OPTIMIZATION OF A POWER SPLITTING PROTOCOL FOR TWO-WAY MULTIPLE ENERGY HARVESTING RELAY SYSTEM

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Abstract – Energy Harvesting (EH) joined with agreeable correspondences comprises a promising answer for future remote advances. They empower extra productivity and expanded lifetime to remote systems. This paper explores a different transfer choice plan for an EH-based two-way relaying (TWR) framework. All transfers are considered as EH hubs that gather vitality from sustainable power source and radio recurrence (RF) sources. Some of them are chosen to advance information to the goals. The power part (PS) convention, by which the EH hub parts the information RF motion into two segments for EH and data transmission, is embraced at the hand-off hubs. The goal is to together enhance I) the arrangement of chose transfers, ii) their PS proportions, and iii) their transmit control levels so as to expand information rate-based utilities over different cognizant vacancies. A joint advancement arrangement dependent on geometric programming (GP) and paired molecule swarm improvement is proposed to take care of non arched issues for two utility capacities mirroring the dimension of reasonableness in the TWR transmission. Numerical outcomes delineate the framework's conduct versus different parameters and demonstrate that the execution of the proposed plan is near that of the ideal branch-and-bound technique and that GP beats the double issue based strategy.

Key Words: *Energy harvesting, green communications, multiple-relay selection, power splitting, two-way relaying*

1. INTRODUCTION

THERE is currently considerable interest in energy harvesting (EH) as one of the most robust methods to perpetuate the lifetime and sustainability of wireless systems. Many promising practical applications that can exploit this technique have been discussed recently, such as emerging ultra-dense small cell deployments, point-to-point sensor networks, far-field microwave power transfer, and dense wireless networks. One of the advantages of such a technique is to cope with the issues related to the supply of wireless devices located in remote or inaccessible areas. For instance, replenishing a new battery of sensors placed in forests or mountains using traditional wired techniques is not always possible. In addition, EH techniques enable networks' owners to have green behavior towards the environment as the devices will be powered by non-polluting alternative sources such as solar, wind, thermoelectric, or vibration. Radio frequency (RF) - based EH, which is also known as wireless energy transfer has been introduced as another effective harvesting technology where energy is collected from RF signals generated by other neighbor devices. Unlike other renewable energy (RE) sources, RF energy is widely available in the ambient atmosphere during all hours, days, and nights.

Two main protocols are proposed in the literature for the RF-based EH technique [8]: 1) the time switching (TS) protocol where the EH node switches over time between the energy harvester equipment and the information decoder, and) the power splitting (PS) protocol where a portion of the received signal is used for EH and the remaining for information processing. The first one consists of using the harvested energy without storing it for future use. It is known as the harvest-and-use approach. In the second one, known as harvest-use-store approach, the harvested energy is instantaneously consumed according to the system need while the remaining energy is stored for future use. The third approach, which is considered in this paper, named as harvest- store-use, consists of partially or totally storing the harvested energy before using it in the future.

A. Related Work

Most of the studies proposed in the literature utilize the RF-based EH technique and the RE-based EH one separately. In cooperative relaying network, the RF-based EH techniques are mainly designed for the traditional OWR technique, the authors proposed AF delay-limited and delay-tolerant transmission modes and investigated the outage probability and the ergodic capacity for each mode. In, a single relay selection scenario is discussed. The work presented in proposed a continuous time and discrete time EH scheme based on TS protocol. The buffer-aided throughput maximization problem is proposed in where both the source and the relay are considered as harvesting nodes and equipped with finite energy and data buffers.

B. Contributions

In this paper, we introduce a framework of a hybrid RF/Rebased EH scheme using the PS protocol for two-way multiple relay systems. With the AF strategy, the relays receive a superimposition of the terminals' signals and broadcast an amplified version of it to the destinations.

