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# Joint Fixed Power Allocation and Partial Relay Selection Schemes for Cooperative NOMA

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***Abstract***

*In the future wireless systems, non-orthogonal multiple-access (NOMA) with partial relay selection scheme is considered as developing research topic. In this paper, dual-hop relaying systems is deployed for NOMA, in which the signal is transfered with the assistance of decode-and-forward (DF) scheme. This paper presents exact expressions for outage probability over independent Rayleigh fading channels, and two partial relay selection schemes are provided. Using matching analytical result and Monte-Carlo method, we introduce forwarding strategy selection for fixed user allocation and exactness of derived formula is checked. The presented simulations confirm the the advantage of such considered NOMA, and the effectiveness of the proposed forwarding strategy.*

***Keywords:*** *non-orthogonal multiple-access (NOMA), decode-and-forward relaying, forwarding strategy selection.*



## 1. Introduction

In rececent years, non-orthogonal multiple-access (NOMA) with advantages of spectrum efficiency, improved cell-edge user throughput and low transmit latency is introduced. Such technique has recently expected great development for future wireless as a favorable system to achieve concerned advantages. In principle, both time and frequency resources, adjusting the power allocation ratio is deployed to share among NOMA users. In particular, the better users (i.e. comparison based on their channel conditions) eliminate the the weaker users's signals planned by decoding their own signals and performing successive interference cancelation (SIC). Increased data traffic in mobile internet can be reported in [1], many topics proved that non-orthogonal multiple-access (NOMA) have extensively cabability in wireless communication [2], [3]. In order to achieve higher spectral efficiency than conventional orthogonal frequency division multiple access (OFDMA), superimposed coding used at the transmitter and success interference cancellation (SIC) applied at the receiver to adapt to requirement in seprating different signals in NOMA. Many NOMA users at the same time access and the same frequency or time resource, so it can support more connections than orthogonal multiple-access (OMA) [4-6], for example these leading techniques can be deployed in location services [7]. Thus, the next generation of mobile communication networks could use NOMA to meet the explosion of the number of users [8-9]. For example, investigation in [10] provided massive connections for huge number of users. With the same bandwidth and time slot allocated, NOMA can simultaneously served for multiple users [11]. The basic conception of NOMA with SIC receivers was presented in [12]. The system performance including ergodic rate and power efficiency with fixed power allocations can be seen in recent works, such as [13]. The outage performance in relaying networks with better coverage can be combined with NOMA have been investigated in many works, such as [14-17].

In order to gain advantages of the space diversity and improving the spectral efficiency, the relay selection (RS) scheme is deployed to cooperative communication systems [18-21]. For example, the diversity of single RS scheme is studied in [18] derived and exhaustive search is investigated to decreasing the complexity of multiple RS scheme. The RS problem of AF cooperative system was presented under condition of obtainability of different instantaneous CSI

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as analysis in [19]. It is shown that error floor exists in the FD-based RS scheme and a zero diversity order is obtained. The outage probability performance of the cognitive radio networks related to relay selection scheme was considered [20].

To the best of our knowledge, few of the existing works have studied the partial relay selection (RS) for a NOMA, this paper presents two specific schemes related to partial relay selection [21-25]. In particular, in this paper we investigate a new scheme assuming joint power allocation for NOMA and partial relay selection. To evaluate system performance, the outage performance of partial relay selection applied in NOMA schemes with DF relay scheme is investigated. To look insight in considered schemes, the closed-form expressions for the outage probabilities (OPs) are derived, and it is shown that, for a proper minimum desired target rate, the OP can decrease significantly with appropriate select of the power allocation assigned to users. Finally, Matlab simulation results are offered to corroborate the correctness of the attained analytical results.

