DSSC based RF energy harvesting using 2RRS scheme

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Abstract: In recent years, radio frequency (RF) energy harvesting (EH) has gained prominence in wireless networks. Both data transmission and powering energy-constrained network nodes are possible using RF. Fading is one of the many issues that prevent wireless networks from transmitting signals effectively. Data is sent from the source to the destination with fewer hops when cooperative communication is used. This thesis considers a twin-hop relay-aided network with wireless energy harvesting. The source's RF energy is captured by the relays and used for data transmission. Using the results from the simulations and the Distributed Switch and Stay Combining (DSSC) combining technique at the receiver, the performance of the proposed relay selection that is Two Round Relay Selection (2RRS) network in terms of outage probability, throughput, and spectral efficiency are analysed.

Keywords: RF Energy, Relay Selection, Spectral Efficiency, Throughput, Outage Probability.

1. Introduction

It is crucial to assess the relay-aided RF- Energy Harvesting Network's (EHN) output performance since the data delivered from the relay node to the destination may not always be adequately communicated. Other solutions to the aforementioned issue include distributed space-time coding and full-duplex relay nodes, which can send and receive data simultaneously. The simplest and most useful of these procedures is relay selection. Whilst theoretically sound, none of these models may hold up in practical situations where the best channels for enhancing service quality are relaying links that are undergoing severe fades.

The source used the best relay out of many relays in an RF EHN examined in (Hasna et al., 2002). by employing the optimal relay selection (ORS) approach. In a relay-assisted DSSC- based RF energy harvesting network, this served as motivation to evaluate the system performance of a recommended 2 RRS scheme with the present PRS scheme. Bit-error-rate (BER), outage probability, throughput, and spectral efficiency are used to gauge a wireless channel's physical layer performance.

To compare the performance of the proposed Two Round Relay Selection (2 RRS) relay selection strategy and the Partial Relay Selection (PRS) strategy, this thesis work analyses the performance of a relay-aided RF energy harvesting network using the Distributed Switch and Stay Combining (DSSC) technique at the receiver. According to the authors (Lu et al., 2014), the main elements of an RF-Energy harvesting Network (EHN) include RF energy sources, information gateways, and network nodes/devices. Figure 1 and 2 show, respectively, the architectures of RF-EHNs with and without infrastructure (Lu et al., 2014).

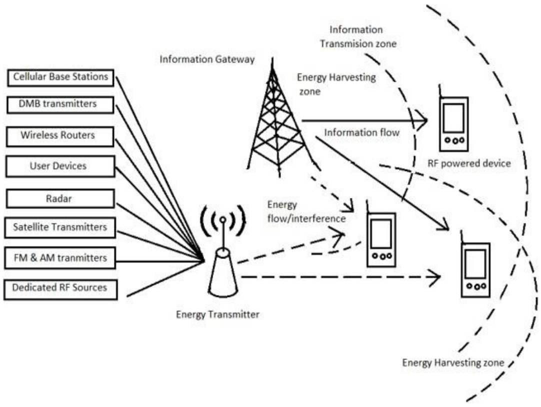

Figure 1. An infrastructure-based architecture of RF-EHN

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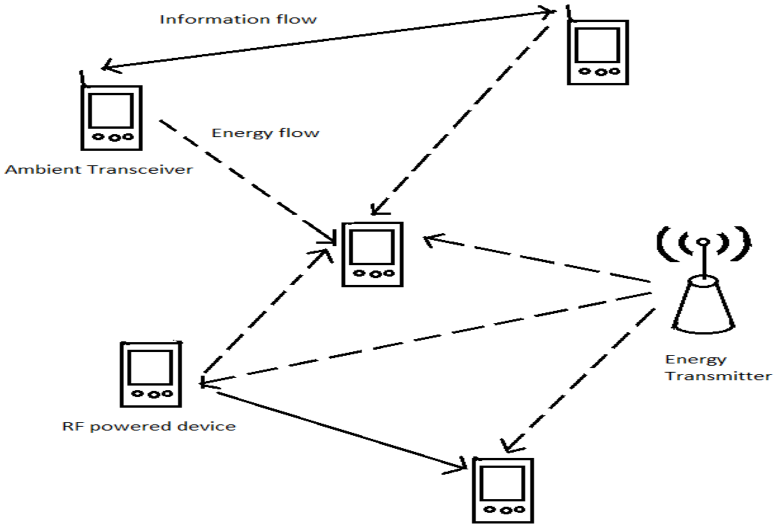

