SWIPT Enabled Device To Device Communication on PSO Based Resource and Power Allocation Using Energy Harvest Model

Tapaswini choudhury, Rashmita Routray, Dr. Tapas Kumar Patra

Dept. Of E&I Engineering, OUTR, BBSR, Odisha, India
Assistance Professor, Dept. Of E&I Engineering, OUTR, BBSR, Odisha, India
Professor, Dept. Of E&I Engineering, OUTR, BBSR, Odisha, India

---***---

Abstract - Wireless information and power transfer system is an encouraging result to enhance ling life and tone reliant wireless network. The battery life capacity is limited in IoT devices such as mobile devices as a guaranteed solution simultaneous wireless information and power transfer is introduced can transfer information and power simultaneously by capturing the powers from the radio frequency for mobile devices. Then in this paper, our main focus is to maximize the sum of the entire device to the device under a mobile network by maximizing the power and resource allocation based on a nonlinear EH scheme.. Then in this paper, our main focus is to maximize the sum of the entire device to device under a mobile network by maximizing the power and resource allocation based on a nonlinear EH scheme. Here we firstly model a clustering-based PSO algorithm to differentiate the device to device link in a Simultaneous wireless information and power transfer enable energy harvest group and non energy harvest grope which can't satisfy the energy harvest circuit sensitive and use two layer energy efficiency iterative algorithm which will maximize the device to device power transmission and the PS power splitting ratio to optimize the energy efficiency of all the Simultaneous wireless information and power transfer enabled device to device links and cellular user link . The two-layer energy efficiency iterative algorithm has two type one is inner loop iterative algorithm where we covert the convex maximization problem for optimizing the total energy harvest power and other one is outer loop iterative algorithm on this algorithm we list out the preference for the device to device link and cellular link. Then we used one to one constraint stable matching algorithm to optimize the sum of all Energy efficiency of the Simultaneous wireless information and power transfer to enable the device to device link by maximizing the spectrum resource sharing between all device to device links and cellular links. By using an iterative power control algorithm and one to one matching algorithm, the non energy harvest sum rate can increase. The simulation result shows that our proposed algorithm gives much high energy efficiency than the existing one.

Key Words: MATLAB, D2D, Energy effectiveness, Matching proposition, Power control, Resource allocation, Underlay, simultaneous wireless information and power transfer.

1. INTRODUCTION

With the rapid growth of device to device communication system, now a day our requirement is to increase the data rate. There many technique are there, like wifi , Zigbee which are support IoT[5]. And most of them are worked in unlicensed band that means we cannot promise on the quality of service. one of the advantage in cellular network is it gives direct communication with each other without help of BS [8] by reuse the resource allocation of cellular network which improve the energy efficiency of network. But there will be improve self interference during data transmission and reception between the cellular user and the device to device user, which we have to minimize by using correct resource allocation mode. In this paper we develop RF-EG (radio frequency-energy harvest) where the receiver harvests the energy from the radio frequency signal [7]. Simultaneous information and power transmission is one of the best technique which can harvest energy and also transfer the information to the receiver. Energy harvest technique is divided into two types that are power splitting mode and time switching mode [3]. SWIPT can operate in shorter distance because it is depends upon the received power and throughput to activate the energy harvest technique. There has been many work have assumed a simple linear energy harvest model, where the harvested energy by the receiver is linear proportional to the receive power, but due to some non linear element like diode, capacitor, inductors in practice energy cannot harvest linearly.

In this paper our main focus is to optimize the energy efficiency of all device to device under laid cellular network.

1.1 Device to Device communication (D2D)

D2D communication is the encouraging technology in 5G network [4].5G comes a lots of devices which generating data and it is difficult to managing the data at a single BS .In device to device communication two user communicate directly without help of base station [8]. Communication technology provides D2D for the 5G to communicate devices with each other without sharing the infrastructure or partial sharing thereof. There are common technologies for D2D available for wireless transmission for example Bluetooth and Wi-Fi Direct, but they are short-range and therefore most technologies cannot directly communicate between the two devices to achieve the perceived connection of 5G .There must be a change in the basic structure of the existing networks.

Modern cellular network is mainly divided into two types, first on is called Micro cell tier, Device tier. The cell layer contains a large number of base station (BS) attached to the device as it is known in conventional cell systems. While the device layer contains D2D connections .if one of the device is connected to another device through base station then it is operating is micro cell mode. And if one device is connected to other device without BS or directly then it is in device mode.