## 2. System Model and Relay Selection Scheme

### 2.1. System model

As illustration in Figure 1, we determine a downlink cooperative NOMA network with one base station (BS), *K* relays, and only selected relay serve for two NOMA users. It is noted that the relay operates in half-duplex mode and decode-and-forward (DF) protocol is applied. We denote *P* as the transmit power for both the BS and relays. In this scenario, a single antenna is equipped in each node. Meeting deep fading, it can not existence of direct link between the BS and the NOMA users and helping relay with relay selection is required for such transmission. We denote $h_{SRi}$ and $h_{RiD1}, h_{RiD2}$ as the frequency flat channel coefficients from the BS to $i-th$ relay and from $i-th$ relay to user D1, D2 respectively, $i \in (1, 2, \ldots, K)$.

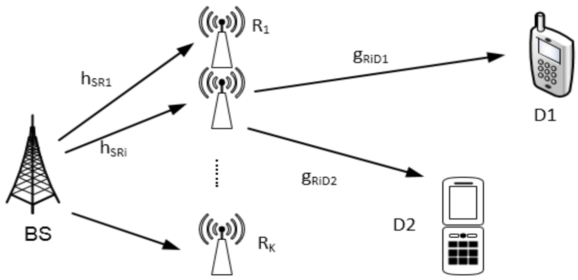


Figure 1. System model of partial relay selection NOMA

As many previous works, such channel quantities satisfy unchanged during one fading block but independently vary from one fading block to another independent or they also called as slowly Rayleigh fading. These channel gains' averages are assumed as:

$$\mathrm{E}\left[\left|h_{SRi}\right|^2\right] = \frac{1}{\lambda_0},\ \mathrm{E}\left[\left|g_{RiD1}\right|^2\right] = \frac{1}{\lambda_1}, \mathrm{E}\left[\left|g_{RiD2}\right|^2\right] = \frac{1}{\lambda_2}. \quad (1)$$

It is worth noting that we have assumed in (1) that the *K* relays are clustered relatively closely together such that they have equivalent distances to the same node, and hence the channel gains between a certain node and the relays are independent identically distributed (i.i.d.), as commonly assumed in the past work. However, the proposed RS schemes do not depend on this assumption, and it is used to simplify the analysis only. Moreover, each relay is assumed to know channel state information (CSI) of $h_{SRi}$ and $h_{RiD1}, h_{RiD2}$, whereas no CSI is known by the BS. The BS will send a message to each user within each fading block, and each fading block is divided into two time slots. During the first time slot, the BS transmits a codeword

$s_0, \mathrm{E}\left\{|s_0|^2\right\} = 1$ carrying a mixed message which is formed by the two users' messages for D1, D2. It is required that $R_0 = R_1 + R_2$ holds, where $R_1, R_2$ are the rate of the message for D1, D2, respectively. Therefore, the received signal can be obtained at relay $i-th$ as:

$$y_{Ri} = \sqrt{P} h_{SRi} s_0 + n_{Ri}, \ i \in [1:K], \tag{2}$$

and the received signal at destination D1, D2 from the $i-th$ relay node can be expressed as:

$$y_{i,D1} = \sqrt{P} h_{RiD1} s_i + n_{D_1}, \ y_{i,D2} = \sqrt{P} h_{RiD2} s_i + n_{D_2}, \tag{3}$$

where $n_{Ri}, n_{D1}, n_{D2}$ are the Gaussian noise with same variance $N_0$.

Without loss of generality, it is assumed that relay $i-th$ is nominated for message transmission. During the second time slot using power-domain NOMA, and the corresponding user order is deployed for detecting signal. Specifically, relay $i-th$ sends a superposition codeword $\left(\sqrt{\alpha} s_1 + \sqrt{\beta} s_2\right)$ to the two users, where power allocation coefficients satisfy $\alpha + \beta = 1$. Therefore, the signal to noise ratio (SNR) to detecting D1's signal can be calculated by:

$$\gamma_{i,1} = \frac{P\alpha |h_{SRi}|^2}{N_0 + P\beta |h_{SRi}|^2} = \frac{\rho\alpha |h_{SRi}|^2}{1 + \rho\beta |h_{SRi}|^2}, \tag{4}$$

where $\rho = P / N_0$ represents the transmit SNR.

