IOP Conf. Series: Materials Science and Engineering **428** (2018) 012012 doi:10.1088/1757-899X/428/1/012012

Reduce Energy Consumption in SWIPT System by Discontinuous Service Base Stations

Wenjie Dong*, He Zhang and Xiang Liao

School of Mechanical Engineering, Nanjing University of Science and Technology, Nanjing, China

*E-mail: 2578726158@qq.com

Abstract. In this paper, we investigate energy consumption reduction problem of simultaneous wireless information and power transfer (SWIPT) systems by establishing a discontinuous service base station (DSBS) scheme for SWIPT. Service time of the DSBS is minimized by optimizing the time allocation between energy harvesting (EH) and information transfer (IT), and the power consumption allocation between intermittent IT and continuous target detect. To solve the optimization problem, A method to reduce the dimensions of optimization subject is put forward. Out of service probability of the system is analysed, where the failure event is defined as the terminal required service time is lager then the maximum allowed DSBS service time. Analytical and simulation results reveal that, the system we presented possesses effective energy consumption ability with little reliability lost.

1. Introduction

Energy harvesting (EH) is a promising method to expand the life length of energy limitation devices, which are always constrained by energy storage capacity, such as wireless sensor networks (WSNs) and cellular networks. Among the EH methods being studied, one of the method where wireless devices harvest energy from dedicated RF power is wireless powered communication (WPC), as introduced in [1]. With consideration of transmit power limitation, the tradeoffs between information transfer rate and power harvest efficiency were analyzed in [2], [3], where simultaneous wireless information and power transfer (SWIPT) was first put forward. Authors in [4], [5] designed dynamic power splitting (DPS) schemes in receiver to split SWIPT signal into EH steam and information transfer (IT) steam and proposed optimal PS rules to achieve maximum ergodic capacity and average harvested energy. Two special case of DPS schemes, time switching (TS) and power splitting (PS) were widely discussed in later researches, hybrid PS receiver architectures which combined TS and PS scheme were designed in [6], [7]. Optimization analyses in [4], [5] only considered simplex information and power transfer. [6], [8], [9], [10] studied duplex SWIPT systems with downlink energy transfer and duplex information transfer. A half-duplex SWIPT protocol for an amplify-and-forward relaying system was designed in [6], where the system receives power and information from BS first, then closes the receiver and switches to the information forward mode. [8], [9], [10] analyzed full-duplex relay systems with power recycle, where the relay node receives and forward information simultaneously, and their antennas would recycle the relay transmission energy. Information self-interference effect of the energy recycle was analyzed by treating the self-interference as a noise signal at antenna. outage probability of SWIPT relaying system was analyzed in [11], [12], where channels

IOP Conf. Series: Materials Science and Engineering **428** (2018) 012012 doi:10.1088/1757-899X/428/1/012012

fading and noise cause the outage. To the best of our knowledge, most researches about SWIPT systems assumed that the BS in SWIPT system is stationary and has continuous power supply.

However, for green energy powered BS like the solar powered BS (SPBS) in [13], energy consumption reduction must be considered, where an optimal energy allocation policy for maximizing total utility and reducing energy consumption of the SPBS was proposed. Authors in [14] introduced a kind of sleep-mod BS to increase energy efficiency of cellular networks, where the BSs switch between low and high energy consumption modes based on their loads. These BS are named as discontinuous service BS (DSBS). In this paper, in order to reduce energy consumption of the whole SWIPT system, we apply DSBS to SWIPT systems. To keep the SWIPT terminal continuous working, based on hybrid PS receivers, we propose an adaptive SWIPT terminal scheme, where the terminal has an intermittent SWIPT module, and a continuous module for target detection in WSNs, which makes our scheme different from the sleep-wake policy of sensor nodes in [15]. Service time of the DSBS is minimized by optimizing the time allocation between energy harvesting (EH) and information transfer (IT), and power allocation between IT and target detect consumption.