1.2 Simultaneous Wireless Information and Power Transfer (SWIPT)

It extension of wireless power transfer (WPT), known from contactless smart phone charging. Beside wireless power transfer in SWIPT data can transmit simultaneously via the same magnetic or electric field [6], where receiver harvest energy and process the information simultaneously. SWIPT gives spectrum efficiency to the system as same bandwidth is used for power and information transfer. In wireless communication interference is a major issue which we have to address and reduce. In cooperative communication, for relay information relay node needs energy, so EH is one of the technique of the energy problem at the relay node[10]. Hence first harvest energy by relay node and then use this harvest energy for relaying purpose. Wireless communication with SWIPT, batter the quality of service of the system by giving EE and spectrum efficiency, cancelling near far effect, increasing the coverage area and improving channel capacity.

There are two protocols in SWIPT based wireless communication and theses protocols defined how relay node harvest energy and process information simultaneously.

2. SWIPT ENABLED ENERGY EFFICIENCY MAXIMIZATION

First, we set the energy harvest sensitivity (minimum energy required for activating the energy harvest technique) [9]. We propose a Clustering based PSO algorithm to verify the device-to-device link can operate in SWIPT enable EH technique where circuit sensitivity and depth required throughput build on PSO algorithm. We used the constraint match algorithm to optimize the sum of all Energy efficiency of the SWIPT to enable the D2D link by maximizing the spectrum resource sharing between all D2D link and CUE links. In the matching algorithm, the partner matching link list for CEU users and the D2D user is created based on the solution of per device-to-device link energy efficiency optimization problem, which will maximize the transmission power of the D2D link and PS rate according to the piecewise linear energy harvest model.

By the power control, iterative algorithm, and matching algorithm, the energy efficiency of the non energy harvest model can be maximized.

Algorithm 1. Prematching Algorithm

Input: $\widehat{D}, \hat{C}, P_{th}^{1}, P_{max}, P_{min}^{d}$

Output: S_i^d, Inf^d, Eha^d

Initialize: $s_i^D = \hat{C}, Inf^d = \emptyset, Eha^d = \emptyset$

3. ***for*** $i \in \widehat{D}$ do
4. ***for*** $k \in \hat{C}$ do
5. Obtain $\gamma_{i,min}^{e}$, obtain $T_{i,max}^{d}$
6. ***if*** $\gamma_{i,min}^{e} > 1$ or $T_{i,max}^{d} \leq T_{min}^{d}$
7. ***then*** $S_i^d \backslash k$.
8. ***end if***
9. ***end for***
10. ***if*** $S_i^d = \emptyset$
11. ***then*** $Inf^d \cap i$
12. ***else***
13. $S_i^d \neq \emptyset$, $Eha^d \cap i$.
14. ***end if***
15. ***end if***

In pre matching algorithm we divide device to device link into two part, one is part is Eha^d for SWIPT enabled device to device link which harvest the energy (activate energy harvest circuit sensitivity) and another group Inf^d is for non EH D2D link. Were we have taken a partner selection set S_i^d for each D2D link and we initialize as $\hat{C}$. When cellular user k's reusing resource block (smallest unit of resource assigned to a single user) and sending maximum power P_{max}, D2D link i cannot fulfill the energy harvest circuit sensitivity or the device to device throughput requirement, the cellular user is deleted from the partner selection set S_i^d [1].

Algorithm 2. PSO Algorithm

Initialize: $w, c_1, c_2, u_b, l_b, p, d$

Initialize: position $X \sim U[u_b, l_b]$

Initialize: velocity $V \sim U([-|u_b - l_b|, |u_b - l_b|])$

1. $P_{best} = \min(f(X))$
2. $P_{sol} = X(\arg\min(f(X)))$
3. $G_{best} = P_{best}$
4. $G_{sol} = P_{sol}$
5. **While** termination criteria not met **do**
6. V=w $\times V + c_1 \times r_p \times (P_{sol} - X) + c_2 \times r_p \times (G_{sol} - X)$
7. X= X+V
8. X= X + V
9. $P_{best} = \min(f(X))$
10. $P_{sol} = X(\arg\min(f(X)))$
11. **If** $G_{best} > P_{best}$ **then**
12. $G_{best} = P_{best}$
13. $G_{sol} = P_{sol}$
14. **end if**
15. **end while**
16. final G_{sol} is the optimal solution
17. end procedure