In priciple of NOMA, the user D1 first attempts to decode $s_2$ by considering its own signal as noise, and the consistent SNR is represented by $\gamma_{i,21}$ then it revokes user D1's signal from its observation, and the receive SNR for decoding D2's signal is denoted by $\gamma_{i,22}$, where:

$$\gamma_{i,21} = \frac{\rho\alpha_i |h_{RiD2}|^2}{1 + \rho\beta_i |h_{RiD2}|^2}, \ \gamma_{i,22} = \rho\beta_i |h_{RiD2}|^2. \tag{5}$$

In this paper, fixed power allocation will be considered as it is simply processed without require instantaneous CSI, reducing overhead usage in signal frame transfer.

Regarding on Relay Selection Schemes, the subset of the relays is confirmed in the first stage by concentrating on correctly decoding the mixed message $s_0$:

$$\Delta S = \left\{ i : i \in [1:K], \frac{1}{2} \log\left(1 + |h_{SRi}|^2 \rho\right) \geq R_1 + R_2 \right\}. \tag{6}$$

Next, the best relay from *K* relays can be found in the second stage to transmit messages to the users D1 and D2. Two partial RS schemes will be considered according to the channel condition compared with target rates.

In such scenario, fixed power allocation is assumed at each relay, power allocation coefficients retain unchanged within each fading block; it means that $\alpha_1, \alpha_2$ allocated for fisrt signal and second signal in NOMA for every relay, $\forall i \in [1:K]$. some parameters need be defined as:

$$\eta_i = 2^{2R_i} - 1, \ i = 1, 2; \tag{7}$$

$$M_1(x) = \frac{x}{[\rho\alpha_1 - x\rho\alpha_2]^+}, \quad M_2(x, y) = \max\left(M_1(x), \frac{y}{\rho\alpha_2}\right), \tag{8}$$

$$X_k(u,v)=\min\left\{\frac{|h_u|^2}{M_1(\eta_1)},\frac{|h_v|^2}{M_2(\eta_1,\eta_2)}\right\},\ \ u,v\in\{1,2\}. \tag{9}$$

It is noted that $[x]^+=\max\{0,x\}$, as requirement of NOMA, the channel necessities for relay $i-th$ to correctly communicate with both users' signals are specified by:

$$|h_{RiD1}|^2\geq M_1(\eta_1),\ \ |h_{RiD2}|^2\geq M_2(\eta_1,\eta_2). \tag{10}$$

In the second stage, the optimal partial RS scheme can be expressed as:

$$i^*=\operatorname{argmax}_{i\in\Delta S}\min\left\{\frac{|h_u|^2}{M_1(\eta_1)},\frac{|h_v|^2}{M_2(\eta_1,\eta_2)}\right\}. \tag{11}$$

### 2.2. Outage performance analysis

In general, to adapt to the users' quality-of-service (QoS) requirements, outage performance of the two users are determined with respect ot the target SNRs. In particular, each user has its own preset target SNR. Based on the NOMA scheme, an outage event occurs in considered transmission links in the proposed model.

#### 2.2.1 Partial relay selection scheme I

With condition $|h_{RiD2}|^2/|h_{RiD1}|^2\notin(\varphi_1,\varphi_2)$, the outage probability of partial relay selection scheme I can be expressed as [21].

$$\mathrm{P}(O_1)=\underbrace{\Pr\left\{\frac{|h_{RiD1}|^2}{A_1}<1,\ \frac{|h_{RiD2}|^2}{|h_{RiD1}|^2}>\varphi_1\right\}}_{Q_1}+\underbrace{\Pr\left\{\frac{|h_{RiD2}|^2}{\psi}<1,\ \frac{|h_{RiD2}|^2}{|h_{RiD1}|^2}<\varphi_2\right\}}_{Q_2}. \tag{12}$$

