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Research paper

Multi-relay Antennas for Energy Harvesting Cognitive Radio Networks using Energy-Assisted Decode Forward Method

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Abstract:

The single antenna relay energy-assisted decode forward (EDF) was not applicable for multi cognitive users that has less data rates. In order to achieve higher data rates with increased user demands energy harvesting or Simultaneous Wireless Information and Power Transfer (SWIPT) enabled networks with multi antenna relays are highly recommended. The proposed work considers multi relay EDFSWIPT for 5G systems with presence of transmitter and an antenna array. The transmitter affords information and energy to various multiple single-antenna secondary receivers (SR). The SR outfitted with a power splitter receiving system where multiple primary relays are introduced. The goal of proposed work is to amplify weighted sum rate harvested energy for SR using multi relay EDF. The simulation considers the capacity, outage probability, and throughput for both primary and secondary networks with respect to both single multi relay EDF. The simulation results afford that multi relay EDF has better performance than single antenna array EDF.

Keywords: *Energy harvesting, multi relay, cognitive network, SWIPT, EDF*

1. Introduction

SWIPT has been introduced in [1]-[5] and it has a special architecture explained in [4]-[5]. Theoretical swipt contains only one signal that are used for transmitting information and energy without any loss of the information. But practically it was not possible because the energy harvesting is performed in RF domain. In existing system, single relay and access point and destination are used. The relay network has only one relay [6] so the data rate and number of users are less, so to increase data rates and more number of cognitive users multi relay SWIPT has been proposed in this work.

Energy harvesting has been growing in research territory for both scholastics and industry, because it understands the usage of battery-controlled remote gadgets. Energy Harvesting was particularly vital, more helpful in wireless sensor networks because of restricted energy. In this scenario, the Radio Frequency has brought two information and power from transmitters to beneficiaries [7-14], suggested as "synchronous remote data and power exchange". In this way, new pre-coding procedures for transmitters and optimizing design systems for receivers has been explored. This paper proposes to use multi relay EDF to increase higher data rates with more number of cognitive users as suggested in [6] to analyze the performance of network capacity, outage probability and throughput compared with existing single relay EDF.

The preparation of the article are as follows: Section 2 summarizes the Related Work, Section 3 examines Problem statement and the System Architecture of proposed System. Section 4 contributes the Simulation Results. The Conclusion was conferred in Section 5.

2. Related Literatures

Multi- antenna source and recipients [11] framework has been considered to examine these issues, cooperative networks [12], and obstruction channels [13], and additionally secure transmission [14]. Furthermore, the creators in [15,16,17] considered the transmit control minimization issue for multiuser SWIPT MISO frameworks below the deficient channel state information (CSI) with limited channel vector blunders and stochastic channel vector mistakes. As an imperative measure, the total reaped energy amplification in multiuser power-splitting SWIPT MISO framework has been explored under the ideal channel side data of channels from sender to recipients [17]. Be that as it may, the arrangement of [17] constructed on progressive second- order cone programming cannot remain connected to cognitive radio networks (CRN) where interference limitations of Primary User (PU) ought to be measured by the instance of imperfect CSI.

Like the mechanism presented by [18], the uses of RF-controlled procedures to reap energy and move information in CRN were briefed by [19]. Different specialists considered SWIPT for various situations with a specific end goal to give energy to destination though guaranteeing nature of administration. In [20], the secondary system manipulated both range and energy in primary systems by helping essential information broadcasting.

Single optional information link within the sight of various energy harvesting recipients and PUs were studied by [21]. SWIPT in cognitive relay and cognitive wirelessly powered networks were additionally examined by [22] and [23] respectively. However, CRNs with power-splitting (PS) SWIPT and beam forming outlines in multiuser situations has not been very much concentrated up until now. In the earlier work by [24], SWIPT CRN situations has been considered by critical two criteria: one is “max– min harvested energy of cognitive users” and the other was “the most exceedingly worst user exchange off between harvested energy of cognitive users and obstruction power of primary users” under the ideal CSI. Another vital paradigm in SWIPT cognitive radio systems was “weighted total harvested energy” under both perfect CSI and imperfect CSI cases that has not been completely researched still.

3. Problem statement

The existing work uses energy assisted decode and forward (EDF) method to transmit the information and energy that are not transmitted simultaneously. To overcome this SWIPT technique has been introduced [6] that uses single antenna relay which has limited number of cognitive users. To sustain the higher desires of data rate and cognitive users, use of single relay was not sufficient. The proposed work considers multi relay EDF to achieve high data rate that increases the number of cognitive users and compares with existing single antenna relay EDF.

3.1. Proposed system architecture

Fig 1. demonstrates multi relay communication with SWIPT ability that incorporates an Access Point (AP), 3Relays (R_1, R2, R3) and Destination(D). The input to AP are ‘M’ data messages outfitted with N relays to multi relays R_1,R_2,R_3.These multi relays are outfitted with a single antenna at an indistinguishable frequency from L Primary Users (PU's)denoted as $PU_1 \ldots PU_L$.