PSO is a possible optimization approach that is based on a population known as the swarm [2] that is made up of particles that going together in such a search space to find the maximum solution. Each particle holds the objects to be optimized, and its position is modified between iterations to get the best local and global positions. The global best position is where a particle has achieved the population's highest returns, whereas the local best position is where the particle has achieved its own highest thus far. The power splitting ratio was designed to be a fixed number in [3] and a restricted value in obviating the possibility of tuning it to improve the energy efficiency of a SWIPT-enabled device. As a result, it is not optimized for increasing the EE of a SWIPT-enabled D2D under laid network. Our major goal in this method is to divide into two groups. One is for energy harvesting, while the other is for non-energy harvesting. This method's main purpose is to split into two groups. The first is for energy harvesting, and the second is for non-energy harvesting.

Algorithm 3 TLEELLA Outer Loop Algorithm

Input: $Eha^d, S_i^d, \gamma_{i,j}^e, p_{i,j}^d, EE_{i,j}^d$

Output: $p_i^{d'}, \gamma_i^{e'}, EE_i^{d'}$

1. ***for*** $i \in Eha^d$ ***do***
2. ***for*** $k \in S_i^d$ ***do***
3. ***for*** $j = 1{:}N_{max}$ ***do***
4. $j' = \arg\max_j\{EE_{i,j}^d \dots, EE_{i,j}^d, \dots, EE_{i,N_{max}}^d\}$,
5. Obtain $p_i^{d'} = p_{i,j}^d, \gamma_i^{e'} = \gamma_{i,j}^e, EE_i^{d'} = EE_{i,j}^d$.
6. ***end for***
7. ***end for***
8. ***end for***

The energy efficiency of SWIPT enabled the device to devise a link this algorithm consists three-step to maximize the EE. The first step is to maximize the number of segments that P_i^R belongs to, which denoted by N_{max}. We solve the maximization problem in i by solving **P3** and we found maximum power allocation and resource allocation $\{\gamma_{i,j}^d \dots, \gamma_{i,j}^d, \dots, \gamma_{i,N_{max}}^d\}$ and determine the $\{P_{i,j}^d \dots, P_{i,j}^d, \dots, P_{i,N_{max}}^d\}$, corresponding energy efficiency.

Algorithm 4 TLEELLA Inner Loop Algorithm

Require: Eha^d, S_i^d

Output: $\gamma_{i,j}^e, p_{i,j}^d, EE_i^d$

Initialize: $Q_i^d(t) = Q_i^d(0), p_i^d(t) = p_i^d(0), i, \varphi, t = 0$

1. Obtain $p_{i,r}^{max}$ and will take the decision for highest number of segments: N_{max}
2. ***for*** $i \in Eha^d$ ***do***
3. ***for*** $k \in S_i^d$ ***do***
4. ***for*** j=1: N_{max} ***do***
5. use the starting value $p_i^d(0)$ to get γ_i^e(t)
6. ***while*** t < I ***do***
7. ***if*** $T_i^d[\gamma_i^e(t+1), p_i^d(t+1)] - Q_i^d(t)[EC_i^d\gamma_i^e(t+1), EC_i^d\gamma_i^e(t+1), p_i^d(t+1)]] > \varphi$
8. **then** $Q_i^d(t+1) = T_i^d[\gamma_i^e(t+1), p_i^d(t+1)] / [EC_i^d\gamma_i^e(t+1), p_i^d(t+1)]$
9. **continue**
10. **else** $p_i^d = p_{i,j}^d(t+1), \gamma_{i,j}^e = \gamma_i^e(t+1), EE_i^d = Q_i^d(t)$
11. ***end if***
12. t=t+1
13. ***end while***
14. ***end for***
15. ***end for***
16. ***end for***

In Algorithm 3, we use an inner loop iterative strategy to find the optimal value of $\gamma_{i,j}^e, p_{i,j}^d$, and EE_i^d on the jth segment of the linear piecewise energy harvest model, for each SWIPT-enabled device to device link t signifies the number of iteration steps in Algorithm 3, while i represent the highest number of iterations allowed. The iteration stops when the value of the acquired EE is smaller than the value of the obtained energy efficiency in the preceding step, ψ or when$i$ is reached.