Furthermore, based on the probability density function of channel, it can be shown:

$$Q_1=\frac{\lambda_1\left(1-e^{-\lambda_1A_1-\lambda_2\varphi_1A_1}\right)}{\lambda_1+\lambda_2\varphi_1},\ \ Q_2=\frac{\lambda_2\left(1-e^{-\lambda_2\psi-\lambda_1\psi/\varphi_2}\right)}{\lambda_2+\lambda_1/\varphi_2}, \tag{13}$$

in which $A_1=M_1(\eta_1),\ A_2=M_2(\eta_1,\eta_2),\ B_1=M_1(\eta_2),\ B_2=M_2(\eta_2,\eta_1),\ \varphi_1=A_2/A_1$, $\varphi_2=B_1/B_2$, $\psi=\min\{A_2,B_1\}$.

Combining (14) and (15), the outage probability of partial relay selection scheme I can be expressed as:

$$\mathrm{P}(O_1)=\frac{\lambda_1\left(1-e^{-(\lambda_1+\lambda_2\varphi_1)A_1}\right)}{\lambda_1+\lambda_2\varphi_1}+\frac{\lambda_2\left(1-e^{-(\lambda_2+\lambda_1/\varphi_2)\psi}\right)}{\lambda_2+\lambda_1/\varphi_2}. \tag{14}$$

#### 2.2.2 Partial relay selection scheme II

Similarly, the outage probability of partial relay selection scheme II can be expressed as [21],

$$\mathrm{P}(O_2)=\Pr\left\{\varphi_2\leq\frac{|h_{RiD2}|^2}{|h_{RiD1}|^2}\leq\varphi_1,\frac{|h_{RiD2}|^2}{A_2}<1,\ \frac{|h_{RiD1}|^2}{B_2}<1,\right\}. \tag{15}$$

Similarly, $\mathrm{P}\left(O_2^n\right)$ can be attained as:

$$\mathrm{P}\left(O_2\right)=\frac{\lambda_1\left(1-e^{-(\lambda_2+\lambda_1/\varphi_2)\psi}\right)}{\lambda_1+\lambda_2\varphi_2}-e^{-(\lambda_1 A_1+\lambda_2 A_2)}+e^{-(\lambda_1\psi/\varphi_2+\lambda_2 A_2)}-\frac{\lambda_1\left(1-e^{-(\lambda_1+\lambda_2\varphi_1)A_1}\right)}{\lambda_1+\lambda_2\varphi_1}. \quad (16)$$

### 2.2.3 Outage performance

The overall OPs for the two partial RS schemes can be summarized in the following theorem.

***Theorem 1****:* The overall outage probability for the two partial RS schemes, denoted by $\mathrm{P}_{COP,1}^n$ and $\mathrm{P}_{COP,2}^n$, respectively, can be expressed as:

$$\mathrm{P}_{COP,j}^n=\sum_{n=0}^{K}C_K^n e^{-n\lambda_0\varepsilon}\left(1-e^{-\lambda_0\varepsilon}\right)^{K-n}\left(\mathrm{P}\left(O_j\right)\right)^n,\ \ j\in\{1,2\}, \quad (17)$$

in wich $\varepsilon=\dfrac{2^{2(R_1+R_2)}-1}{\rho}$; $C_K^n=\dfrac{K!}{n!(K-n)!}$.

Note that ther overall COPs for the two partial RS schemes can be expressed as follows:

$$\mathrm{P}_{COP,j}^n=\sum_{n=0}^{K}\Pr\left(\Delta S=n\right)\left(\mathrm{P}\left(O_j\right)\right)^n,\ \ j\in\{1,2\},n\in[0:K]. \quad (18)$$

## 3. Simulation Results

In this section, by using Matlab simulations, we evaluate the outage performance of cooperative NOMA with several RS schemes. The two considerd RS are illustrated and compared to show system performance. Specifically, the averages of the channel gains in (1) are modeled as $1/\lambda_j=1/l_j^{\mu}, j=0,1,2$ where $l_0$ represents the distance between the BS and the relays, $l_1,l_2$ denotes the distance between the relays and user D1, D2, and $\mu=2.7$ denotes the path loss exponent. Moreover, the PA factors for any scheme with fixed PA are set as $\alpha=0.8,\beta=0.2$.

