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On the Outage Performance of Partial Relay Selection Aided NOMA System with Energy Harvesting and Outdated CSI over Non-Identical Channels

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Abstract—In this paper, the outage probability performance of energy harvesting based partial relay selection aided non-orthogonal multiple access (NOMA) system under outdated channel state information is studied. The source to relays link is assumed to follow Rayleigh fading distribution while the relay nodes to users are subjected to Nakagami-m distribution. The relay nodes employ an energy harvesting power splitting-based relaying protocol to transmit the source information to the users. At the destination, each user is equipped with multiple antennas, and maximum ratio combining is considered for signal reception. In order to evaluate the system performance, the outage probability closed-form expression for the concerned system is derived. The results demonstrate the significant impact of system and channel parameters on the system performance. In addition, the advantage of NOMA over the conventional orthogonal multiple access is also presented. Finally, the accuracy of the derived outage expression is validated through the Monte-Carlo simulation.

1. INTRODUCTION

Recently, non-orthogonal multiple access (NOMA) has emerged as a potential technique for 5th generation (5G) multiple access systems due to high traffic volume and optimize spectral efficiency [1]. As a result, it has capacity to improve the spectrum efficiency and system throughput compared to conventional orthogonal multiple access (OMA) [2]. In NOMA systems, power domain is utilized to achieve multiple-access strategies in order to avoid abusing time/frequency/code resources [3]. Based on this, less power is allocated to the user with better channel condition in order to balance the trade-off between the system throughput and user fairness of the network [4]. At the system receiving end, successive interference cancellation (SIC) is employed to separate the signal of multiple users. This enable the user with the best channel condition to decode other users signal before decoding its own signal [5].

Cooperative relaying technique has been recognized as an effective means of enhancing the transmission reliability as well as improving the system capacity without additional transmit power [6, 7]. It involves the source that communicates with multiple users via a decode-and-forward (DF) or amplify-and-forward (AF) relay node(s). The advantage of a cooperative relaying scheme with multiple antennas have inspired researchers to employ relaying technique in NOMA communication systems. The outage performance of an AF-based NOMA system with transmit antenna selection and maximum ratio combining (TAS/MRC) at the source and destination respectively was investigated in [6]. In [8]. performance analysis for downlink relaying aided non-orthogonal multiple access networks with imperfect channel state information (CSI) over Nakagami-m fading was presented. The performance of

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a cooperative NOMA downlink network is investigated over Nakagami-m fading channels with channel estimation errors in [4]. The authors considered direct links between the source and users. However, all these aforementioned existing works on cooperatively NOMA relaying systems were specifically limited to a single relay node. Under multiple relays deployment, attention has been given to different relay selection schemes which significantly improve the system performance. A dual-hop AF-NOMA relaying network with partial relay selection protocol over Nakagami-m fading channels was studied. In [9], the performance of NOMA schemes with partial relay selection was investigated, and direct link was considered between the source and users.

Energy harvesting (EH) has been regarded as a breakthrough for several energy-constrained terminal devices, such as tremendous energy consumption, unfeasible traditional recharging, and additional power equipment, in wireless communication systems [10]. In this case, energy could be harvested from available and free ambient sources such as solar, vibration, wind, and other physical phenomena [7]. However, due to unavailability of these sources as a result of environment or climate, energy harvesting through radio frequency (RF) signals has been considered for use in wireless communication systems [11]. Therefore, harvesting energy from RF signals can be divided into time switching (TS) and power splitting (PS) protocols. In TS protocol, the transmission time is divided into two parts where the receiver nodes spend one to harvest energy from the source and the remaining for information transmission. In PS protocol on the other hand, the relay nodes used part of the receive power for EH and the other for information processing [12, 13]. Combining energy harvesting with NOMA relaying systems to prolong the lifetime of energy-constrained wireless networks has recently received significant attention. In [7], the performance analysis for NOMA energy harvesting relaying networks with TAS and MRC over Nakagami-m fading was studied. However, the work only employed a single relay based energy harvester for signal transmission to the users. The performance analysis of partial relay selection in cooperative NOMA systems with RF energy harvesting was studied in [14], but outdated CSI was not considered for cooperative NOMA relaying system. Motivated by this fact, this paper presents the outage probability performance of an energy harvesting based partial relay selection aided NOMA system under outdated CSI. The relay nodes employ an energy harvesting power splitting-based relaying protocol to transmit source information to the users. The source to relay nodes is assumed to follow Rayleigh fading distribution while the relay nodes to users are subjected to Nakagami-m distribution. The exact closed-form of outage probability is derived for the concerned system. The impacts of channel and system parameters on the system performance are presented.