Algorithm 5. one to one constraint matching Algorithm

Input: $Eha^d, \hat{C}, \Omega_i^d, \Omega_k^c$

Output: φ, φ^r

Initialize: $\varphi = \emptyset$

1. **While** $Eha^d \neq \emptyset$ **do**
2. ***for*** $i \in Eha^d$ **do**
3. ***for*** $k \in S_i^d$ **do**
4. ***if*** a cellular user received only a one request by device to device links and current has not even one partner **then** cellular user and D2D link are matched
5. $Eha^d \backslash i, \varphi = (i, k)$
6. **end if**
7. ***if*** cellular receiver gets another request by D2D link i'
8. **then** cellular user will check $\Omega_i^d, \Omega_{i'}^d$
9. ***if*** device to device connection i or i' is no longer preferred
10. **Then** Cellular user k will then match with D2D link i or i'.
11. The complement device-to-device connection is removed from Eha^d and the mismatched device to device link gets grouped into Eha^d.
12. ***end if***
13. ***if*** Other choices exist for both D2D connections.
14. **then** Cellular user k will supplement with much more preferred options. Device-to-device communication based on Ω_i^dk, the matching D2D connection is deleted from Eha^d and the mismatched device-to-device link is grouped into Eha^d.
15. ***end if***
16. ***end if***
17. ***end for***
18. ***end for***

In this algorithm used that the all the SWIPT enable D2D link have to find there partner. First the entire D2D link will start proposing to the entire cellular user for matching. If the cellular user only gets one request from the device to device link i and presently have no active partner, then cellular user k and D2D user i are matched. If cellular user gets a different request from device to device link i' then cellular user k will analysis the maximum preference between Ω_i^d and $\Omega_{i'}^d$. If D2D link i ori' , has no longer matching then cellular user k would connect with a D2D link, the matched device to device link i and i' will be deleted from the list and the link which is unmatched will added to the Eha^d. If both device to device link have more preference matching then cellular user k will connect with the most favored device-to-device link based on the highest preferred Ω_i^c then the matched device to device link will delete from Eha^d and the link which is unique will added to the Eha^d. In each loop, a device to device link will delete from Eha^d. If cellular network matched with D2D link then it will remove from Eha^d. All device to device links remove from their most preferred cellular user from the choice list at the end of each loop. In the following loop, all unmatched cellular users are gathered in φ^r.

SIMULATION PARAMETER

Simulation parameters	Values
Cell radius R	300 m
Number of D2D links N	10 to 20
Number of CUEs M	10 to 60
Device to device communication distance range r	10 to 60
Path loss exponent α	3
Receiver power $[P_{th}^0, P_{th}^1 P_{th}^2, P_{th}^3]$	[10, 56368, 240.07, 200] uw
Coefficient $[k_1, k_2, k_3, k_4]$	[0, 0.3899,06967,0.1427]
Intercept $[b_1, b_2, b_3, b_4]$	[0, -1.6613, -19.1737,108.2778]
Maximum harvestable power P_{max}^{EH}	250uw
Max transmission power foe any user P_{max}	24 dBm

Cellular transmission power P_k^c	24 dBm
Noise power N_0, N_1	-100 dBm
Circuit power consumption P_{cir}	20 dBm
Throughput requirement for D2D link T_{min}^d	2 bit/s/Hz
Throughput requirement for cellular link T_{min}^c	1bit/s/Hz

Simulation Result

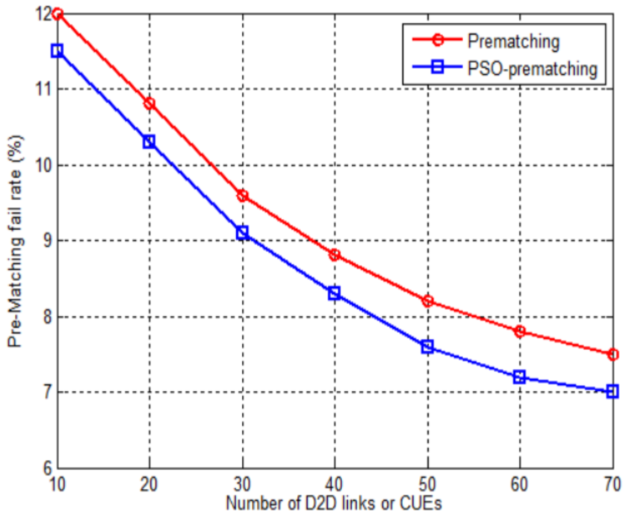

Fig-1: PMFR vs. the number of D2D links or cellular users based on prematching fail rate and number of D2D links or cellular users.