2. System model

Figure1 shows a working period of the system with a fixed length T, which is divided into two phases. In the first phase with dynamic length T_1, DSBS powers the terminal up and communicates with the terminal. In the second phase with length T-T_1, DSBS shutdown the SWIPT power. The target detector in terminal works continuously in the whole T. The first phase is divided into three time slots. In the first time slot of t_1 length, the DSBS powers the terminal up and estimates the channel; In the second time slot of t_2 length, the terminal feedback power up and channel estimation information. In the third time slot of t_3 length, the terminal upload target information to the DSBS and download updated setting information from the DSBS. The terminal harvests energy in all the three time slots, upload information in the second and third time slots, and download information in the third time slot.

The terminal antenna received signal in first phase is

$$y_{Ti}(t) = \sqrt{P_B} h_{BT} s_i(t) + w_i \sqrt{P_T} h_{TS} s_U(t) + n_a(t) \tag{1}$$

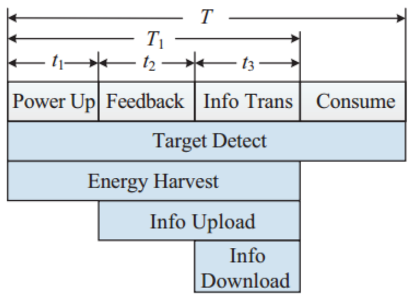


Figure1. A working period of the system

where $y_{Ti}(t)$ represents the received signal in time slot i, $i \in [1,2,3]$, P_B is the BS source power, $s_i(t)$ is the normalized source signal in time slot i, w_i is full-duplex self-interference weights of the terminal, P_T is uplink drive power of the terminal, $S_U(t)$ denotes the normalized sensor uplink signal, $\mathbb{E}(S_U(t)) = 1$, and $n_a(t) \sim \mathcal{CN}(0, \sigma_a^2)$ represents the AWSN noise introduced by antenna at the terminal with variance σ_a^2. Since there is no downlink information transmission in time slot 1 and 2, $s_1(t) = s_2(t) = 1$ is the unmodulated carrier signal, and $s_3(t)$ is the normalized downlink signal, $\mathbb{E}(s_3(t)) = 1$. We assume that self-interference energy of the terminal will be completely harvested by terminal antenna, w_2=w_3=1 and w_1=0.

The base band signal at the terminal is

$$y_{T3}(k) = \sqrt{1 - w_{\rho i}} \left(\sqrt{P_B} h_{BT} s_i(k) + w_i \sqrt{P_T} h_{TS} s_U(k) + n_a(k) \right) + n_d(k) \tag{2}$$

where $n_d(t) \sim \mathcal{CN}(0,\sigma_d^2)$ represents the AWSN noise introduced by base band conversion at the terminal with variance σ_d^2, $w_{\rho i}$ are the power splitting weights, $w_{\rho 1} = w_{\rho 2} = 1$ and $w_{\rho 3}$ equals to power storage factor ρ, which means the terminal harvests the whole received power in time slot 1 and 2.
The DSBS antenna received signal in first phase is

$$y_{Bi}(t) = w_i \sqrt{P_T}\, h_{TB} s_U(t) + n_b(t) \tag{3}$$

where $n_b(t) \sim \mathcal{CN}(0,\sigma_b^2)$ represents the AWSN noise introduced by antenna at the DSBS with variance σ_b^2. Since the noise power cannot be harvested. The harvested power in the first phase equals to

$$P_i = \eta w_{\rho i}\left(P_B\left|h_{BT}\right|^2 + w_i^2 P_T\left|h_{TS}\right|^2\right) \tag{4}$$

where η denotes the energy harvest efficiency. For the sake of simplicity of hardware implementation, the terminal uplink drive power P_T is static and proportional to P_3 in time slot 2 and 3, which is

$$P_T = \frac{\xi\eta\rho P_B\left|h_{BT}\right|^2}{1\text{-}\xi\eta\left|h_{TS}\right|^2} \tag{5}$$

where ξ is the uplink power consumption factor.