The rest of the paper is structured as follows. In Section 2, the system model is provided. We derive analytical expressions of the outage probability in Section 3. Numerical results and discussions are detailed in Section 4, and finally, concluding remarks are given in Section 5.

2. SYSTEM MODELS

An energy harvesting based partial relay selection (PRS) aided NOMA cooperative system under outdated CSI is illustrated in Figure 1. The system operates in half-duplex mode and consists of a source (S), multiple N relay nodes, and K users (D_k) with multiple receive antennas. Due to deep fading, the direct links between the source and the users are unavailable. The S-to-R_n and R_n-to-D_k links are respectively assumed to follow Rayleigh fading and Nakagami-m distributions. Therefore, the complex channel coefficient between the S and R_n is defined as $h_{SR,n} \sim \mathbb{CN}(0, \Omega_{SR,n}), n \in \{1, 2, \dots, N\}$, and the complex channel coefficient between the R_n and D_k is denoted as $h_{RD,k} \sim \mathbb{CN}(0, \Omega_{RD,k}), k \in \{1, 2, \dots, K\}$. Based on the PRS scheme, the source monitors the S-to-R_n CSI quality through the local feedback. As a result of channel fast fading, the source selects a single relay with the nth worst S-to-R_n link based on outdated CSI. Thus, the instantaneous SNR of the first link and the one used for PRS are two correlated random variables with channel correlation coefficient ρ. Therefore, the transmission between the source and users is divided into two time-slots, and AF relay protocol is employed to establish the operation.

During the first time slot, the source transmits the unit-power superposition symbol $x_s = \sum_{k=1}^{K} \sqrt{a_k P_s} x_k$ to R_n with x_k denoting the user D_k transmit information, P_s the transmit power, and a_n the power allocation coefficient of user D_n which define the proportion of the transmit power allocated to x_n. According to NOMA concept, $a_1 > a_2 > \dots, a_K$ and $\sum_{k=1}^{K} a_1 = 1$. Therefore, the

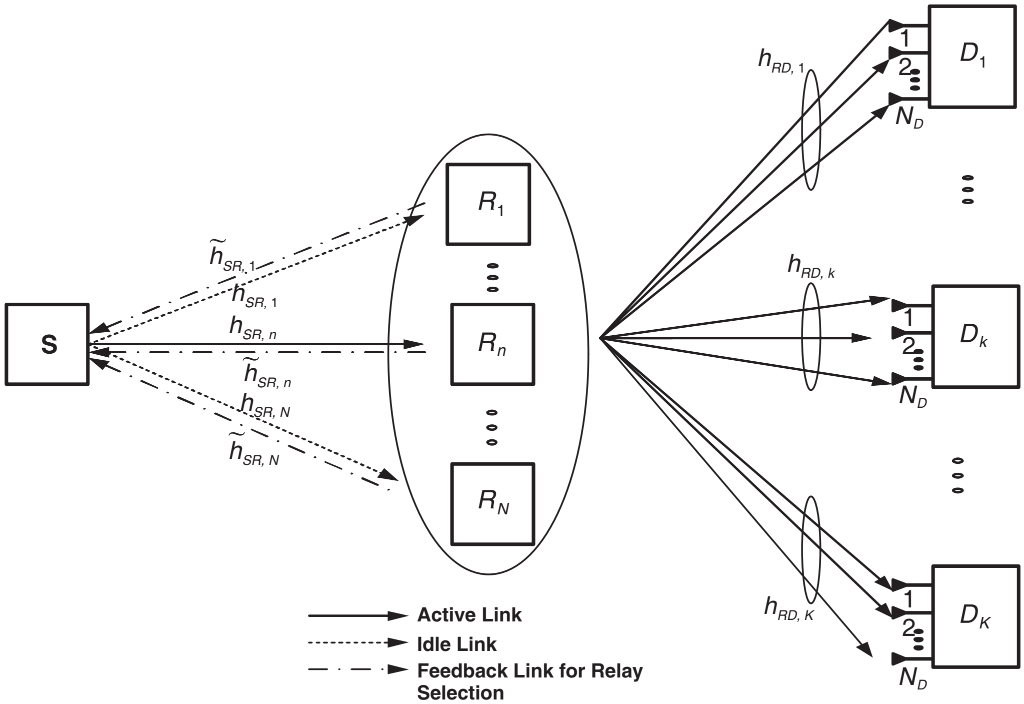

Figure 1. Partial relay selection based energy harvesting cooperative NOMA system model.

received signal at the relay node R_n can be expressed as:

$$y_{R_n} = h_{SR,n} \sum_{n=1}^{N} \sqrt{a_k P_s} x_k + z_{R_n} \tag{1}$$

where w_{R_n} is the AWGN denoted as $z_{R_m} \sim \mathbb{CN}(0, \sigma^2_{R_m})$.

