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Outage probability analysis in DF power-splitting full-duplex relaying network with impact of Co-channel interference at the destination

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ABSTRACT

Nowadays, improving the WPCN efficiency problem is the leading research direction in the communication network. In this research, the outage probability (OP) analysis in DF power-splitting (PS) full-duplex (FD) Relaying Network with Impact of Co-channel interference at the destination is proposed and investigated. In the system model section, we present the DF PS FD Relaying Network with Impact of Co-channel interference at the destination. Then in the system performance section, we analyze and derive the closed-form expression of the OP and investigate the effect of the main system parameters on the system network performance. Then, we perform the Monte Carlo simulation to verify the analytical section. This research can provide a new recommendation for the communication network.

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1. INTRODUCTION

Recently, a wireless- powered communication network (WPCN) has been considered as the critical research direction based on the fact that its capability to deal with the energy scarcity in energy- constrained wireless networks [1-6]. In the latest researches, the energy harvesting (EH) and information transmission (IT) in WPCN with its advantages were presented in [7, 8]. Authors in [9] proposed the partial network-level cooperation for EH networks and resolved its problems. In [10], wireless EH and IT in cognitive relay networks were intensely investigated. Moreover, the WPCN with two TSP and PSP protocols have been popularly studied in recent researches, as shown in [11-15].

In this research, the outage probability (OP) analysis in DF power-splitting (PS) full-duplex (FD) relaying network with impact of Co-channel interference at the destination is proposed and investigated. In the system model section, we present the DF PS FD relaying network with impact of Co-channel interference at the destination. Then in the system performance section, we analyze and derive the closed-form expression of the OP and investigate the effect of the main system parameters on the system network performance. Then, we perform the Monte Carlo simulation to verify the analytical section. This research can provide a new recommendation for a communication network. The main contribution of this paper can be drawn as the follows;

- The DF PS FD Relaying Network with Impact of Co-Channel Interference at the Destination is presented.
- The closed-form expression of the system OP is derived and investigated in the influence of the primary system parameters.
- The Monte Carlo simulation convinces all the results.

2. SYSTEM MODEL

The DF PS FD relaying network with impact of Co-channel interference at the destination is drawn in Figure 1. The energy harvesting (EH) and information transferring (IT) phases of the system model are drawn in Figure 2 [16-21]. In the transmission phase, the received signal at the R can be formulated as (1).

$$y_r = \sqrt{\rho} h_{sr} x_s + h_{rr} x_r + n_r \quad (1)$$

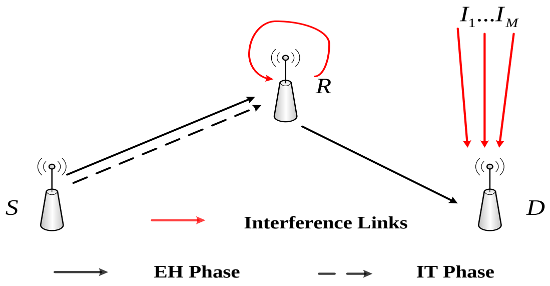

Figure 1. System model

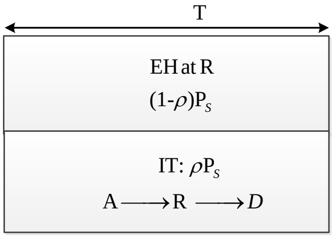

Figure 2. The EH and IT phases

The remaining power $\sqrt{1-\rho}P_s$ of the source will be employed for EH at the lay. Hence, the harvested power at the R can be obtained as (2).

$$P_r = \frac{E_h}{T} = \frac{\eta(1-\rho)P_s |h_{sr}|^2 T}{T} = \eta(1-\rho)P_s |h_{sr}|^2 \quad (2)$$

The received signal at the D can be given as (3):

$$y_D = h_{rd} x_r + \sum_{n=1}^{M} x_{I_n} h_{I_n D} + n_d \quad (3)$$

from (1), the signal to noise ratio (SNR) at the R can be formulated as the (4).