3. Service time optimization

3.1. Optimization Problem

In this subsection, we analysis the optimal problem of this system. As we focus on reducing energy consumption of the whole system, the optimization goal is minimizing the DSBS service phase T_1.

Allocation policy between the time slot length t_1, t_2, t_3, the power storage factor ρ and the power consumption factor ξ has a significant effect on T_1. Thus, we formulate the optimization problem as follows:

$$\min_{t_1,t_2,t_3,\rho,\xi} T_1 \tag{6a}$$

$$\text{s.t. } W_U \log_2\left(1+\lambda_U\right)t_3 \ge I_i \tag{6b}$$

$$W_U \log_2\left(1+\lambda_U\right)(t_2+t_3) \ge I_u \tag{6c}$$

$$W_D \log_2\left(1+\lambda_D\right)t_3 \ge I_d \tag{6d}$$

$$P_1t_1 + P_2t_2 + P_3t_3 \ge P_T(t_2+t_3) + P_CT \tag{6e}$$

$$P_1t_1 \ge E_p \tag{6f}$$

$$0 < \rho < 1 \tag{6g}$$

$$0 < \xi \tag{6h}$$

where I_i in (6b) specifies the minimum required power up feedback information, W_U is the uplink bandwidth, and $\lambda_U = \frac{P_T\left|h_{TB}\right|^2}{\sigma_b^2}$ is the uplink SNR. I_u in (6c) specifies the total need uploading information. In (6d), I_d limits the minimum terminal downlink information, W_D is the downlink bandwidth, $\lambda_D = \frac{(1-\rho)P_B\left|h_{BT}\right|^2}{(1-\rho)(P_T\left|h_{TS}\right|^2+\sigma_a^2)+\sigma_d^2}$ is the downlink SNR. Inequality (6e) represents the total energy balance, where left of it is the harvested energy and right of it is the energy consumption, where P_C is the terminal continuous power consumption, and it is assumed that information processing power consumption is negligible. *Ep* in (6f) is the power up threshold limit. (6g) is the limit that both downlink information demodulation and energy harvesting power must be larger than zero. (6h) is the limit of minimum uplink transmission power.

3.2. Solve the Problem

In this subsection, we seek the optimal value of ρ, ξ, and the optimal allocation between t_1, t_2 and t_3 to minimize T_1. In order to solve the five-dimensional non-convex optimization problem in (6), We present a method to reduce the dimensions. Since $T_1 = t_1 + t_2 + t_3$, (6) is a linear problem with non-linear boundaries when ρ and ξ are fixed, where the optimal value is obtained at the boundaries. We replace ξ with P_T by

$$\xi = \frac{P_T}{\eta\rho\left(P_B\left|h_{BT}\right|^2 + P_T\left|h_{TS}\right|^2\right)} \tag{7}$$

where the ξ is completely determined by P_T and ρ. Then we give out the following proposition to find which boundaries the optimal value is obtained on.

Proposition 1: For any fixed value of P_T and ρ, T_1 gets its optimal value when (6b) is tight and ether (6c) or (6d) is tight. Moreover, for any fixed value of ρ, T_1 gets its optimal value when (6c) and (6d) are both tight.

Proof of the proposition 1 appears in appendix A.

According to the proposition 1, by combining tight (6c) and tight (6d), the relationship between P_T and ρ is

$$\rho = 1 - \frac{\sigma_d^2(F-1)}{(P_B\left|h_{BT}\right|^2 + P_T\left|h_{TS}\right|^2(1-F) + \sigma_a^2(1-F))} \tag{8}$$

Where, $F = (\frac{P_T\left|h_{TB}\right|^2 + \sigma_b^2}{\sigma_b^2})^{\frac{I_d W_R}{I_u W_T}}$.