Figure 2. An infrastructure-less architecture of RF-EHN

Due to the processing of the received signal for information decoding and energy harvesting, two different receiver designs were proposed (Grover et al., 2010). A Time Switching (TS) structure was considered in the initial design (Nguyen et al., 2019), where the signal was given two distinct time slots for delivering power and information, respectively. As opposed to (Nguyen et al., 2019), the Power Splitting (PS) structure (Zhu et al., 2015) used a power ratio to split the signal into two streams for energy harvesting and data decoding. The author's description of the Time Splitting-based Relaying (TSR) protocol may be found in (Zhong et al., 2014). Figure 3 shows the block diagram of a relay receiver implementing the TSR protocol.

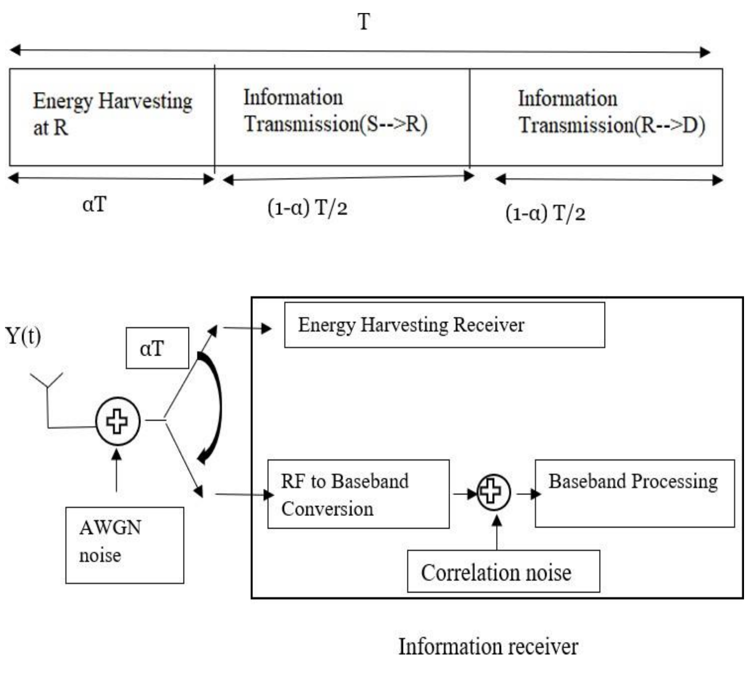

Figure 3. Block diagram of a relay receiver using TSR protocol

The Power Splitting-based Relaying (PSR) technique was described by the authors in (Liu, et al., 2016). Figure 4 depicts the block diagram of a communication system utilizing the PSR protocol, where "P" stands for the received signal power at the relay and "T" for the entire transmission block time.

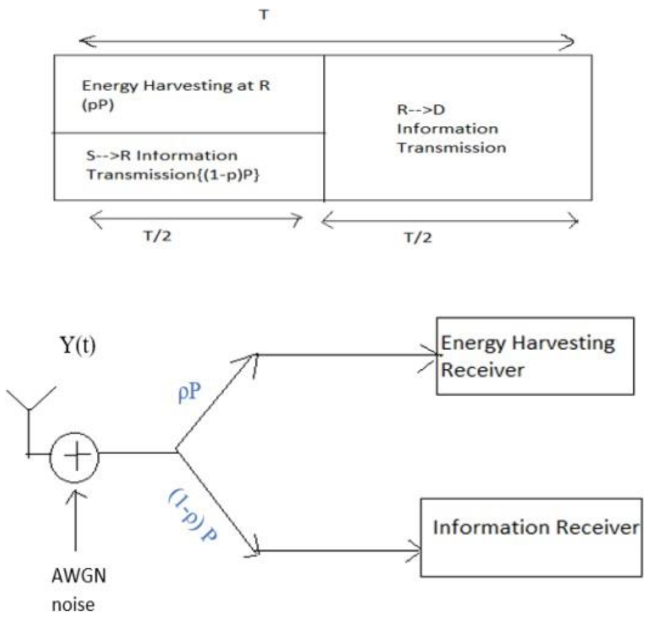

Figure 4. Block diagram of a relay receiver using PSR protocol

The paper is organized as follows. Section 1 describes the introduction and Section 2 shows relay selection strategies. Section 3 describes the methodology of the 2RRS algorithm and Section 4 describes the system model followed by the simulation result in Section 5. Finally, a conclusion is drawn in Section 6.

