International Journal on "Technical and Physical Problems of Engineering" (IJTPE)
Published by International Organization of IOTPE
ISSN 2077-3528
IJTPE Journal
www.iotpe.com
ijtpe@iotpe.com
September 2020 | Issue 44 | Volume 12 | Number 3 | Pages 52-55

PERFORMANCE ANALYSIS OF FULL DUPLEX ENERGY HARVESTING COGNITIVE RADIO NETWORK

A. Bujunuru [1] **S. Tadisetty** [2]

1. ECE Department, Guru Nanak Institutions Technical Campus, Hyderabad, India, anitha.shanala@gmail.com
2. ECE Department, Dean, Kakatiya University, Warangal, India, drstadisetty@gmail.com

Abstract- Throughput of secondary user in cognitive radio will depend on transmission power. In cognitive radio transmission power of secondary can increase by using energy harvesting phenomena. This paper analyses the performance of energy harvesting cognitive radio network with full duplex energy harvesting mode of operation is investigated. Cognitive radio network comprises of set of primary user transmitter, receiver and set of secondary user transmitter and receiver, where secondary receiver is operated in full duplex mode. Expressions for harvested energy and throughput for half duplex and full duplex mode of operations are discussed. The simulation results show that SU transmitter will have better harvested energy and throughput in full duplex energy harvesting mode as compare to half duplex mode operation.

Keywords: Cognitive Radio, Harvested Energy, Transmission Power, Full Duplex, Throughput.

1. INTRODUCTION

In wireless communication, energy harvesting has given an optimistic solution for energy constraint of SU transmission with RF energy harvesting. Energy harvesting of SU can be perform by using non-radio frequency sources as solar, wind or radio frequency sources of PU signal [1], [2], [3]. As compare to non-RF techniques RF energy harvesting methods can exhibits higher energy conversion efficiency [4]. Using RF energy harvesting, SU can support both the information transmission and power transmission [5], [6]. In wireless networks, SU have limited stored energy to perform transmission, thus an external mechanism is required to prolong the life of relay [7], [8], [9]. Energy harvesting process is implemented in such networks to successful transmission of information.

Most of the works are presented on half duplex energy harvesting where secondary user transmitter can harvest energy only from PU transmitter. However, SU can harvest the energy only if the signal from PU is present [10], [11]. Throughput of energy harvesting SU with half duplex operation is analysed in [12].

This harvested power may not sufficient to provide a SU communication. This problem can be solved by suppling another signal to SU transmitter to harvesting which can increase the transmission power by full duplex energy harvesting communication [13]. This has introduced to provide the communication support to PU and increase the harvested energy SU transmitter. If SU transmitter harvest energy even from SU receiver in addition to PU transmitter can increases the SU transmitter transmission power to improve the throughput of SU.

Following are contributions of the paper are:

- An energy-harvesting cognitive radio network with half duplex mode has analysed, harvested power and throughput of SU are calculated.
- An energy-harvesting cognitive radio network with full duplex mode has analysed, harvested power and throughput of SU transmitter are calculated.

The remaining paper organise as follows: section 2 describes full duplex energy-harvesting cognitive radio model. Analysis of energy harvesting full duplex model is given in section 3; results and discussions has explained in section 4 and conclusion describes in section 5.

2. FULL DUPLEX ENERGY HARVESTING COGNITIVE RADIO NETWORK

A parallel full duplex energy harvesting cognitive radio network (PFEHCRN) with parallel sensing and energy harvesting has been introduced in this paper, N SUs will divide in to two groups namely, sensing group and harvesting group. The model of PFEHCRN is shown in Figure 1. SU receiver (SU RV) in harvesting group is operating with full duplex mode, i.e. it can help primary user transmitter (PU TM) to sends its information to primary user receiver (PU RV) and supplies signal to the secondary user transmitter (SU TM). In order to maximize harvested energy to improve the throughput, SU transmitter in harvesting group can collect energy from primary transmitter and also from secondary receiver.

The SU in sensing group detects the existence of licensed user for duration of τ and reports to the FC in reporting slot. A single bit sensing information of 1 or 0 will sends to FC for presence or absence of PU in reporting slot for duration of τ_r. Then FC will take a collective decision-based majority of SU decision. The SU transmitter in harvesting group will harvest the RF energy from PU transmitter and also from SU receiver, which increases the harvested energy as compare to half duplex energy harvesting networks. SU transmitter transmission power changes with harvested energy and it sends its data to SU receiver if the spectrum is free.