In this study, PSR energy protocol is considered in which the received source signal at the nth relay node is divided into $\beta : 1-\beta$ parts. One part is used for the energy harvesting, and the other part is used for information processing. Thus, the energy harvested at the nth relay node can be expressed as [15, 16]:

$$P_{R,n} = \eta \beta P_s \left|\mathrm{h}_{SR,n}\right|^2 \tag{2}$$

where P_s is the source transmit power, and $0 \le \eta \le 1$ is the energy conversion efficiency

During the second time slot, the selected relay R_n amplifies the source signal with amplifying coefficient $G = \sqrt{P_{R,n}/[(1-\beta)P_s|h_{SR,n}|^2 + (1-\beta)\sigma^2_{R_n}]}$. Thus, the received signal at user D_k can be defined as:

$$y_{RD,k} = \sqrt{(1-\beta)} G h_{RD,k} h_{SR,n} \sum_{n=1}^{N} \sqrt{a_k P_s} x_k + G h_{RD,k} z_{R_n} + z_{D_k} \tag{3}$$

where $z_{R_n} = \sqrt{(1-\beta)} z_{R_n}$ is the AWGN at the relay node, and $z_{D_k} \sim \mathbb{CN}(0, \sigma^2_{D_k})$ denotes the AWGN at the kth user.

Since MRC is assumed to combine the received signal at the kth user, the MRC output at the kth user can be expressed as:

$$\tilde{y}_{RD,k} = \sqrt{(1-\beta)} G h_{RD,k} h_{SR,n} \sum_{n=1}^{N} \sqrt{a_k P_s} x_k + G h_{RD,k} \left(z_{R_n} + h^H_{RD,k} z_{D_k} \right) / h_{RD,k} \tag{4}$$

Moreover, the SIC is employed to eliminate the effect of inter-user interference on each user D_n. The SIC decoding order is in increasing order of the effective users' channel gains as $(|h_{RD,1}|^2 \le |h_{RD,1}|^2 \le$

$\ldots, \leq |h_{RD,K}|^2)$. Without loss of generality, $P_s = P_{R,n} = P$, $\sigma^2_{R_m} = \sigma^2_{D_n} = \sigma^2$, and the average SNR of the system can be defined as $\bar{\gamma} = P/\sigma^2$ with $\psi_{1,n} = |h_{SR,n}|^2$, $\psi_{2,k} = |h_{RD,k}|^2$. Thus, signal-to interference-and-noise ratio (SINR) for the kth user to decode the signal of the ith user can be expressed as:

$$\gamma_{RD,\, i\to k} = \frac{a_i \bar{\gamma}\psi_{1,\,n}\psi_{2,\,k}}{\bar{\gamma}\psi_{1,\,n}\psi_{2,\,k}\sum_{j=i+1}^{K} a_j + \mu\psi_{2,\,k} + \xi}, \quad \text{for } i \neq K \tag{5}$$

where $\xi = 1/(1-\beta)$ and $\mu = 1/(\varepsilon\eta\beta)$ with ε representing a constant factor.

This SIC will be iterated until the k-th user decodes all its signals, and the k-th SINR can be defined as:

$$\gamma_{RD,\, k} = \frac{a_k \bar{\gamma}\psi_{1,\,n}\psi_{2,\,k}}{\bar{\gamma}\psi_{1,\,n}\psi_{2,\,k}\sum_{k=i+1}^{K} a_j + \mu\psi_{2,\,k} + \xi} \tag{6}$$

The Kth user needs to decode all the other users' signals, and the SNR for the Kth user to decode its own signal can be expressed as:

$$\gamma_{RD,\, K} = \frac{a_K \bar{\gamma}\psi_{1,\,n} + \psi_{2,\,k}}{\bar{\gamma}\psi_{2,\,k} + \xi} \tag{7}$$