2. Relay selection strategies in RE-EHN

Relay selection strategies for cooperative communications focus on facilitating the transmission of information from the source to the destination, when there may be more than one relay (Zeng et al., 2015). RF energy was first captured by the relays for information decoding and forwarding at the best relay. The system model made use of the two widely utilized relay selection algorithms, ORS and PRS, to lessen outages and boost diversity gains (Rezaei et al., 2018). The ideal relay for information transmission may not be the same as the relay with the strongest channel for energy collecting purposes, which is one of the major issues in the relay selection process of a SWIPT RF-Energy Harvesting Networks (Lumpkins et al., 2013).

The authors in (Chowdhuri et al., 2018a, Chowdhuri et al., 2018b, Varshney et al., 2008, and Chowdhuri et al., 2018c) explored three relay selection strategies (time sharing selection, threshold-checking selection, and weighted difference selection scheme) among two available relays in a Rayleigh fading network with a distinct information receiver and energy harvester. The source node selected the relay with the highest RF energy collection rate during the threshold-checking process (Chen et al., 2014; Nasir et al., 2013; Nasir et al., 2015; Zeng & Zhang, 2015). The weighted difference selection method selected the best relay based on the importance of energy and information transfer. The authors came to the concluded that, for certain RF energy harvesting requirements, using a threshold checking option offers higher capacity results. The authors (Chen et al. 2015, Ju & Zhang, 2013 and Sendonaris et al., 2003) considered the difficulty of selecting the diversity-optimal relay in RF-EHN. The authors concluded that, as compared to a conventional network, the max-min criterion causes a loss of diversity gains in the system model under consideration.

3. Methodology

Three relays, a single source and destination, and a dual-hop full duplex network have been taken into consideration. The relays utilize the Power Splitting Ratio (PSR) protocol to gather RF energy. The most energy - efficient relay for communication is chosen using - the Two Round Relay Selection (2 RRS) approach. The effectiveness of the aforementioned model has been evaluated in terms of the network's throughput, spectral efficiency, and outage probability. To choose the optimum relay for the suggested system model, the "Two Round Relay Selection (2RRS)" relay selection approach has been developed. Via a two-round relay selection process, the strategy chooses the communication's best energy-efficient relay. The relays which are selected in the first round are only applicable for further selection.

4. System model

The Two-Round Relay Selection model is shown in Figure 5.

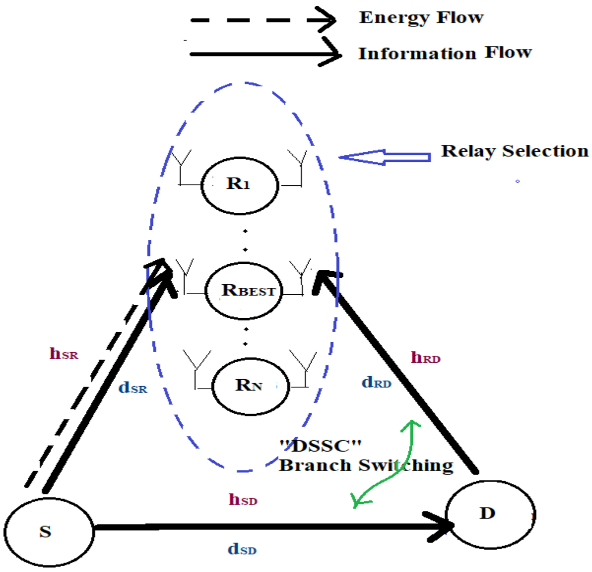

Figure 5. Proposed System Model

The following are some of the assumptions of the considered model (Laneman et al., 2003):

- All the nodes of the system are static and only the relays can harvest RF energy from the source.
- The source and the destination have a fixed power supply.
- The relays are assumed to be in a straight line between "S" and "D" assuming a practical model of distance and path-loss.
- The distance from "source to destination", "source to relay" and "relay to destination" are given by, "d_{SD}", "d_{SR}" and "d_{RD}" respectively.
- "Self-interference" effect from the transmitting antenna of "R_B" to its receiving antenna is assumed to be negligible for the HD mode of operation.