Therefore, a multi-relay selection algorithm is proposed to determine the combination of relays to be activated during multiple periods of time. The contribution of this work compared to others can be summarized as follows:

- A TWR system where the relays are powered by RF signals and RE sources simultaneously is considered. The proposed framework aims to maximize a throughput based utility of the EH TWR system over a certain number of time slots while respecting the relays' power budgets and their storage capacity constraints.
- An energy management scheme is proposed to determine the best relays to be selected for data transmission. In this scheme, the set of selected relays, their transmit power levels, and their PS ratios are jointly optimized. Hence, at each time slot, the selected relays are identified and their PS ratios and amplification gains to be allocated for the TWR communication are determined. This is optimized such that the harvested energy is efficiently managed and the problem's objective function is maximized.
- In this context, some of the relays are not selected and hence, do not participate in the broadcasting process. They continue harvesting energy from other transmitters (i.e., selected relays) to use it during future time slots. Therefore, two throughput-based utilities reflecting the level of fairness in the harvested energy management overthe multiple time slots are investigated.
- Due to the non-convexity of the problem, a joint optimization approach is proposed to optimize the system parameters. A binary particle swarm optimization (BPSO) algorithm is adopted to find the set of selected relays involved in the data transmission. To optimize other decision variables (i.e., relays' power levels and PS ratios),a geometric programming (GP) formulation is developed.It allows the achievement of a near-optimal solution of the problem . The choice of selected relays depends essentially on the channel quality and the amount of generated energy at each relay.

C. Paper Organization

The remainder of the paper is organized as follows. Section II presents the EH TWR system model. The problem formulation with the PS protocol is given in Section III. The GP-based optimization approach jointly implemented with BPSO and BB is proposed in Section IV. Section V discusses selected numerical results. Finally, the paper is concluded in Section VI.

II. SYSTEM MODEL

A half-duplex TWR communication system consisting of two terminals denoted by S1 and S2, respectively, and separated by a distance D is considered. These two terminals aim to exchange information between each other through the help of multiple self-powered EH relays, denoted by Rl, l = 1, ..,L, placed randomly within the communication range of both terminals. The relays are placed within a circle with radius 2 and S1 and S2 are two ends of the diameter as shown in Fig. 1.

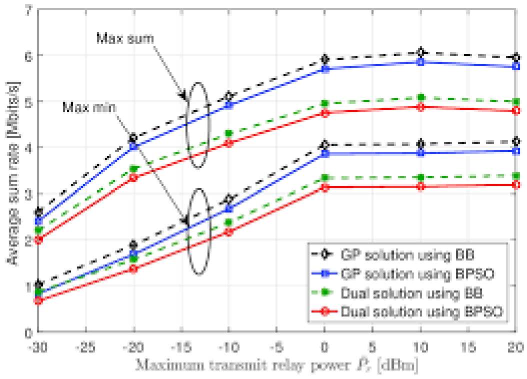


Fig. 1. relays are placed within a circle

B. Energy Harvesting Model

In this paper, two EH sources are combined, i.e., the RE and RF sources. We model the RE stochastic energy arrival rate as a random variable _ Watt defined by a probability density function (pdf) f(ϕ). In this paper, ϕrl,b represents the instantaneous amount of available RE during time slot b at relay l, where each relay can harvest from RE during the whole Tc. Define Jb as the set of relays selected to cooperate with the terminals S1 and S2 during time slot b. The selected relays contribute in the data transmission and can harvest energy from RF signals coming from S1 and S2 during MAP. However, the non-selected relays remain silent and harvest energy during the whole period Tc including the RF signals coming from S1 and S2 during MAP and from the selected relays during BP. The harvested energy is partially or totally stored to be used in future time slots. Denote by ηRF and ηRE the energy conversion efficiency coefficients of the RF and RE sources, respectively, where both ηRF and ηRE are in [0, 1]. A binary variable, denoted by ϱrl,b, is introduced to indicate the status of each relay where ϱrl, b = 1 if the relay is selected to forward the signals, and ϱrl,b = 0.

C. Relay Power Model

Since the energy arrival and energy consumption rates are random and the energy storage capacities are finite, some relays might not have enough energy to serve users at a particular time. Under such a scenario, it is preferred that these relays are non-selected and hence, continue recharging their batteries. Hence, each relay can be selected for transmission or not at each time slot b. The decision of relays selection is made centrally. The total power consumption of a relay, denoted by Ptrl,b, can be computed as follows :

III. PROBLEM FORMULATION

In this section, the optimization problem maximizing an achievable rate based utility for a two-way multiple energy autonomous relay system is formulated. The section starts by deriving the data rate expression of the system using the PS protocol. Afterwards, it introduces the problem constraints and decision variables. The used utility functions reflecting different level of fairness are then presented.