3. OUTAGE PROBABILITY ANALYSIS

The outage probability is a vital metric which occurs when the k-th user fails to decode its own signal or the i-th user signal $(1 \geq i \geq k)$, then the transmission fails. The outage probability for the k-th user can be expressed as [17]:

$$\begin{aligned} P_{out} &= \int_{o}^{\phi_k} f_{\psi_{2,k}}(x)dx + \int_{\phi_k}^{\infty} f_{\psi_{2,k}}(x)\, F_{\psi_{1,n}}\left(\frac{\phi_k \xi}{\mu\,(x-\phi_k)}\right)dx \\ &\triangleq \underbrace{F_{\psi_{2,k}}(\phi_k)}_{R_1} + \underbrace{\int_{\phi_k}^{\infty} f_{\psi_{2,k}}(x) F_{\psi_{1,n}}\left(\frac{\phi_k \xi}{\mu\,(x-\phi_k)}\right)dx}_{R_2} \end{aligned} \tag{8}$$

where

$$\begin{cases} \phi_k = \max\left[\theta_1, \theta_2, \ldots, \theta_k\right] \\ \theta_i = \dfrac{\bar{\gamma}_{thi}}{\bar{\gamma}\left(a_i - \bar{\gamma}_{thi}\displaystyle\sum_{j=i+1}^{K} a_j\right)}, \text{ for } a_i > \bar{\gamma}_{thi}\displaystyle\sum_{j=i+1}^{K} a_j \end{cases} \tag{9}$$

Since the S-to-R link follows Rayleigh distribution, the channel PDF can be expressed by following the same approach detailed in [18] as:

$$f_{\psi_{1,n}}(x) = n\begin{pmatrix} N \\ n \end{pmatrix}\sum_{q=0}^{n-1}\begin{pmatrix} n-1 \\ q \end{pmatrix}\frac{(-1)^q}{((N-n+q)\,(1-\rho)+1)\,\Omega_{SR,n}}\exp\left(-\frac{\Psi}{\Omega_{SR,n}}x\right) \tag{10}$$

where $\Psi = (N-n+q+1)/((N-n+q)(1-\rho)+1)$ and it CDF can be defined as:

$$F_{\psi_{1,n}}(x) = 1 - n\begin{pmatrix} N \\ n \end{pmatrix}\sum_{q=0}^{n-1}\begin{pmatrix} n-1 \\ q \end{pmatrix}\frac{(-1)^q}{((N-n+q)+1)}\exp\left(-\frac{\Psi}{\Omega_{SR,n}}x\right) \tag{11}$$

Similarly, since each user is considered to employ MRC for signal combining, the PDF of the unordered R-to-D_k channel is given as [19]:

$$f_{\overline{\psi_{2,\,k}}}(x) = \left(\frac{m}{\Omega_{RD,\,k}}\right)^{mN_D}\frac{x^{mN_D-1}}{\Gamma\,(mN_D)}\exp\left(-\frac{m}{\Omega_{RD,\,k}}x\right) \tag{12}$$

where m is the fading parameter for the R-to-D_k channel. In other words, its CDF can be expressed as:

$$F_{\overline{\psi_{2,\,k}}}(x) = 1 - \sum_{t=0}^{mN_D-1} \exp\left(-\frac{m}{\Omega_{RD,\,k}}x\right) \frac{\left(\frac{mx}{\Omega_{RD,\,k}}\right)^t}{t!} \tag{13}$$

Thus, through the order of statistics, the ordered R-to-D_k channel PDF can be defined as [20]:

$$f_{\psi_{2,\,k}}(x) = \frac{K!}{(K-k)!\,(k-1)!} \sum_{p=0}^{K-k} (-1)^p \binom{K-k}{p} f_{\overline{\psi_{2,\,k}}}(x) \left[F_{\overline{\psi_{2,\,k}}}(x)\right]^{k+p-1} \tag{14}$$

then, its CDF can be given as:

$$F_{\psi_{2,\,k}}(x) = \frac{K!}{(K-k)!\,(k-1)!} \sum_{p=0}^{K-k} \frac{(-1)^p}{k+p} \binom{K-k}{p} f_{h_{\overline{RD}}}(x) \left[F_{h_{\overline{RD}}}(x)\right]^{k+p} \tag{15}$$

Thus, R_2 in Eq. (8) can be expressed by putting Eqs. (11) and (14) into Eq. (8) as follows:

$$\begin{aligned} R_2 \;&=\; 1 - R_1 - \frac{\Delta_k n}{\Gamma(mN_D)} \left(\frac{m}{\Omega_{RD,\,k}}\right)^{mN_D} \binom{N}{n} \sum_{p=0}^{K-k}\sum_{q=0}^{n-1} \binom{n-1}{q} \binom{K-k}{p} \frac{(-1)^{p+q}}{((N-n+q)+1)} \\ &\times \int_{\phi_k}^{\infty} x^{mN_D-1} \exp\left(-\frac{mx}{\Omega_{RD,\,k}}\right) \exp\left(-\left(\frac{\Psi\phi_k\xi}{\Omega_{SR,\,n}\mu(x-\phi_k)}\right)\right) \underbrace{\left[F_{\overline{\psi_{2,\,k}}}(x)\right]^{k+p-1}}_{J_1} dx \end{aligned} \tag{16}$$

where $\Delta_k = K!/((K-k)!(k-1)!)$.