A. Two Round Relay Selection (2RRS) Scheme

The proposed 2 RRS relay selection considers both the harvested energy and the channel conditions of both the hops for relay selection. The algorithm operates in two rounds; where the relays selected in the first round undergo another selection evaluation in the second round to be deemed as the best relay (“R_B”). The two rounds of relay selection can be described below:

#**Round 1**: The source sends information to all of the relays in the first round. The relays convey their channel status information (CSI), which includes the received SNR and the amount of energy gathered, to the destination after receiving the transmitted data. All relays' SNRs (γ_{RjD}) are compared to a predetermined threshold (γ_q). Relays whose SNR is higher than the threshold SNR value can now correctly decode the information of the source “S”. They are chosen as the top relays and go through a second round of selection.

#**Round 2**: In the second round, the SNR of all the relays is evaluated using the top relays from the first round. The best relay is the one with the highest "R"- "D" channel strength (SNR). The SNR of the "j-th" relay in the group of relays is given in equation (1),

$$\gamma_{R_jD} = \frac{P_R h_{R_jD}^2}{\sigma_0} \tag{1}$$

The most effective relay out of N number of relays is selected based on the following algorithm in Table 1. The destination notifies each relay of the best relay it has chosen. The most effective relay then transmits the information from the source to the target.

Figure 6 provides a schematic illustration for the 2-RRS relay selection and the corresponding algorithm for the 2-RRS relay selection system parameter settings is elaborated in Table 1.

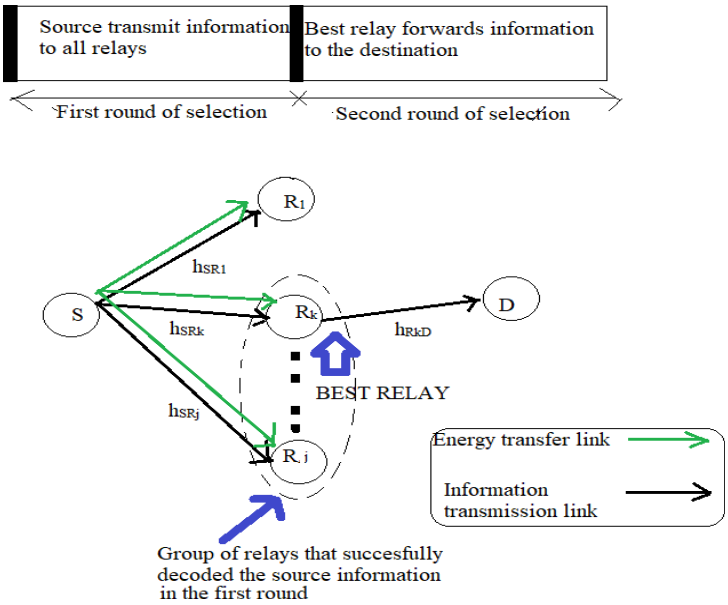

Figure 6. A schematic representation of 2RRS strategy

Table 1. Parameter Setting

Number of relays (N)	3
Transmission rate of source (R)	3 bps/Hz
Energy efficiency (η)	0.4
Harvesting time (Γ)	0.4s
Distance from source to relay	0.5m
Distance from source to destination	1m
Noise power (watt/Hz)	1[24]
Path loss exponent (m)	3[24]
Switching threshold (k)	7[24]
Outage threshold (FD/HD)	7 (2^r -1) / 63 (2^{2r} -1)

B. Algorithm for Two Round Relay Selection (2RRS) Scheme

Algorithm: Two Round Relay Selection (2-RRS) Scheme

Begin

Input N number of relays, threshold SNR($\gamma_{\_q}$)

while S transmits to N relays

Update γ_{SRi};

for i = 1 to N **do**

Initialize round_1_success

while (γ_{SRi}>=$\gamma_{\_q}$)

round_1_success=round_1_success +1;

end while

end for

First Round Relay Selection

if round_1_success>0

for j=1 to round_1_success **do**

Update γ_{RjD};