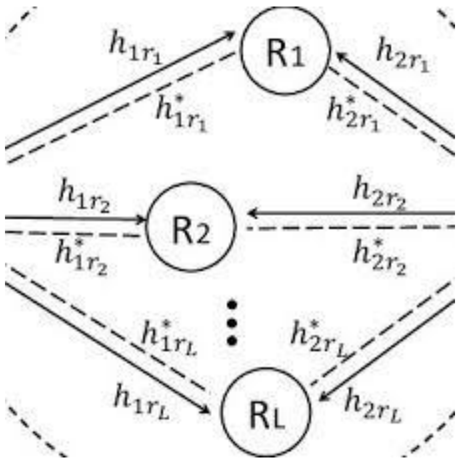


Fig. 3. Data Expression

A. Data Rate Expression

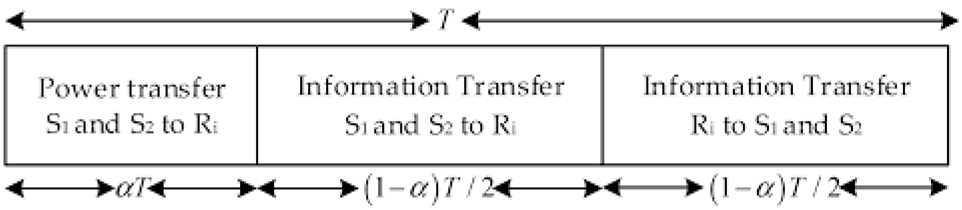
In the MAP, the received signal at the lth relay during each
Tc is given by:

yrl,b = pP1h1rl,bx1,b +pP2h2rl,bx2,b + nrl,b. (4)

where nrl,b is the sum of two noises: 1) an additive white Gaussian noise (AWGN) at the lth relay during time slot b with variance Nr introduced by the receive antenna and, 2) a noise introduced by the signal processing circuit from passband to baseband and also assumed to be AWGN with zero mean and variance N0. In practice, the antenna noise has a negligible effect on both the information signal and the average power of the received signal as well. Hence, we ignore its impact in (4) (i.e., Nr ≪ N0)

B. Optimization Problem

We denote by E¯s and P¯r the maximum storage capacity expressed in Joules and the maximum transmit power expressed in Watts at the relay, respectively. Let U(Rb,q) be the rate utility of the TWR system. Thus, the optimization problem of maximizing the TWR utility using multiple-relay selection while satisfying the energy consumed and stored constraints with EH PS protocol using AF strategy is given as:



C. Utility Selection

In this section, we present two different utility metrics that will be employed in the optimization problem given . These utilities reflect different degrees of fairness in the transmission over the B time slots.

1) Max Sum Utility: The utility of this metric is equivalent to the sum data rate of the network for all time slots:

U(Rb,q) =PBb=1P2q=1 Rb,q .

This utility promotes the time slots with favorable channel and energy conditions by allocating to them most of the resources. On the other hand, the time slots suffering from poor channel conditions will be deprived from data transfer as they will have very low data rates.

2) Max Min Utility: Due to the unfairness of the max sum utility, the need for more fair utility metrics arises. Max-min utility is a family of utility functions attempting to maximize the minimum data rate over all the time slots

U(Rb,q) = minb,q(Rb,q), ∀b = 1, · · · ,B, ∀q = 1, 2,

By increasing the priority of time slots having poorer channel conditions, Max-min utilities lead to more fairness in the system. Note that the max sum utility might lead to cases where there is no data transfer during certain time slots. This is because the system might prefer to harvest the maximum of energy during these time slots and then use it during the next time slots in order to maximize the total rate. Max-min utility can be employed to avoid this unfairness among time slots. If a terminal requires a certain minimum rate at each time slot b, max min utility impels the system to guarantee a non-zero rate at each time slot.

IV. JOINT-OPTIMIZATION SOLUTION

Due to the non-convexity of the optimization problem formulated, we propose to proceed with a joint optimization approach where we optimize the binary matrix ϱ using the BPSO algorithm (or the BB method) and the other continuous decision variables (β and Pr) using GP. For a fixed and known ϱ, we apply a successive convex approximation (SCA) approach to transform the non-convex problem into a sequence of relaxed convex sub-problems.