The multi-dimensional problem (6) is transformed to a one-dimensional optimization Problem

$$\begin{aligned} &\min_{P_T} T_1 \\ &\text{s.t. (6e),(6f),(6g),(6h)} \end{aligned} \tag{9}$$

which can be solved by using line search method. The DSBS energy consumption reduction algorithm is:

Algorithm: DSBS energy consumption reduction

1: **Initial** $P_T^{(0)} > 0$, the iteration index μ = 0, the searching distance d = 1, and tolerance $\varepsilon > 0$;
2: **while** μ ≤max-index **or** $\left|T_1^{(\mu)} - T_1^{(\mu-1)}\right| < \varepsilon$ **do**
3: $\mu = \mu + 1$, $P_T^{(\mu)} = P_T^{(\mu-1)} + d$;
4: Calculate $P^{(\mu)}$ by equation (8), Solve $T_1^{(\mu)}$ through (6) with $\rho^{(\mu)}$ and $P_T^{(\mu)}$;
5: **if** $(T_1^{(\mu)} - T_1^{(\mu-1)}) \geq \varepsilon$ **then**
6: $d = -d/2$;
7: **end if**
8: **end while**
9: Output current $\mu, P_T^{(\mu)}, T_1^{(\mu)}, \rho^{(\mu)}, \xi^{(\mu)}$.

3.3. Out of Service Probability Analysis

In this subsection, we analyze the out of service probability of the system. It is assumed that all channels in this system are independent quasi-static flat Rayleigh fading channels in a working period, $h_{BT} \sim \mathcal{CN}(0,\left|h_1\right|^2)$, $h_{TS} \sim \mathcal{CN}(0,\left|h_2\right|^2)$, $h_{TB} \sim \mathcal{CN}(0,\left|h_3\right|^2)$. We define random variables $x \triangleq \left|h_{BS}\right|^2$, and $x \triangleq \left|h_{TB}\right|^2$, whose probability density functions are $f_x(x) = \frac{1}{\left|h_1\right|^2} e^{\frac{x}{\left|h_1\right|^2}}$, $f_y(y) = \frac{1}{\left|h_2\right|^2} e^{\frac{y}{\left|h_2\right|^2}}$, and

$f_z(z) = \frac{1}{|h_3|^2} e^{\frac{z}{|h_3|^2}}$. Out of service situation includes leakage of energy and failure of information transfer, whose probability is

$$P_o = P\{T_{1\min} > T_{1M}\} = \iiint T_{1\min}(x,y,z) > T_{1M}\, f_x(x) f_y(y) f_z(z) dxdydz \quad (10)$$

where $T_{1M} \leq T$ is the maximum allowed service time. We assume that fading of the self-interference channel is negligible, $y = |h_2|^2$. An effective approximation of optimization problem (9) is tightening (6e), (6f) and solving the combined equation. The approximation may cause the second type of error in low SNR situation, where some of the result may outside the boundaries in (6). The function of T_1 is

$$T_1 = \frac{(A - D\rho)P_T - B(\rho I_d + I_i)x}{Bx\log_2(1 + \frac{P_T z}{\sigma_b})} + \frac{E_C}{Bz} \quad (11)$$

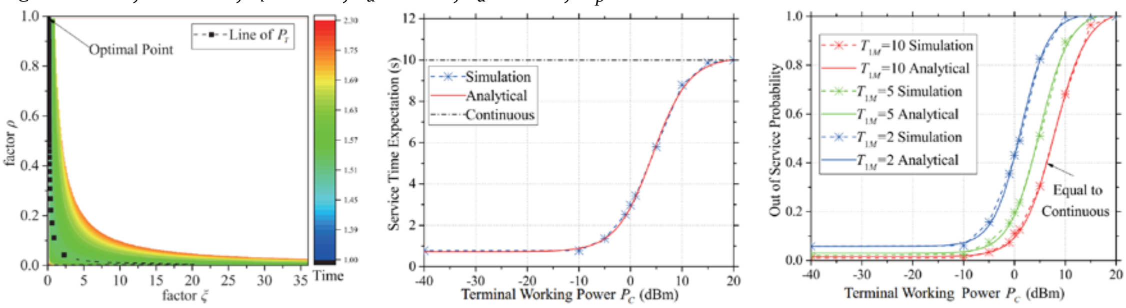
where $A = I_d + I_i(1 - \eta|h_2|^2 W_R)$, $B = \eta P_B W_R$, $D = I_d \eta |h_{TS}|^2 W_R$. P_T is solved by equation