R_B=arg{max (γ_{RjD})}

end for

Second Round Relay Selection

end if

end while

End

5. Results analysis of 2RRS algorithm

Different parameters are analyzed in the subsequent section using Two Round Routing Scheme. Figure 7a and Figure 7b show the outage probability vs. SNR for AF and DF mode considering half duplex and full duplex 2RRS algorithm. Figures 8a and Figure 8b show throughput vs. SNR and Figure 9a and Figure 9b show spectral efficiency vs. SNR. Finally Figure 10 shows outage probability vs. efficiency.

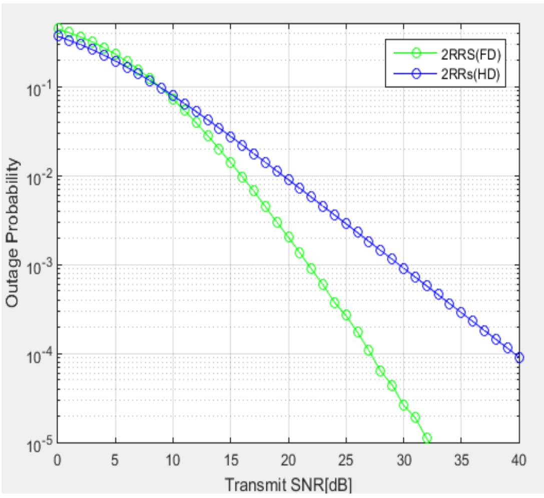

Figure 7a. Outage Probability VS SNR (AF)

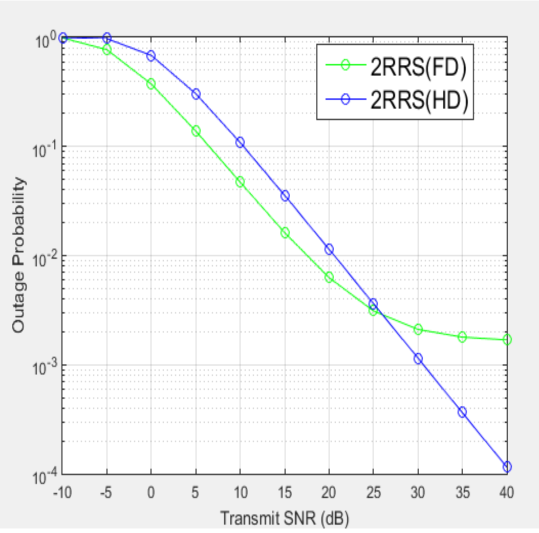

Figure 7b. Outage Probability VS SNR (DF)

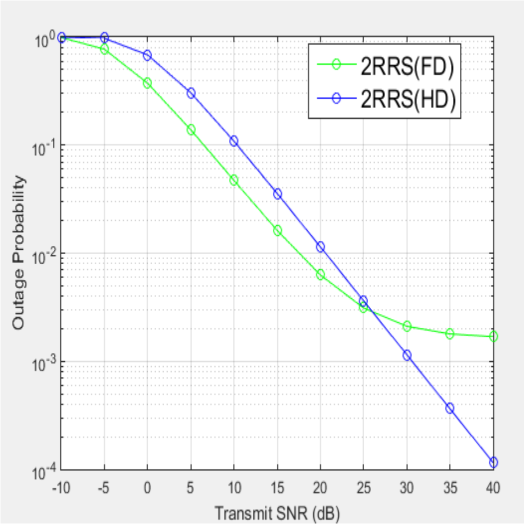

Figure 8a. Throughput VS SNR (AF)

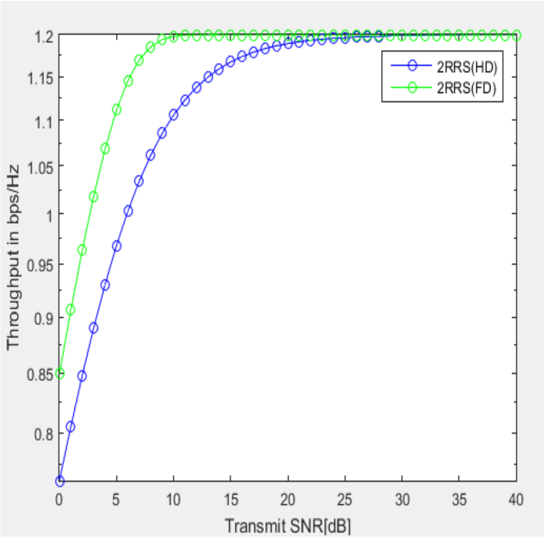

Figure 8b. Throughput VS SNR (DF)