The signals from AP to SR i.e., multi relay and PU_l are denoted as $\mathbf{h}_i \in \mathbb{C}^{N\times 1}$, I ∈ {1...M} and $\mathbf{g}_l \in \mathbb{C}^{N\times 1}$, l∈ {1...L} as the baseband proportional channels [25]. The transmitter receives the channel vectors consummately with components as autonomous and indistinguishably appropriated circularly symmetric complex Gaussian (CSCG) factors.

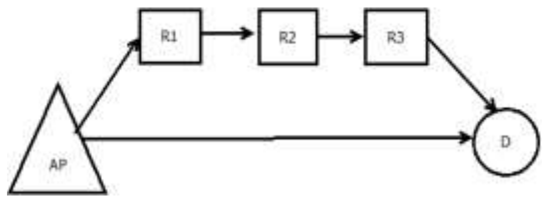

Fig 1: Proposed multi relay communication

The transmitter can basically accomplish CSI vectors from the transmitter to the SRs by using the traditional channel estimation techniques. The harvested energy of SRs for imperfect CSI and power splitting (PS) among the relays are considered as semi definite relaxation (SDR). The SDR based solution using particle swarm optimization (PSO) as minimization for transmit power has been considered in the proposed work. The proposed algorithm has been shown in Table 1.

Table 1: The proposed algorithm based on PSO-SDR with multi relay EDF

Initialization:

1. Allocate iteration index of MR-EDF loop: m = 1.
2. Set Xn’s values of elements, $\forall_n$, are allocated randomly in [θ_{min}, 1].
3. Assign the global maximum value: $f(g_b)=\max_{1\leq n\leq N_S} f(Xn)$.
4. Set the best position of particle: P_b,n = x_n, $\forall_n$. Fix the sum rate of particle: $V_n = 0$, $\forall_n$.
5. **repeat**(MR-EDF loop)
6. for n = 1:N_S do
7. Calculate particle’s new sum rate:
8. **Velocity update**: $V_n \leftarrow i_w V_n + C_1 \pi_{1,n} \odot (P_{b,n} - X_n) + C_2 \pi_{2,n} \odot (g_b - X_n)$, where ⊙ denotes the Hadamard product, and the vectors $\pi_{1,n}$, $\pi_{2,n}$ have independent uniformly distributed elements in [0, 1].
9. Limit vector v_n’s each element in [$-V_{max}$, V_{max}].
10. Compute particle’s new position: $X_n \leftarrow X_n + V_n$.
11. Limit each element of vector X_n in [θ_{min}, 1].
12. **Assessment**: Calculate $f(X_n)$ and optimal beam forming variables $\{w_i\}n$, $\forall_i$ from the solution of SDR according to the PS ratios set, X_n.
13. Update the new best position of particle: if $f(X_n) > f(P_{b,n})$ then Assign: $P_{b,n} \leftarrow X_n$. end if. Update particle’s new global best position: if $f(X_n) > f(g_b)$ then Assign: $g_b \leftarrow X_n$, $\{w*i\} \leftarrow \{w_i\}n$, $\forall_I$ end if
14. end for
15. Update iteration index: m ← m + 1.
16. until m > T_{max} (end MR-EDF loop)
17. **Final results**: the global best value $f(g_b)$ is the optimal value of WSHE according to the optimal PS ratios $\{\theta*i\}=g_b$, and the optimal beam forming vectors {w∗i}, ∀ i.

The proposed method has been performed for AP and secondary receivers who are assumed as multiple relays that makes use of the efficient optimized PS proportions from the transmitters. As a result, the SR incoming signal was split by optimal PS. Therefore, the proposed algorithms efficiently use to increase the data rate with multi relay EDF for CR sensor networks.

4. Simulation results

The performance analysis based on simulated results considered are Symbol Error Rate (SER) over Signal to Noise Ratio (SNR), Cumulative Distributive Function (CDF) for both primary and secondary network, Outage Probability and Sum Throughput over power splitting factor and variance for both single and multi-relay EDF. The simulation parameters [6] are as shown in Table 2.

Table 2: Simulation Parameters

Factors	Values
Transmit Power	20dBm
Energy Harvester Co-efficient	C_1=0.05
	C_2=1
Path loss exponent	3
Primary and Secondary data rates	R_p=1 bit/cu
	R_s=0.1bit/cu
Access Point (AP)	3m
Relay R_1,R_2,R_3	1.5m
Destination (D)	2m

The achievement of SNR over SER is shown in Fig.2. The SER response of Multi Relay EDF was much better than EDF and DF. At $1e^{-4}$ of SER, the SNR of MR EDF was decreased by an amount of 22 dB to EDF, 25 to DF and 30 dB to AF. It was realized that the MR-EDF SER response has been nearer to the theoretical response.