$$P_T = \frac{(W_U E_C - W_U E_P)\log_2(1 + \frac{P_T z}{\sigma_b}) - \eta P_B I_u x}{(\eta|h_2|^2 - 1)I_u} \quad (12)$$

Numerical result of integration (10) will be given out in the next section.

4. Numerical results

Numerical simulation results are presented by assuming that the P_B is normalized to 1W, h_{BT}=-20dB, $\sigma_a = -70$dBm, $\sigma_d = -65$dBm, $\sigma_b = -70$dBm, $h_{TS} = -15$dB, $h_{TB} = -20$dB, W_U = 1Hz, W_D = 1Hz, η = 0:9, P_C = 0dBm, T = 10s, I_i = 1bit, I_u = 2bit, I_d = 1bit, E_p = 1mJ.



(a) T_1 vs. ρ and ξ (b) $\mathbb{E}[T_1]$ vs. P_C (c) P_o vs. P_C

Figure2. Numerical Results

Figure. 2a shows the service time optimization result by using our algorithm vs. direct searching the ρ-ξ plane, where the color represents optimized service time. In Figure2.a, the optimal result lies in the flat green zone. Searching line P_T is a curve line in the ρ-ξ plane. Searching points on the searching line are equal spacing P_T values, which become dense on the ρ-ξ plane when approaching the optimal value. Thus, the algorithm reduces the computation complexity and improves the computation accuracy. The optimal value is ρ = 0:9997, ξ = 0:0111, $P_T = -23$dBm and T_1 = 1:4s.

Then, we focus on the system reliability performance versus P_C, which represents how much energy the terminal could use besides the SWIPT consume. The solid line in Figure2.b is the analytical expectation of service time E(T_1) versus P_C calculated by (10), and the dash line with star points represents its simulative result. Figure2.b shows that $\mathbb{E}[T_1]$ increases with P_C increasing when $P_C > -10$dBm. When $P_C \leq -10$dBm, $\mathbb{E}[T_1]$ approaches to a non-zero service time constant, which represents the SWIPT energy consumption of the system. It is worth noting that, as the P_B is nominalized, $\mathbb{E}[T_1]$ can be treated as the expectation of DSBS energy consumption. The dash-dot line represents the energy consumption of continuously full duplex PS, which are constant under any P_C value. Therefore, the DSBS effectively reduce the system energy consumption. Figure2.c shows the analytical and simulative out of service probability versus P_C with different maximum service time T_{1M} values. In Figure2.c, under the small power storage condition, where the terminal power storage capacity equals to P_CT, continuous BS out of service probability equals to the out of service probability DSBS at $T_{1M} = T$. The DSBS can save energy without causing performance degradation. In low P_C condition, better energy saving effect can be gotten with a small performance degradation.

5. Conclusion

In this paper, energy consumption reduction problem of the SWIPT system has been studied, where the DSBS are applied to the SWIPT system. To minimize the service time of DSBS, A dynamic hybrid PS scheme is designed, and the optimal time and power consumption allocation are solved. The out of service probability of the system is analyzed, where the failure event is defined as the terminal required service time is lager then the maximum allowed DSBS service time. Analytical and simulation results reveal that, the system we presented possesses effective energy consumption reduction ability with little reliability lost under small power storage condition.