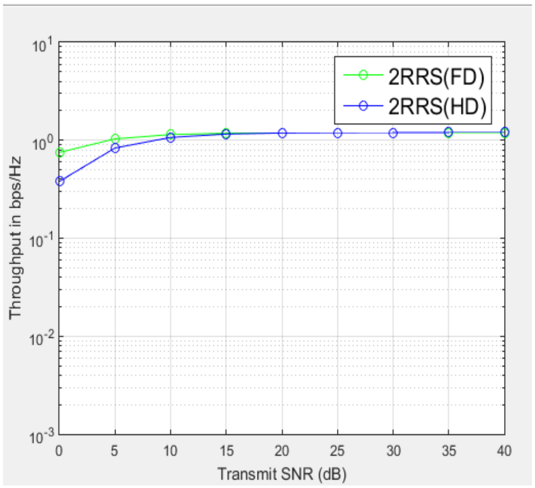

Figure 9a. Spectral_Efficiency VS SNR (AF)

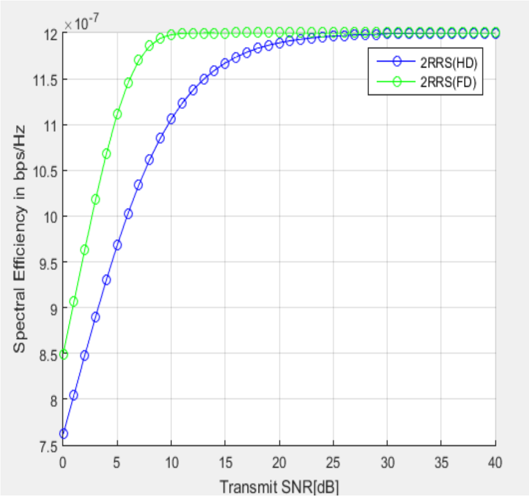

Figure 9b. Spectral_Efficiency VS SNR (DF)

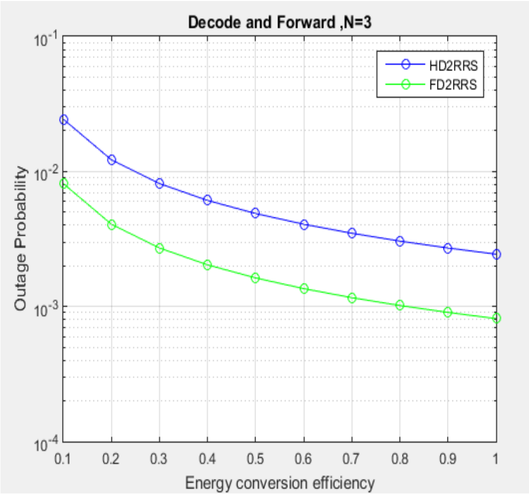

Figure 10. Outage probability vs. Efficiency

6. Conclusion

In this paper, the benefits of cooperative diversity in a wireless communication network that uses RF energy harvesting have been investigated. The paper provides a comprehensive examination of the relay selection strategies along with relaying protocols and combining methods that could be used in a relay-aided RF energy harvesting network to increase signal transmission efficiency. The suggested system model is simulated using MATLAB and the overall performance is examined for the two relay selection strategies. The effectiveness of the proposed 2-RRS DSSC-based system is investigated in terms of all three parameters – outage probability, throughput, and spectrum efficiency. The outage probability of the 2RRS scheme is contrasted with the varying transmits SNR and the corresponding performance gain of 2RSS over the existing has been mentioned here. Moreover, due to the lack of an error-correcting code at the relay terminal, the performance of the 2 RRS DSSC- based system under Amplify and Forward protocol is inferior to the Decode and Forward protocol when DSSC is employed.

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