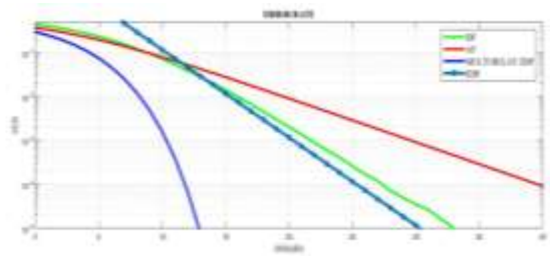

Fig.2: SER VS SNR

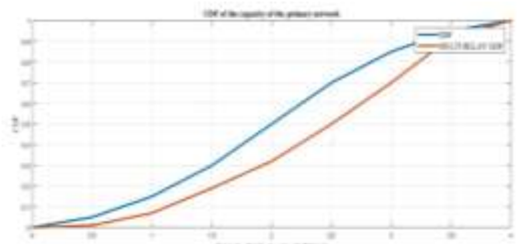

Fig.3: CDF of Primary Network Capacity

The achievement of CDF of Primary Network Capacity is shown in Fig.3. CDF was used to calculate the Peak to Average Power (PAPR) values. PAPR was the important metric to calculate the power amplitude fluctuations of the signal. The CDF curve shows according to what Capacity the signal spends at or above a given power level. The CDF response of Multi Relay EDF was much better than EDF. At 2 bits/cu of Capacity, the CDF of MR EDF was decreased by an amount of 0.2 to EDF.

The achievement of CDF of Secondary Network Capacity is shown in Fig.4. The CDF response of Multi Relay EDF was much better than EDF. At 2.5 bits/cu of Capacity, the CDF of MR EDF was decreased by an amount of 0.2 to EDF.

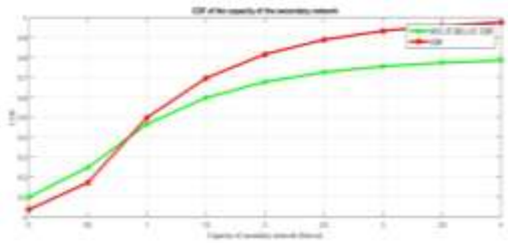

Fig.4: CDF of Secondary Network Capacity

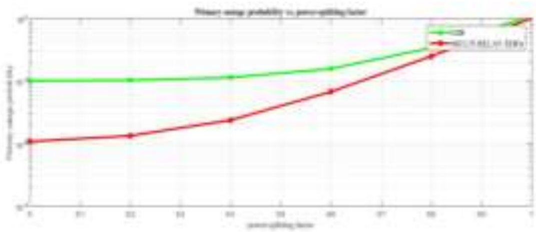

Fig.5: Primary Outage Probability over Power splitting factor

The achievement of Primary Outage Probability over Power splitting factor is shown in Fig.5. The Primary Outage Probability (POP) response of Multi Relay EDF was much better than EDF. At 0.2 of Power Splitting factor, the POP of MR EDF was decreased by an amount of 1^{e-1} to EDF.

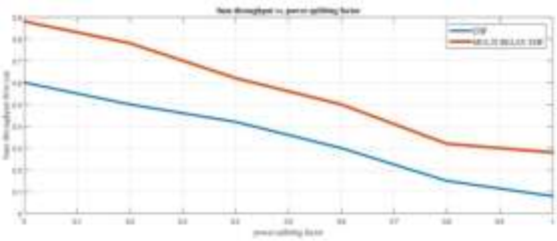

Fig.6: Sum Throughput over Power splitting factor

The achievement of Sum Throughput over Power splitting factor is shown in Fig.6. The Sum Throughput response of Multi Relay EDF was much better than EDF. At 0.2 of PS factor, the throughput of MR EDF was increased by an amount of 0.3 bits/cuas compared to EDF.

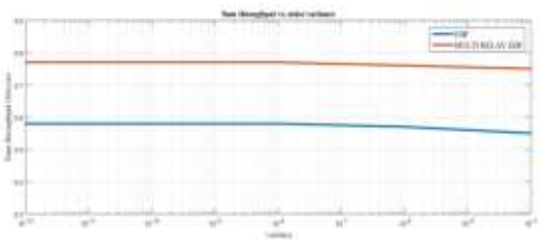

Fig.7: Sum Throughput over Variance

The achievement of Sum Throughput over Variance is shown in Fig.7. The Sum Throughput response of Multi Relay EDF was much better than EDF. All the time, the throughput of MR EDF was increased by an amount of 0.25 bits/cu to EDF.

5. Conclusion

A multi relay EDF SWIPT to increase the data rates with enhanced cognitive users are proposed and performance of simulated results justifies it. Though the existing method tried to prove with single relay antenna with respect to decode forward and energy assisted decode forward, the proposed work proves better performance with respect to outage probability, sum throughput and network capacity. The proposed algorithm satisfies the optimal sum rate and power splitting ratios for both perfect and imperfect CSIs. The proposed MR-EDF SWIPT achieves faster convergence than single relay EDF. Further the user scheduling, energy harvesting scheduling and relay beam forming can be considered as future work for both single and multi-relay EDF.

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