SELF SUSTAINED COMMUNICATION WITH EDF FOR ENERGY HARVESTING COOPERATIVE COGNITIVE NETWORKS

B.SIVA PHANENDRA
M.Tech (ECE), Department of Electronics & Communication Engineering, Helapuri Institute of Technology and Science, Eluru, A.P.

Ms.RAMA DEVI CHILAKA
Assistant Professor, Department of Electronics & Communication Engineering, Helapuri Institute of Technology and Science, Eluru, A.P.

Abstract

In this paper, we consider a simultaneous wireless information and power transfer (SWIPT)-enabled cooperative cognitive network that addresses energy scarcity and spectral scarcity, two important issues in 5G wireless communications. In the considered network, the self-sustainable, SWIPT-enabled relay assists primary user's transmission, while the relay itself is also a secondary user with its own information superimposed on the regenerated primary information for transmission. The SWIPT relay employs the proposed energy-assisted decode-and forward (EDF) protocol, which enhances the conventional decode and-forward (DF) protocol with energy-dimension-augmented information decoding. We conduct a comparative analysis of the proposed EDF and the conventional DF and amplify-and-forward (AF) protocols in this SWIPT cooperative cognitive framework in terms of capacity, outage probability, and throughput for both primary and secondary networks. Simulation corroborates the analysis and demonstrates performance advantages of EDF over DF/AF from various perspectives.

Index Terms*—Simultaneous wireless information and power transfer (SWIPT), energy harvesting, cooperative communications, cognitive networks, relay protocols.*

I. INTRODUCTION

SIMULTANEOUS wireless information and power transfer (SWIPT) has been introduced [1]–[5] as a green and sustainable solution for 5G wireless communications [6]–[10]. The fundamental tradeoff between the energy transfer rate and reliable information transfer rate was first studied in [1] and further investigated in [2]. An information-theoretic view of the capacities of energy harvesting (EH) communications with different battery sizes was presented in [3]. The SWIPT receiver architectures were studied in [4], [5], where the now established concepts of separated and co-located (based on time switching (TS) or power splitting (PS) operation) receiver architectures were proposed in [5]. The transceiver module for practical SWIPT implementations was presented in [11], [12], where the power management unit (PMU) inside a wireless power receiver module was introduced to serve different functions such as coordinating between information processing and energy harvesting, monitoring the level of the harvested power, etc.

SWIPT has been studied in the context of cooperative networking [13]–[20]. The performance of SWIPT-enabled amplify-and-forward (AF) relaying was analyzed with [13] and without [14], [15] considering the direct link between the source and destination. SWIPT-enabled decode-and-forward (DF) relaying was studied in [16]–[20]. Power allocation strategies were investigated with multiple source-destination pairs served by a single PS-based SWIPT DF relay [16]. Joint optimization of the TS factor and power allocation was pursued for SWIPT DF relay networks [17]. Optimization of transmission rate and outage probability was studied for PS/TS-based SWIPT DF relay networks [18]. Throughput optimization was performed for PS-based SWIPT DF relaying by considering the availability of full or partial channel state information (CSI) at the source and relay [19]. Full-duplex PS-based SWIPT DF relaying was proposed [20] to achieve improved outage probability and average throughput performance as compared to the half-duplex counterpart.

2.LITERATURE SURVEY

To meet the increasing demands of higher data rates and growing number of users, the efficient use of spectrum and energy is highly desired for 5G communications. To increase spectral resource utilization, the role of centralized networks is shifted to user-centric cooperative networks, and dynamic spectrum allocation is used for sharing the licensed spectrum with unlicensed users/networks in overlay, underlay, or interweave cognitive radio scenarios [21], [22]. Thus, the consideration of EH- or SWIPT-enabled cooperative cognitive networks is highly motivated to simultaneously realize energy and spectrum efficiency, as studied in [23]–[29]. The outage performance of a cognitive network with Ehen bled secondary transmitters was studied in the vicinity of DF relay-assisted primary network by considering zero forcing beamforming at the primary base station (BS) for EH at the secondary user [23]. The PS-based SWIPT AF relay (secondary transmitter) was considered for cognitive networks [24], [25]. In [24], the ergodic capacity and outage performance was examined, which shows that the performance is limited by the interference and noise amplification. Also, an interference cancellation scheme based on prior knowledge of interfering signal and perfect CSI was considered at the secondary user. In [25], the system energy efficiency and rate energy tradeoff with optimization of PS factors and power allocation at the relay were comprehensively studied.

