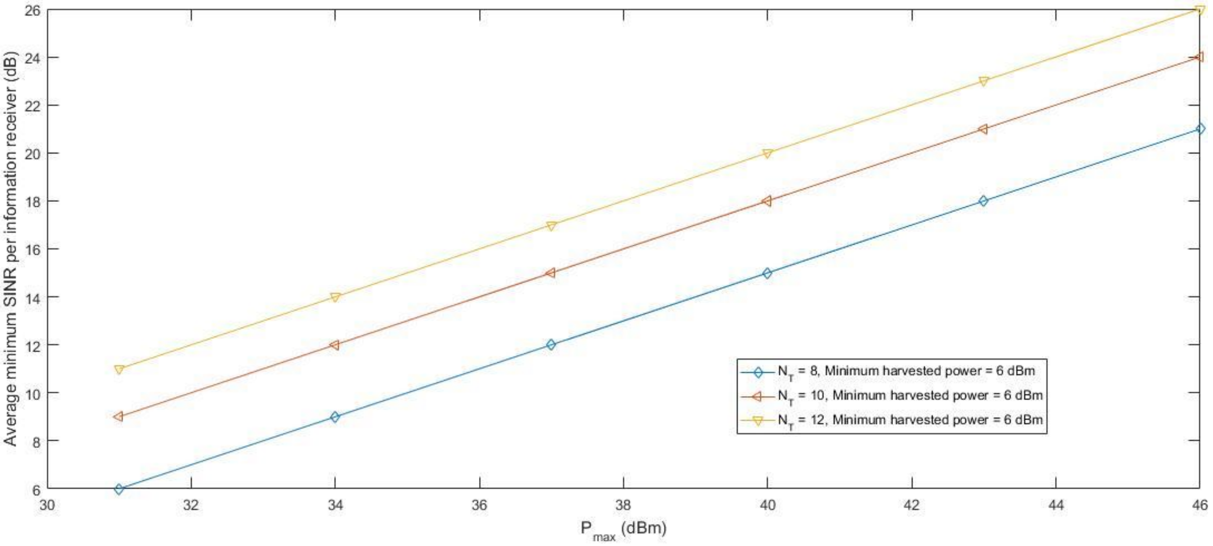

Figure 6.2: Average minimum SINR (dB) per information receiver versus minimum harvested power, for $N_T = 4,6,8$, $P_{min} = 6dBm$

Receiver decreases as energy used for information decoding shares a smaller proportion in received energy. Besides, the average minimum SINR increases when number of transmit antennas increases. More transmit antennas provide more spatial degrees of freedom which facilitates the resource allocation. In particular, a shaper energy beam can be formed.

7 Conclusion

In this paper, we discuss the resource allocation problem in the SWIPT system that is transmitting signal and energy simultaneously. The key of this optimal problem is to solve a non-convex problem for maximize the minimum SINR. Based on the SDP relaxation and KKT conditions, we can change it into a convex problem and solve it efficiently. Simulation results show that the optimal solution and tradeoff of this system.

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