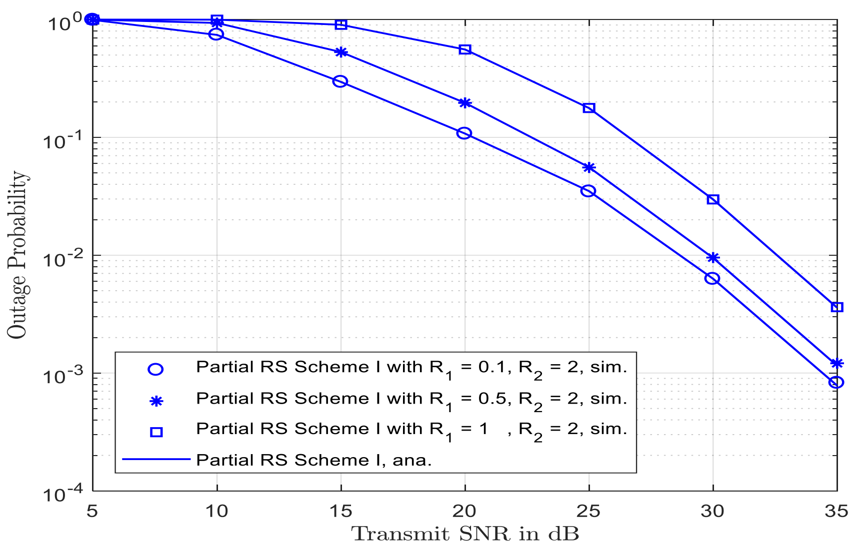


Figure 2. Outage performance of RS in scheme I vesus transmit SNR

The curves of outage probabilities versus transmit SNR is presented in Figure 2 for Scheme I and in Figure 3 for Scheme II, the analytical results can match the simulations very well. Obviously, compared with the target rate with different values it can be obtaind different outage performance. When the transmit SNR comes to higher value case, the outage peformance will be enhanced. It coincides with the analysis in previous section and leads to choose a target rate which can yield lower outage probability. In this figure, lower target rate for signal of D1, outage performance is the best case among considered scenarios. It is confirmed that the achievable data rate for each user in NOMA becomes the bottleneck of the outage performance.