A large EH cooperative cognitive network comprising multiple primary transceivers was considered [26]. The outage and throughput performance at the secondary source and secondary DF relay was analyzed. Besides, it was observed that increasing the number of primary transceivers beyond an optimal value could overshadow the benefits of EH because of the interference from primary transmissions. An asymptotic analysis of the outage probability of a SWIPT enabled cooperative cognitive network was performed with the consideration of secondary transmit power allocation subject to the primary interference constraint [27]. A time division multiple access (TDMA)-based cooperative medium access control (MAC) protocol for EH cooperative cognitive networks was proposed [28], where an opportunistically selected secondary EH-enabled DF relay transmits information of both primary and secondary users based on the TDMA protocol. An overlay cognitive radio scheme was proposed for EH cooperative cognitive networks [29], where primary and secondary information is transmitted simultaneously using Alamouti and superposition coding techniques.

3. PROPOSED ENERGY HARVESTING COOPERATIVE COGNITIVE SYSTEM

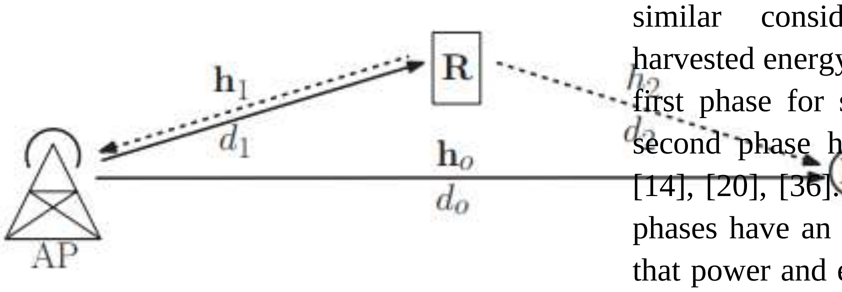

Fig. 1. A cooperative cognitive radio network with an AP, a SWIPT relay (R), and a destination (D). The communication includes primary links AP–D and AP–R–D and secondary link R–AP. Solid/dashed lines indicate transmissions in first/second phases.

We consider a SWIPT-enabled cooperative cognitive radio network as shown in Fig. 1. An access point (AP) transmits information to a distant primary user (PU) D with the help of a SWIPT relay R in the primary network, where the AP–D link is naturally much weaker than the R–D link and may be severely occluded by obstructions such as in the indoor applications. The SWIPT relay as a secondary user (SU) transmits its own information to the AP in the secondary network. The considered system exemplifies the practical cooperative cognitive radio network [33], [34]. The AP is equipped with N antennas while nodes D and R are each equipped with a single antenna. Each node operates in half-duplex mode. The transmission occurs in two phases. In the first phase, the AP performs a gain-based transmit antenna selection [35] and transmits to the SWIPT relay which decodes/regenerates information and harvests energy with the power splitting (PS) scheme. In the second phase, the relay uses the harvested energy in full to broadcast a superposed signal of the regenerated information (intended for D) and its own information (intended for AP) using an analog superposition scheme. A similar consideration of using the harvested energy at the SWIPT relay in the first phase for signal transmission in the second phase has been adopted in, e.g., [14], [20], [36]. We consider that the two phases have an equal duration of unity so that power and energy are interchangeable terms.1 The quasi-static fading channel model is adopted with coefficients denoted by $h_{oj} \sim CN(0, d^{-m}_o)$, $h_{1j} \sim CN(0, d^{-m}_1)$, and $h_2 \sim CN(0, d^{-m}_2)$, where h_{oj} and h_{1j} are the jth element of $h_o = [h_{o1}, h_{o2}, ..., h_{oN}]$ and $h_1 = [h_{11}, h_{12}, ..., h_{1N}]$, respectively, with the suffix j indicating the jth antenna at AP and 0 ≤ < 1 denoting the deep fading coefficient of the direct link [19] that describes the level of occlusion in the AP–D path; do, d1, and d2 denote the distances between AP–D, AP–R, and R–D links, respectively, which are all greater than one meter [38]; and m ∈ [2, 5] is the path loss exponent [39]. In the following, we describe the signaling scheme and the functioning of each phase.