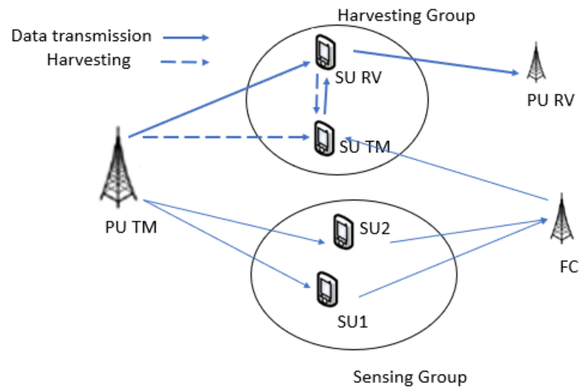

Figure 1. Model of PFEHCRN Structure

3. ANALYSIS OF PFEHCRN

Considering Parallel full duplexing energy harvesting cognitive radio network shown in Figure 1 consisting PU TM, PU RV, SU TM and SU RV. SU transmitter is harvesting energy from PU transmitter RF signal. PU TM, PU RV and SU TM are supporting with half duplex operation mounted with single antenna and SU receiver is supporting full duplex operation consisting two antennas, one for receiving a signal from PU TM and other for sending signal to SU TM for harvesting.

Initially PU TM sends its data to PU RV and SU RV, during this time SU TM collects RF signal and harvest the energy. SU RV operating in full duplex mode, it can collect the signal from PU TM and sends to SU TM for energy harvesting. Data transmission in FD SU receiver can be done in two time slots, in first time slot SU RV receives the signal from PU TM and sends to SU TM and in second time slot, it receives the its required information from SU TM.

The received signal of PU RV from the PU TM is given as

$$y_1 = \sqrt{P_1 N_{12}}\, h_{12} x_p + n_p \tag{1}$$

Calculated SNR at PU RX is

$$\gamma_{PR} = \frac{P_1 N_{12} \left| h_{12} \right|^2}{\sigma^2} \tag{2}$$

where, P_1 is PU TM power, N_{12} path loss component, h_{12} is channel gain from primary transmitter to primary receiver, xp is primary user signal, np is AWGN noise with variance σ^2.

The SU RV receives a signal from transmitter of PU in first time slot is

$$y_2 = \sqrt{P_1 N_{14}}\, h_{14} x_p + n_s \tag{3}$$

where, N_{14} path loss component, h_{14} is channel gain from primary transmitter to secondary receiver.

Calculated SNR at SU RV is

$$\gamma_r = \frac{P_1 N_{14} \left| h_{14} \right|^2}{\sigma^2} \tag{4}$$

The received signal at ST from PU TM is

$$y_{st} = \sqrt{P_1 N_{13}}\, h_{13} x_p + n_p \tag{5}$$

where, N_{13} path loss component, h_{13} is channel gain from primary transmitter to secondary transmitter.

SU TM utilizes the spectrum in second time slot and transmits its data to SU RV. At SU RV the received signal with SNR γ_{sr} is

$$y_{sr} = \sqrt{P_1 N_{34}}\, h_{34} y_{st} + n \tag{6}$$

$$\gamma_{sr} = \frac{P_1 N_{34} \left| h_{34} \right|^2}{\sigma^2} \tag{7}$$

Harvested energy of SU transmitter in half duplex mode is

$$E_h = \eta \left(P\left(H_1\right) P_1 h_{13}^2 + \sigma_n^2 \right) \tau \tag{8}$$

Half duplex transmission power of SU transmitter is described by $\Delta P_h\left(\tau\right) = \frac{E_h}{T}$.

Harvested energy of SU transmitter from SU receiver is

$$E_h = \eta \left(P\left(H_1\right) P_1 h_{14}^2 + \sigma_{ns}^2 \right) \tau \tag{9}$$

Full duplex transmission power of SU transmitter is given by $\Delta P_f\left(\tau\right) = \frac{E_h + E_s}{T}$.

Throughput of SU transmitter in half duplex operation Rh is described in Equation (10)

$$R_h = \frac{T-\tau}{T}\left(1 - Q\left(Q^{-1}\left(P_d\right)\left(\gamma_{13}+1\right) + \gamma_{13}\sqrt{\tau f_s}\right) P\left(H_0\right)\right) \times \\ \times B \log\left(1 + \frac{\left(P_t + \Delta P_h\left(\tau\right)\right) h_{34}^2}{\sigma_n^2}\right) \tag{10}$$

where, P_d is probability of detection, B is bandwidth and P_t is initial power of SU transmitter.