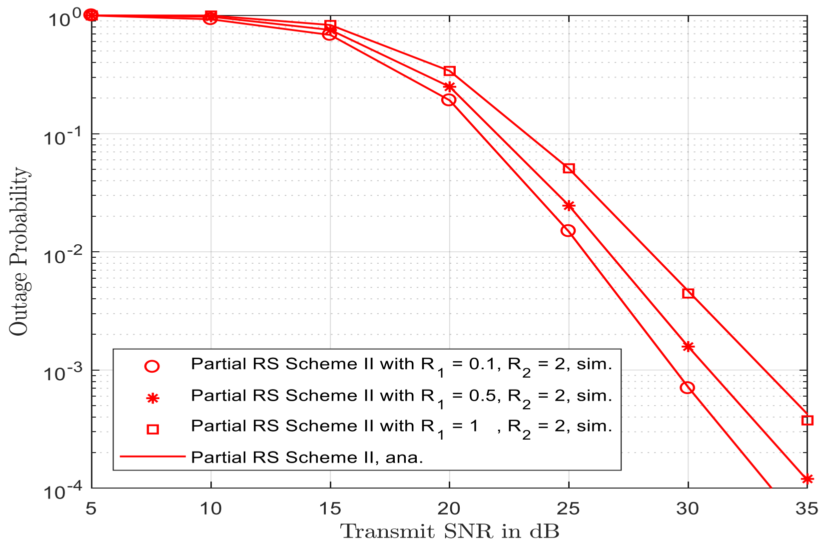


Figure 3. Outage performance of RS in scheme II vesus transmit SNR

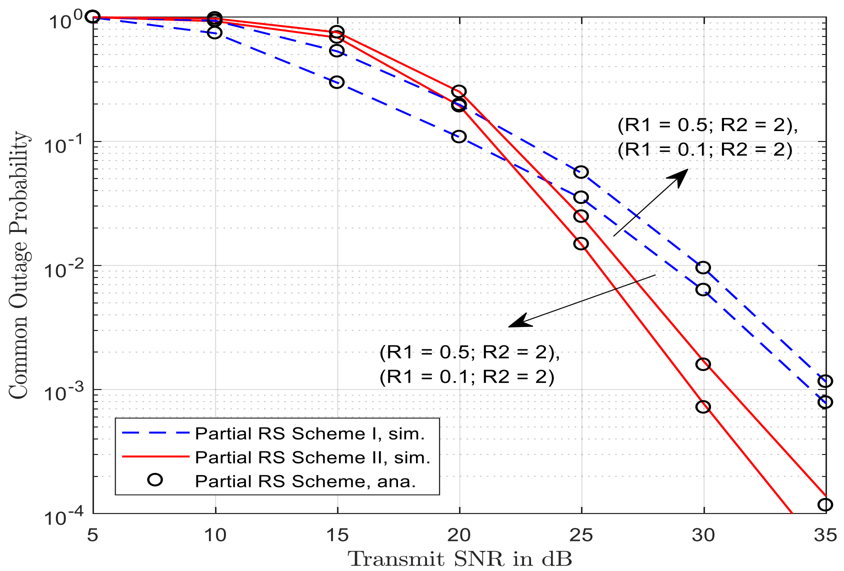


Figure 4. Outage performance comparison study of RS in scheme I and scheme II

As can be further observation as Figure 4, the effect of the selection relay scheme on outage probability can be seen, in which the system parameters are set as $R_1 = (0.1; 0.5)$ and $R_2 = 2$. Note that all the configurations fall in the first case of *Theorem 1*, and the outage probability decreases at high transmit SNR. The reason is that, in this case, more power for signal processing and outage will become enhanced. The RS in scheme II better than Scheme I as the transmit SNR greater than about 22 dB. This result is guidline for design of NOMA where RS is selected for optimal performance.

Next, the influence of relay numbers *K* on the outage probability of the considered system with two RS schemes is shown as Figure 5 and 6, respectively. As observation in these two figures, it can be seen that the outage performance can be improved by increasing the number of relay of two RS schemes. In addition, compared to the three cases regarding on the number of relay in considered schemes, the performance gap achieves a similar performance among these schemes.