A. Geometric Programming Method for PS Ratios and Relays'

Transmit Power Optimization GP is a class of nonlinear and non-convex optimization problems that can be efficiently solved after converting them to nonlinear but convex problems. The interior-point method can be applied to GP with a polynomial time complexity

1) Introduction to Geometric Programming: The standard form of GP is defined as the minimization of a polynomial function subject to inequality polynomial constraints and equality monomial constraints as given below:

A. Simulation Parameters

We consider two sources S1 and S2 aiming at exchanging their messages during B = 8 time slots unless otherwise stated where each time slot length is equal to Tc = 175 milliseconds (ms). In the following simulations, we consider the scenario of small wireless devices employing the ZigBee protocol.

B. System Performance

In Table II, we study the behavior of the TWR system for a given channel realization, a relay power budget ¯ Pr = 0 dBm, and a terminal transmit power Ps = 0 dBm. The objective is to study in details the advantages and disadvantages of the max sum and max min utilities and the differences in the corresponding decision variables. It can be noticed that the use of max min utility helps in avoiding low rates achieved in certain slots with the sum utility such as the rates in slots 4, 5, and 8: R4 = 2.12, R5 = 1.32, and R8 = 1.72 Mbps, respectively.

C. Convergence Speed

The analysis of convergence speed of the proposed solution is studied in Fig. 9 and Fig. 10. In Fig. 9, we compare between the performances of BPSO using max sum utility and those of the BPSO with the max min utility by investigating their convergence speed defined by the number of iterations needed to reach convergence. Note that an iteration in corresponds to one iteration of the "while loop" given in Algorithm 2 (i.e., line 3-12). In other words, it corresponds to one iteration of BPSO but it includes the execution of the SCA. The figure shows that BPSO achieves its near optimal solution with little iteration only (i.e., 10-20 iterations). In BPSO, we executed it for at most 100 iterations and we stop it if the achieved utility remains constant for a certain number of consecutive iterations. In , we plot number of GP iterations needed to find the best approximation solution given in Algorithm 1

V. CONCLUSION

In this paper, we proposed a multiple-relay selection scheme for power splitting protocol-based energy harvesting two way relaying system. The relays harvest energy from renewable energy and radio frequency sources. We formulated an optimization problem aiming to maximize the total sum rate over multiple time slots. Due to the non-convexity of the optimization problem, we adopted a joint-optimization approach based on binary particle swarm optimization and geometric programming. The proposed solution enables the system to achieve near optimal solutions with a significant gain compared to dual problem-based solution. The behavior of the TWR system is studied via multiple numerical simulations. In our ongoing work, we will study a more realistic scenario where uncertainty aspects are considered.

REFERENCES

[1] H. Tabassum, E. Hossain, A. Ogundipe, and D. I. Kim, "Wireless powered cellular networks: Key challenges and solution techniques," IEEE Communications Magazine, vol. 53, no. 6, pp. 63–71, June 2015.

[2] Z. Hasan, H. Boostanimehr, and V. Bhargava, "Green cellular networks: A survey, some research issues and challenges," IEEE Communications Surveys Tutorials, vol. 13, no. 4, pp. 524–540, Nov. 2011.

[3] V. Raghunathan, S. Ganeriwal, and M. Srivastava, "Emerging techniques for long lived wireless sensor networks," IEEE Communications Magazine, vol. 44, no. 4, pp. 108–114, Apr. 2006.

[4] A. Alsharoa, A. Celik, and A. E. Kamal, "Energy harvesting in heterogenous networks with hybrid powered communication systems," in Proc. of IEEE 86th Vehicular Technology Conference (VTC Fall), Toronto, Canada, Sept. 2017, pp. 1–6.

[5] X. Lu, P. Wang, D. Niyato, D. I. Kim, and Z. Han, "Wireless networks with RF energy harvesting: A contemporary survey," IEEE Communications Surveys Tutorials, vol. 17, no. 2, pp. 757–789, May 2015.

[6] B. Medepally and N. Mehta, "Voluntary energy harvesting relays and selection in cooperative wireless networks," IEEE Transactions on Wireless Communications, vol. 9, no. 11, pp. 3543–3553, Nov. 2010.

[7] F. Yuan, S. Jin, K. Wong, and H. Zhu, "Optimal harvest-use-store policy for energy-harvesting wireless systems in frequency-selective fading channels," EURASIP Journal on Wireless Communications and Networking, vol. 2015, no. 1, Mar. 2015.