Throughput of SU transmitter in half duplex operation Rf is described in Equation (11)

$$R_f = \frac{T-\tau}{T}\left(1 - Q\left(Q^{-1}\left(P_d\right)\left(\gamma_{13}+1\right) + \gamma_{13}\sqrt{\tau f_s}\right) P\left(H_0\right)\right) \times \\ \times B \log\left(1 + \frac{\left(P_t + \Delta P_f\left(\tau\right)\right) h_{34}^2}{\sigma_n^2}\right) \tag{11}$$

4. RESULTS AND DISCUSSIONS

Variation of SU transmitter harvested power and throughput with half duplex and full duplex energy harvesting has analysed. Harvested power of SU is shown in Figure 2, harvesting energy of SU transmitter can increase with the power of PU transmitter. In half duplex mode SU can harvest power only from PU transmitter where as in full duplex mode it can harvest the energy from PU transmitter as well as from SU receiver. So, the harvested energy of SU transmitter in full duplex mode is more as compare to half duplex mode.

After harvesting energy, SU transmitter can transmits it information to SU receiver with higher energy efficiency. As the harvested power increases, throughput of SU transmitter is also increases.

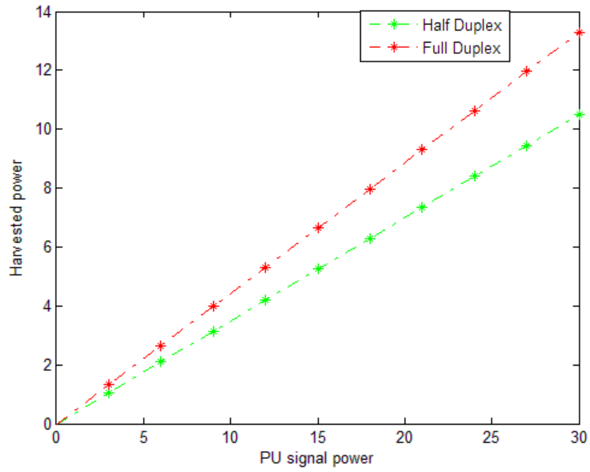

Figure 2. Harvested Power of SU Transmitter

Figure 3 shows the variation of throughput in half duplex and full duplex mode with harvested power and indicates that SU throughput is better in full duplex than half duplex mode operation.

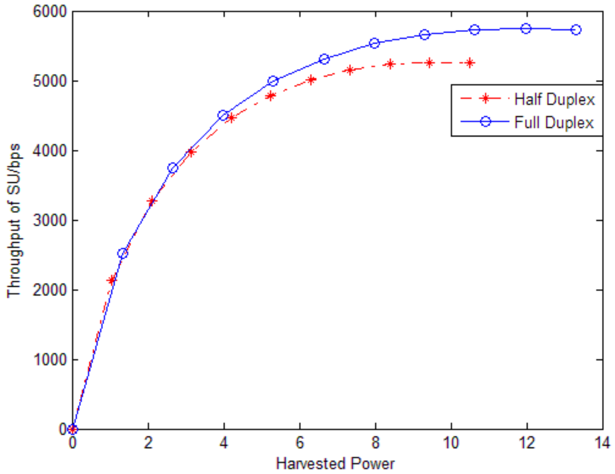

Figure 3. Throughput Variation of SU with Harvested Power

Table 1. Performance of Half and Full Duplex Mode of Operations

Harvested Power (W)	Half Duplex	1.05	3.15	5.25	7.35	9.45	10.5
	Full Duplex	1.33	3.99	6.65	9.31	11.9	13.3
Throughput of SU (Kbps)	Half Duplex	2138	3977	4784	5149	5361	5351
	Full Duplex	2520	4493	5312	5661	5746	5720

Variation of harvested power and throughput of SU with half duplex and full duplex operations are summarized in Table 1.

5. CONCLUSION

In this article, cognitive radio network with energy harvesting using full duplex mode of operation has proposed and compared energy harvesting with half duplex mode of operation. Harvested power and throughput analysis of the two modes has discussed and proven that energy harvesting with full duplex mode out performs the half duplex mode and provides better throughput of SU transmitter.