The term J_1 in Eq. (16) can be determined by using Eq. (13), and through binomial expansion, J_1 can be expressed as follows:

$$J_1 = \sum_{s=0}^{k+p-1} (-1)^s \binom{k+p-1}{s} \exp\left(-\frac{mx}{\Omega_{RD,\,k}}\right) \underbrace{\left[\sum_{t=0}^{mN_D-1} \frac{1}{t!}\left(\frac{mx}{\Omega_{RD,\,k}}\right)^t\right]^s}_{\lambda} \tag{17}$$

Thus, J_1 can be further expressed by applying binomial expansion to the term λ as:

$$J_1 = \sum_{s=0}^{k+p-1} \binom{k+p-1}{s} (-1)^s\, \Sigma_s \Lambda_s \Xi_s x^{\hat{s}} \exp\left(-\frac{msx}{\Omega_{RD,\,k}}\right) \tag{18}$$

where

$$\begin{cases} \Sigma_s = \displaystyle\sum_{s_1=0}^{s}\sum_{s_2=0}^{s-s_1}\dots\sum_{s_{mN_D-1}=0}^{s-s_1-\dots s_{mN_D-2}} \\ \Lambda_s = \dbinom{s}{s_1}\dbinom{s-s_1}{s_2}\dots\dbinom{s-s_1-\dots s_{mN_D-2}}{s_{mN_D-1}} \\ \Xi_s = \displaystyle\prod_{t=0}^{mN_D-1}\left(\frac{m^t}{t!\Omega_{RD,k}^t}\right)^{s_{t+1}} \left(\left(\frac{m}{\Omega_{RD,k}}\right)^{mN_D-1} \frac{1}{(mN_D-1)!}\right)^{s-s_1-\dots s_{mN_D-1}} \\ \hat{s} = (mN_D-1)(s-s_1) - (mN_D-2)\,s_2 - (mN_D-3)\,s_3 - \dots s_{mN_D-1} \end{cases} \tag{19}$$

By putting J_1 into Eq. (16), R_2 can be expressed as:

$$R_2 \;=\; 1 - R_1 - \frac{\Delta_k n}{\Gamma(mN_D)} \left(\frac{m}{\Omega_{RD,\,k}}\right)^{mN_D} \binom{N}{n} \sum_{p=0}^{K-k}\sum_{q=0}^{n-1}\sum_{s=0}^{k+p-1} \binom{n-1}{q}\binom{K-k}{p}\binom{k+p-1}{s}$$

$$\times \frac{\Sigma_s \Lambda_s \Xi_s (-1)^{p+q+s}}{((N-n+q)+1)}$$
$$\underbrace{\int_{\phi_k}^{\infty} x^{mN_D+\hat{s}-1} \exp\left(-\frac{mx}{\Omega_{RD,k}}\right) \exp\left(-\frac{msx}{\Omega_{RD,k}}\right) \exp\left(-\left(\frac{\Psi\phi_k\xi}{\Omega_{SR,n}\mu(x-\phi_k)}\right)\right) dx}_{J_2} \tag{20}$$

If $y = x - \phi_k$, then the J_2 term in (20) can be expressed as:

$$J_2 = \sum_{r=0}^{mN_D+\hat{s}-1} \binom{mN_D+\hat{s}-1}{r} \phi_k^{mN_D+\hat{s}-r-1} \exp\left(-\frac{m(s+1)\phi_k}{\Omega_{RD,k}}\right)$$
$$\times \int_0^{\infty} y^r \exp-\left(\frac{(s+1)}{\Omega_{RD,k}} y\right) \exp-\left(\frac{\Psi\phi_k\xi}{\mu\Omega_{SR,n} y}\right) dy \tag{21}$$

By applying the integral identity defined in [21, Eq. (3.471.9)], the J_2 can be solved as:

$$J_2 = \sum_{r=0}^{mN_D+\hat{s}-1} \binom{mN_D+\hat{s}-1}{r} \phi_k^{mN_D+\hat{s}-r-1} \exp\left(-\frac{m(s+1)\phi_k}{\Omega_{RD,k}}\right)$$
$$\times 2\left(\frac{\Psi\phi_k\xi\Omega_{RD,k}}{(s+1)\mu m\Omega_{SR,n}}\right)^{r+1/2} K_{r+1}\left(2\sqrt{\frac{m\Psi\phi_k\xi(s+1)}{\mu\Omega_{SR,n}\Omega_{RD,k}}}\right) \tag{22}$$

where $K_v(\cdot)$ is the vth order of modified Bessel function of second kind.