The power splitting(PS) ratio was considered to be a limited value in [1] and a fixed value in losing out on the possibility to adjust it for increasing the energy efficiency of a SWIPT-enabled device to device underlay system. By using PSO algorithm the pre-matching fail rate is reduce to 11.5% (while in pre matching algorithm the PMFR is 12 %) when the number of D2D or cellular user increases from 10 to 70.

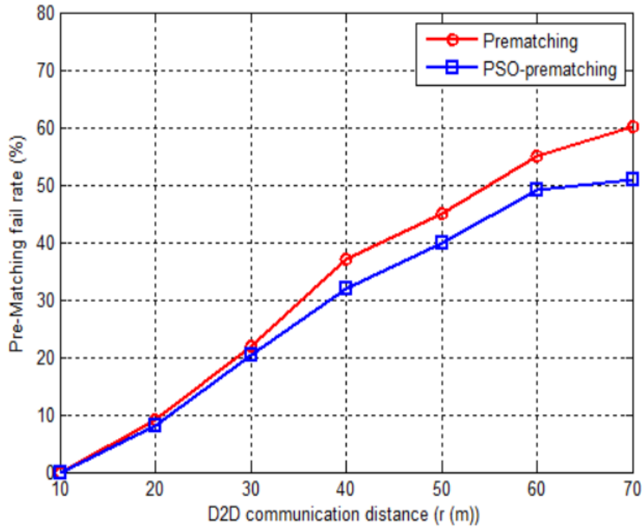

Fig-2: PMFR versus the distance of D2D link or cellular user.

Fig 2 shows prematching failure rate increases from 1% to 52% with large device-to-device communication distances ranging from 10 to 70 m. When the distance of the device to device communication improves, the device to device link needs to increase the transmission power to get energy harvest constraints, after the required transmission exceeds maximum power then, the device-to-device link cannot perform SWIPT which will increase the non energy harvest device-to-device link, and we get higher pre matching rate. In the PSO algorithm, the percentage of prematching fail rate gets decreases while increasing the number of D2D user, as compared to prematching algorithm. In prematching there is a restriction to select the energy harvest group and non energy harvest but in the PSO algorithm, we set all the receive signals to a bit stream that is only 0 and 1, for that we have taken an objective function. PSO will take information according to the bit stream if the bit stream is greater than 0.5 then it will be removed from the selection matching group S_i^d and grouped as a non harvest D2D link Inf^d else it will harvest the energy denoted as Eha^d.

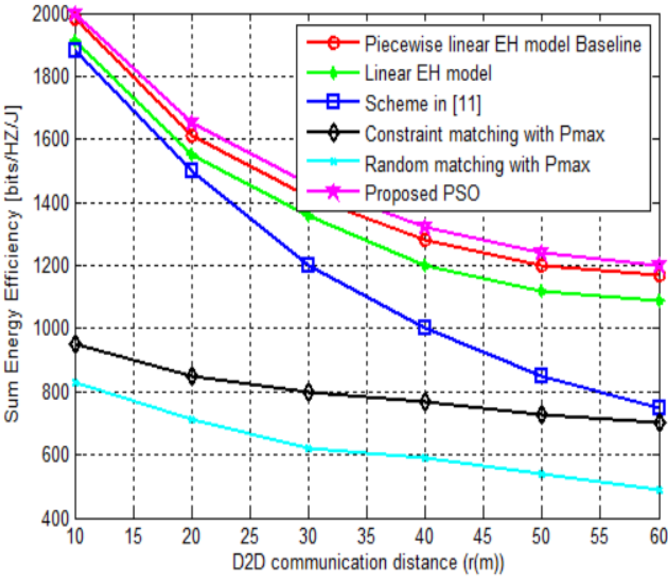

Fig-3: Sum energy efficiency versus distance of device to device link or Cellular users using PSO algorithm.