6. Appendix A: proof of the proposition

Proof: For any fixed value of P_T and ρ which satisfies (6g) and (6h), we assume a set of [t_1, t_2, t_3] which satisfy all constraints in (6), and transform t_2 and t_3 to

$$t_2 = \Delta t_2 + \frac{I_i}{I_1} = \Delta t_2 + t_2^*, t_3 = \Delta t_3 + \max(\frac{I_u - I_i}{I_2}, \frac{I_d}{I_D}) = \Delta t_3 + t_3^* \quad (13)$$

where $\Delta t_2 \geq 0$, $\Delta t_3 \geq 0$. The energy balance constraint (6e) is transformed to

$$P_1 t_1 + P_2(\Delta t_2 + t_2^*) + (P_3 - P_T)(\Delta t_3 + t_3^*) \geq E_C \quad (14)$$

Since $|h_{TS}|^2 \leq 1$ and η < 1, $\eta P_T |h_{TS}|^2 - P_T < 0$. According to equation (4), we can get inequity $P_1 > (P_2 - P_T) > (P_3 - P_T)$. Thus, (6e) is transformed to

$$P_1(t_1 + \Delta t_2 + \Delta t_3) + (P_2\text{-}P_T)t_2^* + (P_3 - P_T)t_3^* \geq E_C \quad (15)$$

where the equal achieves only when $\Delta t_2 = \Delta t_3 = 0$. When $\Delta t_2 > 0$ or $\Delta t_3 > 0$, a Δt_1 can always be found, which satisfies $0 \leq \Delta t_1 \leq \Delta t_2 + \Delta t_3$ and inequality

$$P_1(t_1 + \Delta t_1) + (P_2 - P_T)t_2^* + (P_3 - P_T)t_3^* > E_C \quad (16)$$

We define a new $T_1^* = t_1 + \Delta t_1 + t_2^* + t_3^*$. According to the analyses above, $T_1^* \leq T_1$, where the equal achieves only when $\Delta t_2 = \Delta t_3 = 0$. Thus, the first part of the proposition that For any fixed value of P_T and ρ, T_1 gets its optimal value when (6b) is tight and ether (6c) or (6d) is tight is proved.

Then, for any fixed value of ρ, we assume a P_T to make (6c) tight and (6d) loose, which is

$$P_T = \frac{(2^{\frac{I_u - I_i}{W_R t_3^*}}\text{-}1)\sigma_b^2}{|h_{TB}|^2} < \frac{P_B |h_{BT}|^2}{(2^{\frac{I_d}{W_T t_3^*}} - 1)|h_{TS}|^2} - \frac{\sigma_d^2}{(1-\rho)|h_{TS}|^2} - \frac{\sigma_a^2}{|h_{TS}|^2} \quad (17)$$

With the value of ρ and P_T we assumed, the optimal value of the first phase length is $T_1^* = t_1^* + t_2^* + t_3^*$. We can find a $\Delta P_T > 0$ which satisfies inequality

$$\frac{(2^{\frac{I_u - I_i}{W_R t_3^*}}\text{-}1)\sigma_b^2}{|h_{TB}|^2} < P_T + \Delta P_T \leq \frac{P_B |h_{BT}|^2}{(2^{\frac{I_d}{W_T t_3^*}} - 1)|h_{TS}|^2} - \frac{\sigma_d^2}{(1-\rho)|h_{TS}|^2} - \frac{\sigma_a^2}{|h_{TS}|^2} \quad (18)$$

As $P_T + \Delta P_T > P_T$, $[t_1^*, t_2^*, t_3^*]$ still satisfy the constraints in (6). By using the first part of the proposition with ρ and $P_T + \Delta P_T$, a new value $T_1^{**} \le T_1^*$ can be found, thus, the second part of the proposition is proved.

Acknowledgements
This work was supported by the Key Basic Research Projects of Basic Strengthening Plan (No.2017-JCJQ-ZD-004), Postgraduate Research & Practice Innovation Program of Jiangsu Province (KYCX17_0334). The authors would like to express their appreciation to the reviewers for their valuable suggestions which have helped to greatly improve the manuscript.