By substituting Eqs. (20) and (22) into Eq. (8), the outage probability for the under studied system can be expressed as:

$$P_{out} = 1 - \frac{2\Delta_k n}{\Gamma(mN_D)} \left(\frac{m}{\Omega_{RD,k}}\right)^{mN_D} \binom{N}{n} \sum_{p=0}^{K-k} \sum_{q=0}^{n-1} \sum_{s=0}^{k+p-1} \sum_{r=0}^{mN_D+\hat{s}-1} \binom{n-1}{q} \binom{K-k}{p} \binom{k+p-1}{s}$$
$$\times \binom{mN_D+\hat{s}-1}{r} \frac{\Sigma_s \Lambda_s \Xi_s (-1)^{p+q+s}}{((N-n+q)+1)} \phi_k^{mN_D+\hat{s}-r-1} \exp\left(-\frac{m(s+1)\phi_k}{\Omega_{RD,k}}\right)$$
$$\times \left(\frac{\Psi\phi_k\xi\Omega_{RD,k}}{(s+1)\mu m\Omega_{SR,n}}\right)^{r+1/2} K_{r+1}\left(2\sqrt{\frac{m\Psi\phi_k\xi(s+1)}{\mu\Omega_{SR,n}\Omega_{RD,k}}}\right) \tag{23}$$

4. NUMERICAL RESULTS AND DISCUSSIONS

In this section, the numerical results for the outage performance of NOMA PSR based system are presented. Three users $K = 3$ are assumed with respective power coefficients given as $a_1 = 1/2$, $a_2 = 1/3$, and $a_3 = 1/6$. In addition, the users' threshold values are respectively assumed to be $\gamma_{th,1} = 0.9$ dB, $\gamma_{th,2} = 1.5$ dB, and $\gamma_{th,3} = 2$ dB. The distance between the source and users is normalized such that $d_{SR,m} + d_{RD,n} = 1$ and is related to path exponent α. Thus, we obtain $\Omega_{SR,m} = d_{SR,m}^{-\alpha}$, $\Omega_{RD,n} = d_{RD,n}^{-\alpha}$, and $\alpha = 4$. Except otherwise stated, $m = 2$, $N_D = 2$, $\eta = 0.9$, $\varepsilon = 0.8$, and the number of multiply relays employed for the system is set to $N = 4$. Also, the system is subjected to two relay selection modes, i.e., best relay selection and worst relay selection.

The outage performance of the concerned system with different users of receiving antenna configurations is illustrated in Figure 2. It can be deduced that the analytical result perfectly agreeds with the simulation results which indicate the accuracy of our derived expression. The results depict that the outage performance of the users is significantly improved with the increase in the number of users of receiving antenna.

In Figure 3, the outage probability of the system as a function of source-to-relay distance $d_{SR,n}$ is demonstrated. The results indicate that as $d_{SR,n}$ increases, the system performance gets deteriorated, and less energy is harvested at the relay nodes for the information processing. However, when an optimum $d_{SR,n}$ is reached, the distance between the relays and destination becomes closer, and then the system performance becomes improved. This proves that better outage performance is achieved when the relay nodes are either close to the source or destination. It can also be deduced that as the power splitting ratio increases, the system outage performance becomes better.

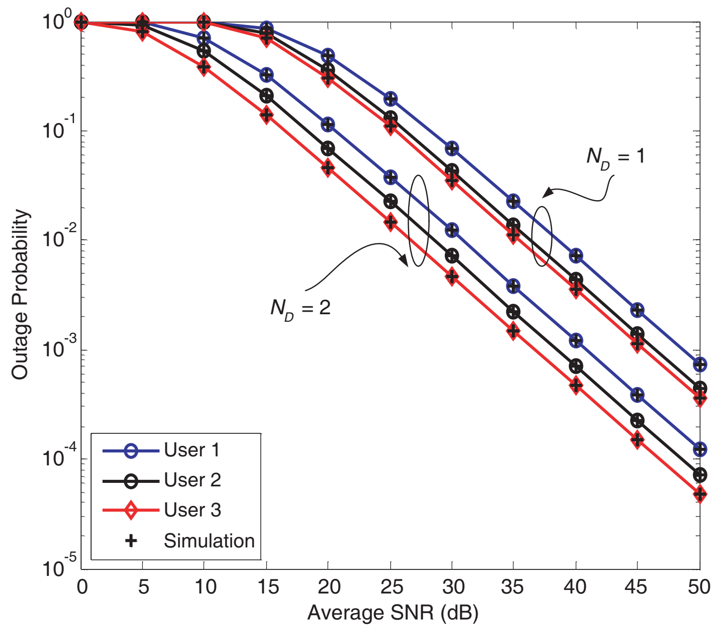

Figure 2. Outage probability performance as a function of average SNR under the effect of N_D for $N = n = 4$, $\rho = 0.2$, $\beta = 0.2$ and $d_{SR,n} = 7$.