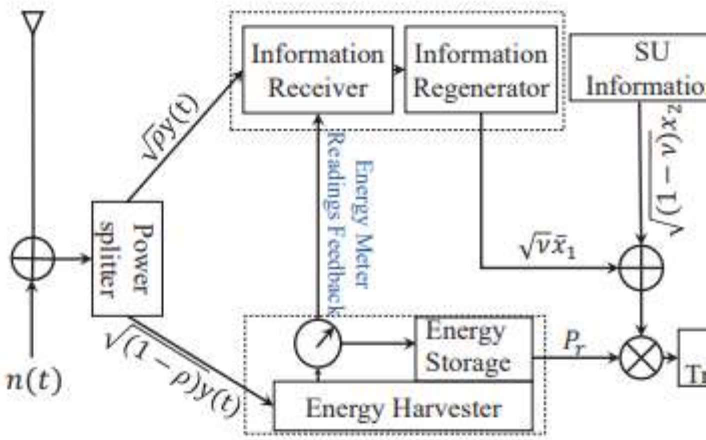

Fig. 2. Architecture of the SWIPT relay implementing the energy-assisted decode-and-forward (EDF) strategy. As compared to the conventional DF, EDF performs information decoding with the aid of the additional energy meter readings feedback from the co-located energy harvester.

This antenna selection criterion, which is based on the AP–R link, maximizes both the harvested energy and information rate at the relay. With our network consideration that the AP–D link is naturally much weaker than the R–D link, this criterion also approximately maximizes the overall capacity of the primary and secondary networks (see the capacity expressions for different relay protocols in the following sections for more details). While the criterion that maximizes the exact overall capacity of the primary and secondary networks will involve the AP–D and R–D channel gains, the considered approximate criterion does not require the CSI of AP–D and R– D links, and therefore strikes a good tradeoff between the implementation complexity and the performance.

4. SIMULATION RESULTS

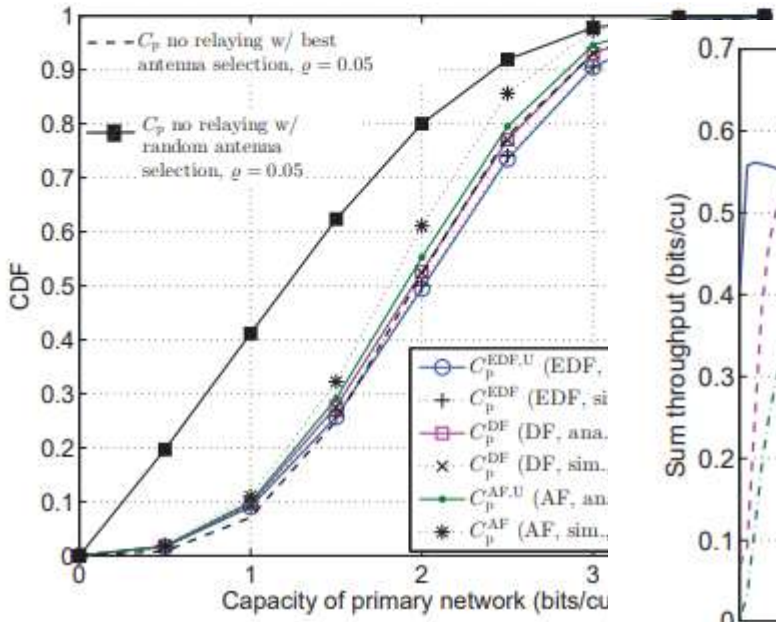

Fig. 3. CDF of the capacity of the primary network with primary outageoptimal power-splitting factor ρ and with = 0.05 (severely occluded direct link). The empirical capacity results for the case of no relaying with best antenna selection and random antenna selection are also plotted, with = 0.05.