$$\gamma_1 = \frac{\rho |h_{sr}|^2 P_s}{|h_{rr}|^2 P_r + N_0} \quad (4)$$

From these (2) and (4), and using the fact that $N_0 << P_s$, the (4) can be rewritten as;

$$\gamma_1 \approx \frac{\rho}{\eta(1-\rho)|h_{rr}|^2} = \frac{\rho}{\eta(1-\rho)X} \quad (5)$$

where $X = |h_{rr}|^2$. Then the SNR at the D can be given by;

$$\begin{aligned}\gamma_2 &= \frac{P_r\left|h_{rd}\right|^2}{N_0+\sum_{n=1}^{M}P_{I_n}\left|h_{I_nD}\right|^2} = \frac{\eta(1-\rho)P_s\left|h_{sr}\right|^2\left|h_{rd}\right|^2}{N_0+\sum_{n=1}^{M}P_{I_n}\left|h_{I_nD}\right|^2}\\ &= \frac{\eta(1-\rho)\psi\left|h_{sr}\right|^2\left|h_{rd}\right|^2}{1+\Delta\sum_{n=1}^{M}\left|h_{I_nD}\right|^2} = \frac{\eta(1-\rho)\psi Y}{1+\Delta Z}\end{aligned} \tag{6}$$

where $\psi = \frac{P_s}{N_0}$, $\Delta = \frac{P_I}{N_0}$, $Y = \left|h_{sr}\right|^2\left|h_{rd}\right|^2$ and $Z = \sum_{n=1}^{M}\left|h_{I_nD}\right|^2$. Finally, the end to end SNR can be given by;

$$\gamma_{DF} = \min\left(\gamma_1,\gamma_2\right) \tag{7}$$

3. OUTAGE PROBABILITY ANALYSIS

- Remark 1:
  The probability density function (PDF) of random variable (RV) Z can be obtained as the following;

$$f_Z(t) = \frac{(\lambda_4)^M}{(M-1)!}t^{M-1}\exp(-\lambda_4 t) \tag{8}$$

- Outage probability (OP)

$$\begin{aligned}OP &= \Pr\left(\gamma_{DF} < \gamma_{th}\right) = \Pr\left[\min\left(\gamma_1,\gamma_2\right) < \gamma_{th}\right]\\ &= \Pr\left[\min\left(\frac{\rho}{\eta(1-\rho)X},\frac{\eta(1-\rho)\psi Y}{1+\Delta Z}\right) < \gamma_{th}\right]\end{aligned} \tag{9}$$

where $\gamma_{th} = 2^R - 1$ is the threshold of system, and R is the target rate. In (9) can be reformulated as the (10).

$$OP = 1-\Pr\left[\frac{\rho}{\eta(1-\rho)X} \geq \gamma_{th}\right]\Pr\left[\frac{\eta(1-\rho)\psi Y}{1+\Delta Z} \geq \gamma_{th}\right] \tag{10}$$

The first term of (10) can be calculated as (11),

$$P_1 = \Pr\left[\frac{\rho}{\eta(1-\rho)X} \geq \gamma_{th}\right] = \Pr\left[X \leq \frac{\rho}{\eta(1-\rho)\gamma_{th}}\right] = 1-\exp\left[-\frac{\lambda_1\rho}{\eta(1-\rho)\gamma_{th}}\right] \tag{11}$$

where λ_1 is the mean of RV $\left|h_{rr}\right|^2$. The second term from (10) can be obtained by (12).

$$\begin{aligned}P_2 &= \Pr\left[\frac{\eta(1-\rho)\psi Y}{1+\Delta Z} \geq \gamma_{th}\right] = 1-\Pr\left[\eta(1-\rho)\psi Y < \gamma_{th}(1+\Delta Z)\right]\\ &= 1-\Pr\left[Y < \frac{\gamma_{th}(1+\Delta Z)}{\eta(1-\rho)\psi}\right]\\ &= 1-\int_0^{\infty}F_Y\left(\frac{\gamma_{th}(1+\Delta z)}{\eta(1-\rho)\psi}\,|\,Z=z\right)\times f_Z(z)dz\end{aligned} \tag{12}$$

Next, the cumulative distribution function (CDF) of Y can be computed as (13).

$$\begin{aligned} F_Y(y) &= \Pr(|h_{sr}|^2 |h_{rd}|^2 < y) = \Pr\left(|h_{sr}|^2 < \frac{y}{|h_{rd}|^2}\right) \\ &= \int_0^\infty F_{|h_{sr}|^2}\left(\frac{y}{a} \,|\, |h_{rd}|^2 = a\right) \times f_{|h_{rd}|^2}(a)da \\ &= 1 - \lambda_3 \int_0^\infty \exp\left(-\frac{\lambda_2 y}{a}\right) \times \exp\left(-\lambda_3 a\right) da \end{aligned} \tag{13}$$