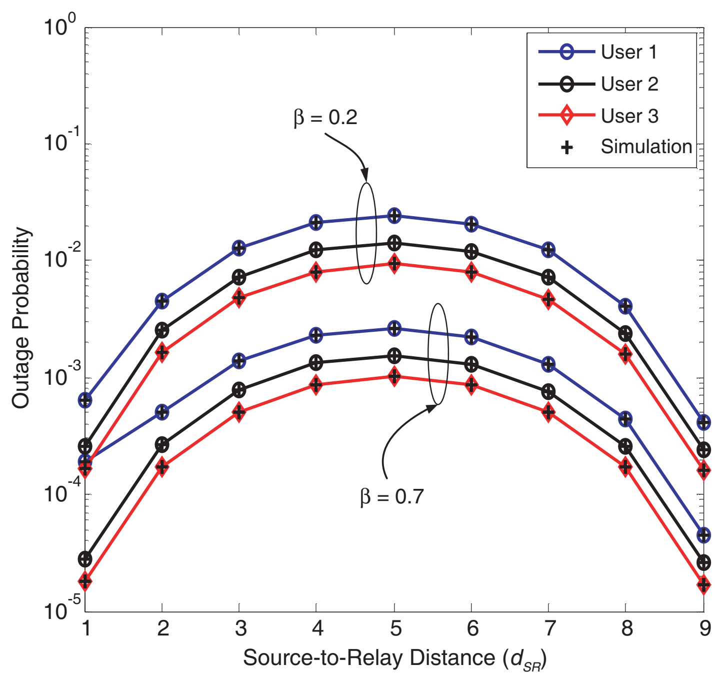

Figure 3. Outage probability vs source-to-relay distance under different values of β for $N = n = 4$, $\bar{\gamma} = 30\,\text{dB}$, $d_{RD,k} = 10 - d_{SR,n}$ and $\rho = 0.2$.

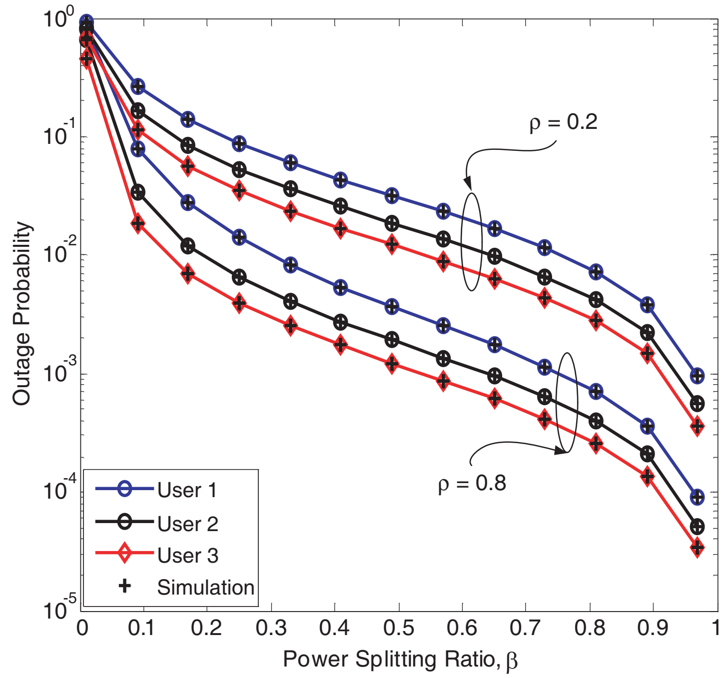

Figure 4. Outage probability as a function of power splitting ratio β under different values of coefficient correlation ρ for $N = n = 4$, $\bar{\gamma} = 30\,\text{dB}$, and $d_{SR,n} = 7$.