REFERENCE

[1] Z. Li, Boyang Liu, J. Si, F. Zhou, "Optimal Spectrum Sensing Interval in Energy Harvesting Cognitive Radio Networks", IEEE Transactions on Cognitive Communication and Networking, 2019.
[2] A. Bhowmick, K. yadav, S. Dhar Roy, S. Kundu, "Throughput of an Energy Harvesting Cognitive Radio Network Based on Prediction of Primary User", IEEE Transactions on Vehicular Technology, Issue 9, Vol. 66, pp. 8119-8128, Sept. 2017.
[3] M. Zile, "Implementation of Solar and Wind Energy by Renewable Energy Resources with Fuzzy Logic", International Journal on Technical and Physical Problems of Engineering (IJTPE), Issue 34, Vol. 10, pp. 46-51, March 2018.
[4] K. Singh, S. Moh, "A Comparative Survey of Energy Harvesting Techniques for Wireless Sensor Networks", Adavnced Science and Technology Letters, Vol. 142, pp. 28-33, Dec. 2016.
[5] L.R. Varshney, "Transporting Information and Energy Simultaneously", IEEE Int. Symp. Inf. Theory, pp. 1612-1616, July 2008.
[6] P. Grover, A. Sahai, "Shannon Meets Tesla: Wireless Information and Power Transfer", IEEE Int. Symp. Inf. Theory, pp. 2363-2367, June 2010.
[7] B. Medepally, N.B. Mehta, "Voluntary Energy Harvesting Relays and Selection in Cooperative Wireless Networks", IEEE Trans. Wireless Commun., Vol. 9, No. 11, pp. 3543-3553, Nov.2010.
[8] P.T. Venkata, S.N.A.U. Nambi, R.V. Prasad, I. Niemegeers, "Bond Graph Modeling for Energy Harvesting Wireless Sensor Networks", IEEE Computer, Vol. 45, No. 9, pp. 31-38, 2012.
[9] N. Bagherzadeh Karimi, S.N. Razavi, H.S. Aghdasi, "Distributed Clustering in Wireless Sensor Networks Using a Game Theoretical Approach", International Journal on Technical and Physical Problems in Engineering (IJTPE), Issue 18, Vol. 6, No. 1, pp. 1-8, March 2014.
[10] M. Usman, I. Koo, "Access Strategy for Hybrid Underlay-Overlay cognitive Radios with Energy Harvesting", IEEE Sensors, Issue 9, Vol. 14, pp. 3164-3173, Sept. 2014.
[11] A. Bujunuru, S. Tadisetty, "Residual Energy of Energy Harvesting Cognitive Radio Networks",

International Journal of Engineering and Advanced Technology, Issue 6, Vol. 8, pp. 1376-1378, Aug. 2019.
[12] A.A. Nasir, X. Zhou, S. Durrani, R.A. Kennedy, "Relaying Protocols for Wireless Energy Harvesting and Information Processing", IEEE Trans.Wireless Commun., Vol. 12, No. 7, pp. 3622-3636, July 2013.
[13] T. Riihonen, S. Werner, R. Wichman, "Comparison of Full-Duplex and Half Duplex Modes with a Fixed Amplify and Forward Relay", IEEE Wireless Commun. and Net. Conf., pp. 1-5, 2009.

BIOGRAPHIES

Anitha Bujunuru received her B.Tech. degree in Electronics and Communication Engineering from Jawaharlal Nehru Technological University, Hyderabad, India in 2005 and M.Tech. degree in Systems and Signal Processing from the same university in 2010. She is research scholar from Kakatiya University, Warangal, India and has 15 years of teaching experience. At present she is working with the Gurunanak Institutions Technical Campus, Telangana, India as an Associate Professor in Department of Electronics and Communication Engineering. She published two text books and research papers at international and national journals.

Srinivasulu Tadisetty received Bachelor of Tech. degree from Srivenkateswara University, India, Master of Technology degree from Indian School of Mines, Dhanbad, India and Doctor of Philosophy from Indian Institute of Technology, Kharagpur, India. He is the Dean in Kakatiya University, Warangal, India and Principal of University College of Engineering and Technology for Women KU, India. He completed 6 major research projects (S&T and Industry Sponsored) and 6 minor research projects (IOCL, ICSA, NIRM and AICTE). He has a member in IEEE USA and senior member in IACSIT Singapore, SDIWC Japan, IJAA Japan, IAENG Hong Kong, Fellow member in IETE, Telangana Academy Sciences and life member of BSCI, ISCA, ISTE, ISOI, Luminescence Socity of India and Indian Society for Rock Mechanics and Tunneling Technology New Delhi. He is editor and reviewer for several international journals and received several prestigious awards from different organizations.