Applying eq (3.324,1) of the table of integral, (13) can be reformulated by (14).

$$F_Y(y) = 1 - 2\sqrt{\lambda_2 \lambda_3 y} \times K_1\left(2\sqrt{\lambda_2 \lambda_3 y}\right) \tag{14}$$

Using (14) and substituting (8) into (12), P_2 can be obtained as (15).

$$P_2 = 2\int_0^\infty \sqrt{\frac{\lambda_2 \lambda_3 \gamma_{th}(1+\Delta z)}{\eta(1-\rho)\psi}} \times K_1\left(2\sqrt{\frac{\lambda_2 \lambda_3 \gamma_{th}(1+\Delta z)}{\eta(1-\rho)\psi}}\right) \times \frac{(\lambda_4)^M}{(M-1)!} z^{M-1} \exp(-\lambda_4 z)dz \tag{15}$$

Substituting (11) and (15) into (10), the OP can be claimed by;

$$OP = 1 - 2\left(1 - \exp\left[-\frac{\lambda_1 \rho}{\eta(1-\rho)\gamma_{th}}\right]\right) \times \left\{ \begin{aligned} &\int_0^\infty \sqrt{\frac{\lambda_2 \lambda_3 \gamma_{th}(1+\Delta z)}{\eta(1-\rho)\psi}} \times K_1\left(2\sqrt{\frac{\lambda_2 \lambda_3 \gamma_{th}(1+\Delta z)}{\eta(1-\rho)\psi}}\right) \\ &\times \frac{(\lambda_4)^M}{(M-1)!} z^{M-1} \exp(-\lambda_4 z)dz \end{aligned} \right\} \tag{16}$$

4. NUMERICAL RESULTS AND DISCUSSION

In this section, we propose and investigate the influence of the primary system parameters on the OP of the proposed model system [21-25]. The influence of ψ and Δ on the system OP are drawn in Figures 3 and 4. In these Figures 3 and 4, we vary ψ from 5 to 25 dB and Δ from 0 to 25 dB. The main system parameters are set as R= 0.25 bps/Hz, ρ=0.5, η=0.8. From the results, as shown in Figure 3, we can see that the system OP crucially falls from 10 to 0 with the rising of ψ. In addition, the system OP has a massive increase from 0 to 1 with an increase of Δ. From the Figures 3 and 4, all the simulations are the same as the analytical results.