References
[1] S. Bi, C. K. Ho, and R. Zhang, “Wireless powered communication: Opportunities and challenges,” IEEE Commun. Mag., vol. 53, no. 4, pp. 117–125, Apr. 2015.
[2] L. R. Varshney, “Transporting information and energy simultaneously,” in Information Theory, 2008. ISIT 2008. IEEE International Symposium On. IEEE, 2008, pp. 1612–1616.
[3] P. Grover and A. Sahai, “Shannon meets Tesla: Wireless information and power transfer,” in Information Theory Proceedings (ISIT), 2010 IEEE International Symposium On. IEEE, 2010, pp. 2363–2367.
[4] X. Zhou, R. Zhang, and C. K. Ho, “Wireless information and power transfer: Architecture design and rate-energy tradeoff,” IEEE Trans. Commun., vol. 61, no. 11, pp. 4754–4767, 2013.
[5] L. Liu, R. Zhang, and K.-C. Chua, “Wireless information and power transfer: A dynamic power splitting approach,” IEEE Trans. Commun., vol. 61, no. 9, pp. 3990–4001, 2013.
[6] R. Tao, A. Salem, and K. A. Hamdi, “Adaptive Relaying Protocol for Wireless Power Transfer and Information Processing,” IEEE Commun. Lett., vol. 20, no. 10, pp. 2027–2030, 2016.
[7] B. He, N. Yang, S. Yan, and X. Zhou, “Regularized Channel Inversion for Simultaneous Confidential Broadcasting and Power Transfer: A Large System Analysis,” IEEE J. Sel. Top. Signal Process., vol. 10, no. 8, pp. 1404–1416, 2016.
[8] D. Wang, R. Zhang, X. Cheng, and L. Yang, “Capacity-Enhancing FullDuplex Relay Networks based on Power Splitting (PS-) SWIPT,” IEEE Trans. Veh. Technol., vol. PP, no. 99, pp. 1 – 1, 2016.
[9] Y. Zeng and R. Zhang, “Full-duplex wireless-powered relay with selfenergy recycling,” IEEE Wirel. Commun. Lett., vol. 4, no. 2, pp. 201– 204, 2015.
[10] Z. Wen, X. Liu, N. C. Beaulieu, R. Wang, and S. Wang, “Joint source and relay beamforming design for full-duplex MIMO AF relay SWIPT systems,” IEEE Commun. Lett., vol. 20, no. 2, pp. 320–323, 2016.
[11] G. Pan and C. Tang, “Outage performance on threshold AF and DF relaying schemes in simultaneous wireless information and power transfer systems,” AEU-Int. J. Electron. Commun., vol. 71, pp. 175–180, 2017.
[12] H. Lee, C. Song, S.-H. Choi, and I. Lee, “Outage Probability Analysis and Power Splitter Designs for SWIPT Relaying Systems With Direct Link,” IEEE Commun. Lett., vol. 21, no. 3, pp. 648–651, 2017.
[13] E. T. Ceran, T. Erkilic, E. Uysal-Biyikoglu, T. Girici, and K. Leblebicioglu, “Optimal energy allocation policies for a high altitude flying wireless access point,” Trans. Emerg. Telecommun. Technol., 2016.
[14] J. Wu, Y. Zhang, M. Zukerman, and E. K.-N. Yung, “Energy-efficient base-stations sleep-mode techniques in green cellular networks: A survey,” IEEE Commun. Surv. Tutor., vol. 17, no. 2, pp. 803–826, 2015.
[15] P. Du, Q. Yang, Z. Shen, and K.-S. Kwak, “Distortion Minimization in Wireless Sensor Networks with Energy Harvesting,” IEEE Commun. Lett., vol. PP, no. 99, pp. 1–1, 2017.