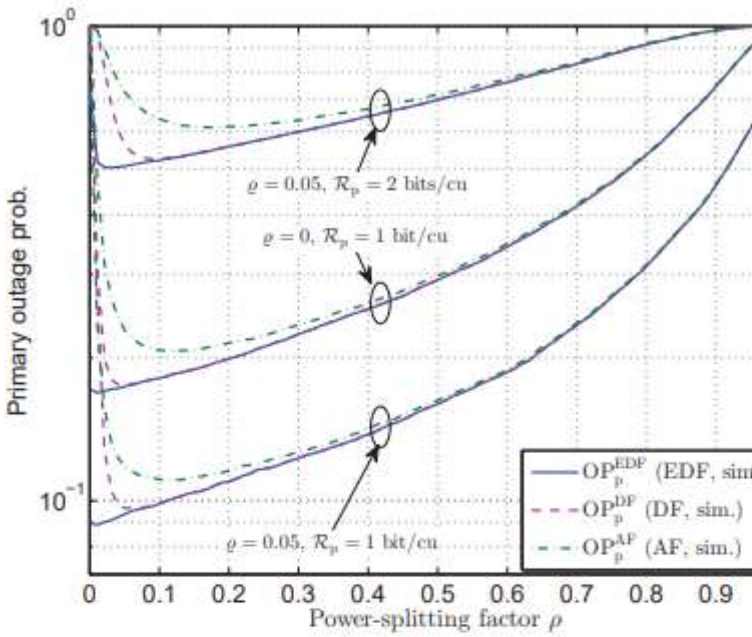

Fig. 4. Primary outage probability vs. power-splitting factor ρ, with different combinations of = 0.05, 0 and Rp = 1, 2.

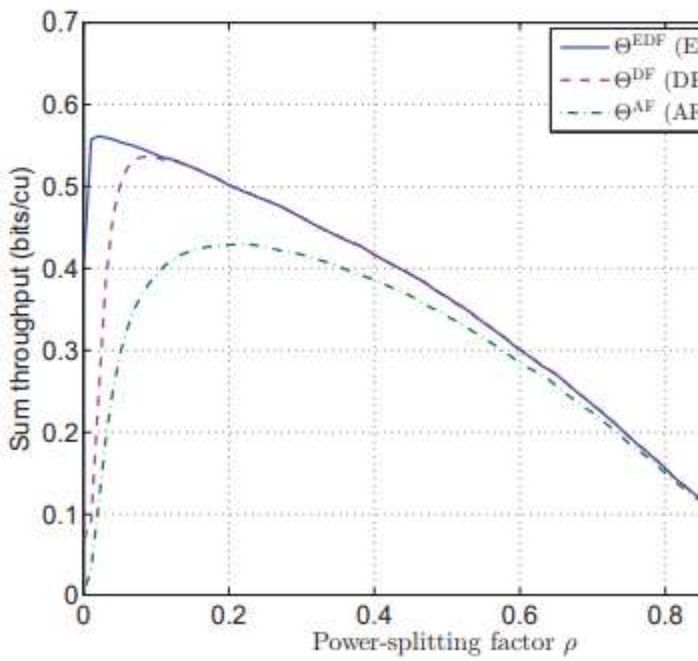

Fig. 5. Sum throughput vs. power-splitting factor ρ, with = 0.05, Rp =2, Rs = 0.2.

5. CONCLUSION

We have proposed the energy-assisted decode-and-forward (EDF) relay protocol for SWIPT-enabled cooperative cognitive networks. EDF is an enhanced DF protocol where the SWIPT relay's information receiver decodes information with the aid of an energy meter readings feedback from the co-located energy harvester. In the considered network, the SWIPT relay employs the EDF protocol in assisting primary user's transmission, while the relay, as a secondary user itself, superimposes its own information on the regenerated primary information for transmission subject to a transmit power constraint for interference management. We have derived the exact capacity expressions for both primary and secondary networks employing an EDF relay. An analytically tractable capacity upper bound was derived for the primary network and verified with the exact empirical result. We have performed a similar analysis for the considered networks employing a DF or AF relay, and thereby established a comparative analysis among the three relay protocols. Simulation results showed performance advantages of EDF over DF/AF, offered insights on the comparisons among EDF, DF, and AF from various perspectives, and corroborated the analysis.

REFERENCES

[1] L. Varshney, "Transporting information and energy simultaneously," in Proc. IEEE ISIT, Jul. 2008, pp. 1612–1616.

[2] P. Grover and A. Sahai, "Shannon meets Tesla: Wireless information and power transfer," in Proc. IEEE ISIT, Jun. 2010, pp. 2363–2367.

[3] O. Ozel, K. Tutuncuoglu, S. Ulukus, and A. Yener, "Fundamental limits of energy harvesting communications," IEEE Commun. Mag., vol. 53, no. 4, pp. 126–132, Apr. 2015.

[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, Nov. 2013.

[5] R. Zhang and C. K. Ho, "MIMO broadcasting for simultaneous wireless information and power transfer," IEEE Trans. Wireless Commun., vol. 12, no. 5, pp. 1989–2001, May 2013.

[6] C.-L. I, C. Rowell, S. Han, Z. Xu, G. Li, and Z. Pan, "Toward green and soft: a 5G perspective," IEEE Commun. Mag., vol. 52, no. 2, pp. 66–73, Feb. 2014.