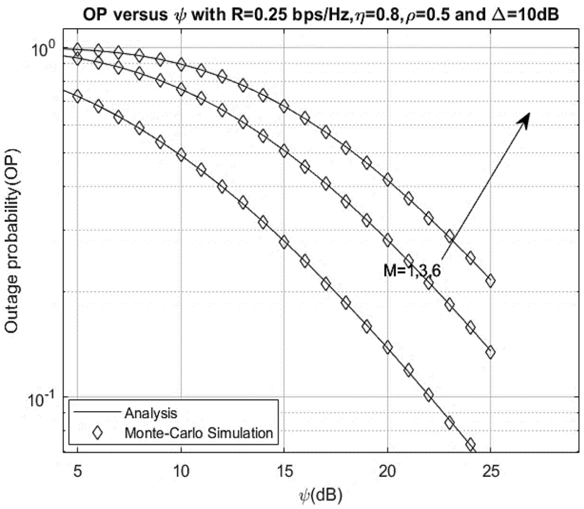

Figure 3. OP versus ψ

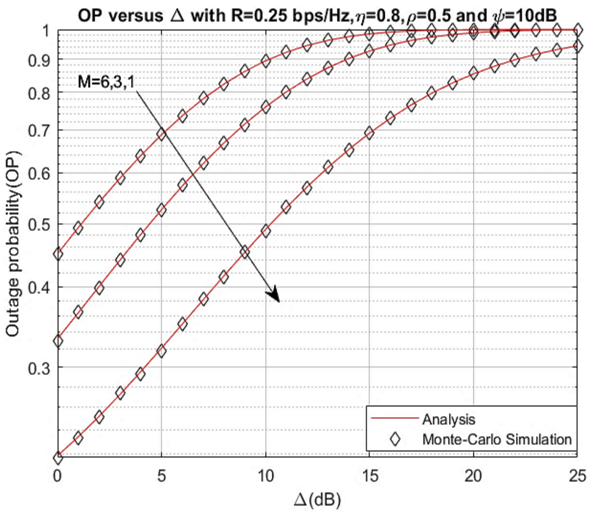

Figure 4. OP versus Δ

Moreover, the effect of ρ, R, and M on the system OP are proposed in Figures 5-7 with the main system parameters, as shown in Figures 5-7. In Figure 5, the system OP decreases when ρ varies from 0 to 0.3, and then has a considerable rise while ρ increases to 1. The optimal value of the system OP can be obtained with ρ from 0.2 to 0.3. Furthermore, the system OP increases significantly when R and M increase, as shown in Figures 6 and 7. In all figures the simulation and analytical results have a good agreement.

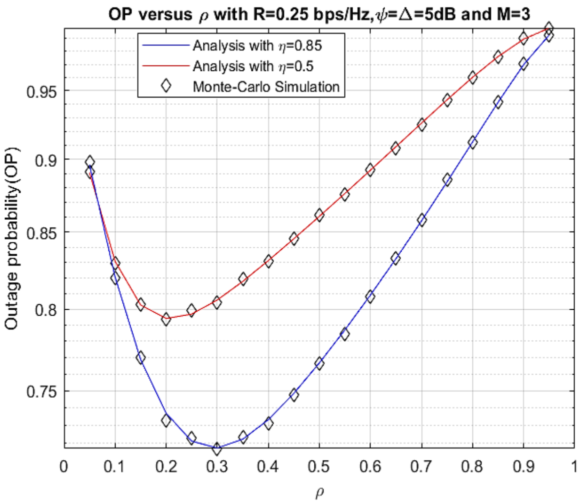

Figure 5. OP versus ρ

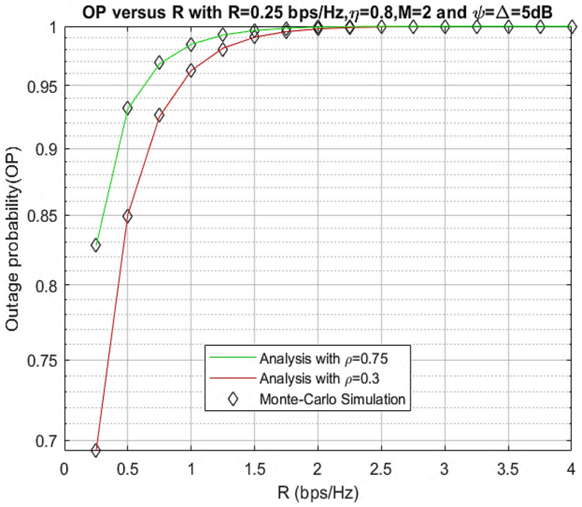

Figure 6. OP versus R

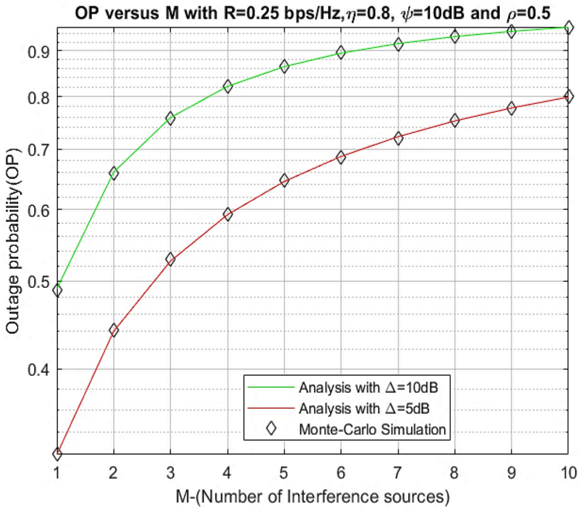

Figure 7. OP versus M

5. CONCLUSION

In this research, the OP Analysis in DF PS FD Relaying Network with Impact of Co-Channel Interference at the Destination is proposed and investigated. In the system model section, we present the DF PS FD Relaying Network with Impact of Co-Channel Interference at the Destination. Then in the system performance section, we analyze and derive the closed-form expression of the OP and investigate the effect of the main system parameters on the system network performance. Then, we perform the Monte Carlo simulation to verify the analytical section. This research can provide a new recommendation for a communication network.

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