Fig 3 shows the sum energy efficiency versus distance of the D2D communication, in the paper, our main motive is to maximize the sum rate, we use a PSO-based algorithm instead of pre matching algorithm and we analyze that by using the PSO algorithm the sum energy is increased with increasing distance

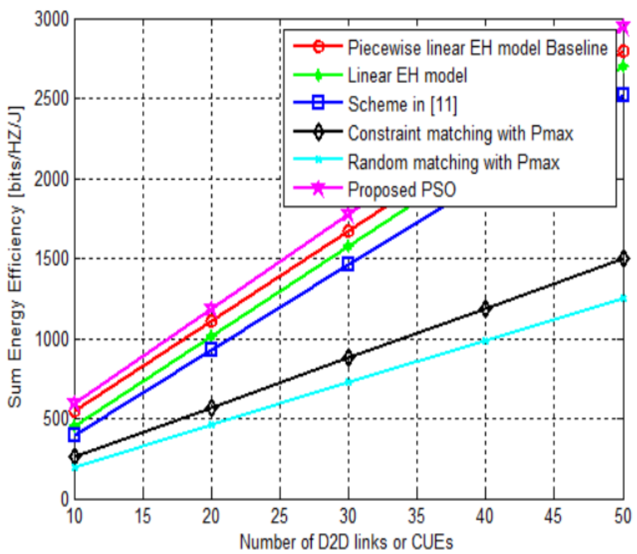

Fig-4: Sum energy efficiency versus the number of D2D link or Cellular users using PSO algorithm

Fig 4 shows the sum energy efficiency versus distance of the D2D communication. Here we analyze that, by using the PSO algorithm the sum energy is increased with increasing of number of D2D link or cellular link.

3. CONCLUSIONS

We optimized the total EE of the entire device to device link in this paper through maximizing the assignment of available spectrum and transmission power in SWIPT enabled device to device links. We propose the PSO algorithm device to device connection into SWIPT enabled EH band and non-EH band. For optimizing the sum energy efficiency of all SWIPT device-to-device links we use stable matching algorithm. The sum energy efficiency of the non-energy harvest device to device link is maximized. The PSO algorithm reduces the prematching fail rate. This improves the energy efficiency of device to device connections.

REFERENCES

[1] H. Yang, Y. Ye, X. Chu and M. Dong, "Resource and Power Allocation in SWIPT-Enabled Device-to-Device Communications Based on a Nonlinear Energy Harvesting Model," in *IEEE Internet of Things Journal*, vol. 7, no. 11, pp. 10813-10825, Nov. 2020, doi: 10.1109/JIOT.2020.2988512.

[2] García, Carla E., Mario R. Camana, and Insoo Koo. "Low-Complexity PSO-Based Resource Allocation Scheme for Cooperative Non-Linear SWIPT-Enabled NOMA." *IEEE Access* 10 (2022): 34207-34220.

[3] Perera, T. D. P., & Jayakody, D. N. K. (2018). Analysis of time-switching and power-splitting protocols in wireless-powered cooperative communication system. Physical Communication, 31, 141-151.

[4] Amanuel, S. V. A., & Ameen, S. Y. A. (2021). Device-to-device communication for 5G security: a review. *Journal of Information Technology and Informatics*, *1*(1), 26-31.

[5] R. Q. Hu and Y. Qian, "An energy efficient and spectrum efficient wireless heterogeneous network framework for 5G systems," in *IEEE Communications Magazine*, vol. 52, no. 5, pp. 94-101, May 2014, doi: 10.1109/MCOM.2014.6815898.

[6] Garg, P. (2022). A Survey on Energy Harvested Cooperative Communication system.

[7] Z. Zhou, C. Gao, C. Xu, T. Chen, D. Zhang and S. Mumtaz, "Energy-Efficient Stable Matching for Resource Allocation in Energy Harvesting-Based Device-to-Device Communications," in IEEE Access, vol. 5, pp. 15184-15196, 2017, doi: 10.1109/ACCESS.2017.2678508.

[8] J. Iqbal, M. A. Iqbal, A. Ahmad, M. Khan, A. Qamar and K. Han, "Comparison of Spectral Efficiency Techniques in Device-to-Device Communication for 5G," in IEEE

Access, vol. 7, pp. 57440-57449, 2019, doi: 10.1109/ACCESS.2019.2914486.

[9] Boshkovska, E., Morsi, R., Ng, D. W. K., & Schober, R. (2016, May). Power allocation and scheduling for SWIPT systems with non-linear energy harvesting model. In *2016 IEEE International Conference on Communications (ICC)* (pp. 1-6). IEEE.

[10] T. D. Ponnimbaduge Perera, D. N. K. Jayakody, S. K. Sharma, S. Chatzinotas and J. Li, "Simultaneous Wireless Information and Power Transfer (SWIPT): Recent Advances and Future Challenges," in IEEE Communications Surveys & Tutorials, vol. 20, no. 1, pp. 264-302, Firstquarter 2018, doi: 10.1109/COMST.2017.2783901.