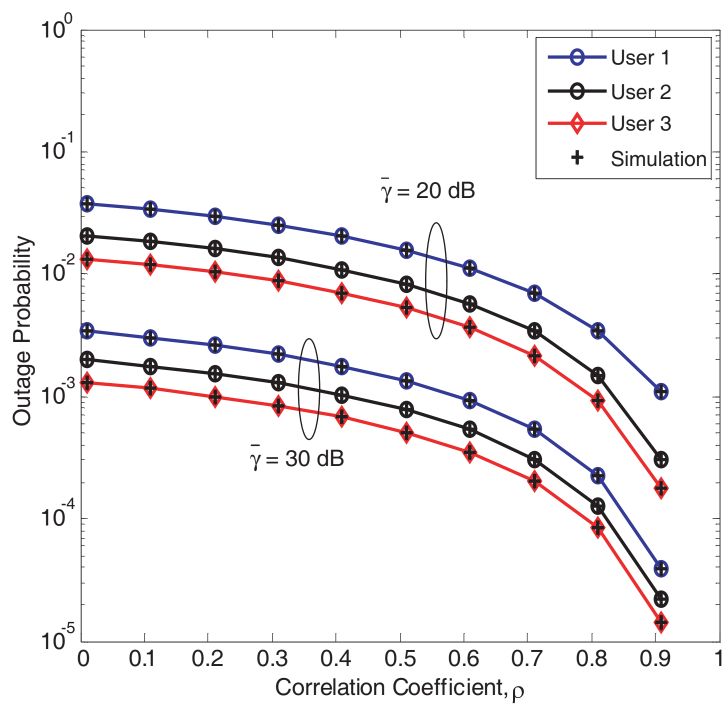

Figure 5. Outage probability vs coefficient correlation ρ under different values of average SNR $\bar{\gamma}$, for $N = n = 4$, and $d_{SR,n} = 7$.

Moreover, the outage probability as a function of power splitting ratio β is presented in Figure 4 under different values of coefficient correlation ρ. The results indicate that the increase in the channel coefficient correlation ρ significantly improves the system outage performance. In both cases, the increase in β offers users better performance. It can be observed that the analytical and simulated results are in excellent agreement which indicates the correctness of the derived outage expression.

The outage probability vs coefficient correlation ρ under different values of average SNR is depicted in Figure 5. It can be deuced from the results that the increase in channel coefficient correlation significantly improves the users' outage performance. It can also be observed that as the transmit power increases, the system outage performance becomes better since relay nodes harvest more energy to process the source information.

The performance comparison between NOMA and OMA systems under different relay selections is presented in Figure 6. It can be observed from the result that the outage probability performances of users 2 and 3 of NOMA system outperform the OMA system. However, the outage performance of user 1 of NOMA is worse than OMA, but NOMA can offer better spectral efficiency than OMA since users are served simultaneously. In both cases, the results show that the system under the best relay selection performs better than the worst relay selection scenario.

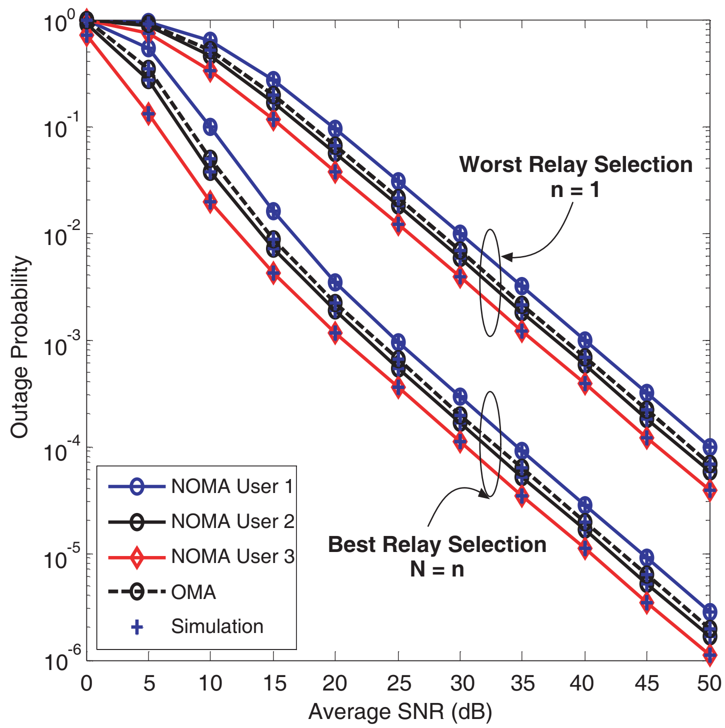

Figure 6. Performance comparison between NOMA and OMA systems under different relay selections for $\rho = 0.2$, $\beta = 0.2$ and $d_{SR,n} = 7$.

5. CONCLUSION

In this paper, the performance of a cooperative NOMA PSR based system over nonidentical channels with energy harvesting and outdated CSI is presented. The outage probability closed-form expression for the system is derived for system evaluation. The analytical results excellently agreed with the simulated ones which shows the correctness of the derived outage probability expression. The results illustrate effect of channel correlation coefficient, relay selection modes, and relay location on the concerned system performance. In addition, the results demonstrate that the performance of the NOMA system is better than the conventional OMA system.

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