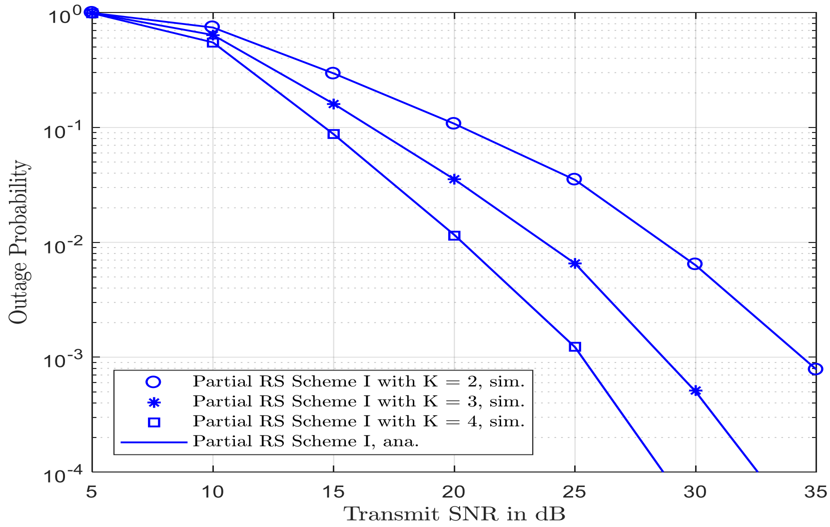


Figure 5. Outage performance RS in scheme I as varying the number of relay

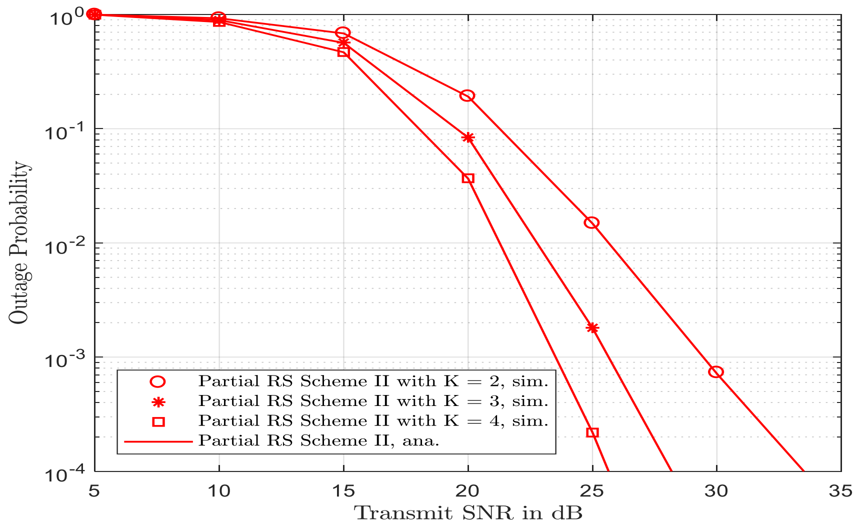


Figure 6. Outage performance RS in scheme II as varying the number of relay

## 4. Conclusion

In this paper, an optimal selection algorithm was proposed to improve the outage probability of cooperative NOMA networks with joint power allocation and partial relay selection. The system performance was analyzed by deriving the closed-form analytical expressions. From the outage probability, we found that the number of relays and the target data rate which exhibit crucial effects on the outage performance. Such relay selection of NOMA users is helpful to expand the transmission quality, it beneficial for the outage probability.

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## References

[1] J Thompson, X Ge, H-C Wu, R Irmer, H Jiang, G Fettweis, S Alamouti. 5G wireless communication systems: Prospects and challenges. *IEEE Commun. Mag.*, 2014; 52(2): 62-64.
[2] L Dai, B Wang, Y Yuan, S Han, C I I, Z Wang. Non-orthogonal multiple access for 5G: Solutions, challenges, opportunities, and future research trends. *IEEE Commun. Mag.*, 2015; 53(9): 74-81.
[3] Z Ding, X Lei, G K Karagiannidis, R Schober, J Yuan, V K Bhargava. A survey on non-orthogonal multiple access for 5G networks: Research challenges and future trends. *IEEE J. Sel. Areas Commun.* 2017; 35(10): 2181-2195
[4] XX Nguyen, DT Do. *Optimal power allocation and throughput performance of full-duplex DF relaying networks with wireless power transfer-aware channel*. EURASIP Journal on Wireless Communications and Networking. 2017: 152.
[5] KT Nguyen, Dinh Thuan Do, XX Nguyen, NT Nguyen, DH Ha. *Wireless information and power transfer for full duplex relaying networks: performance analysis*. Proc. of Recent Advances in Electrical Engineering and Related Sciences (AETA 2015), HCMC, Vietnam. 2015: 53-62.
[6] B Wang, L Dai, Y Zhang, T Mir, J Li. Dynamic compressive sensing-based multi-user detection for uplink grant-free NOMA. IEEE Commun. Lett., 2016;.20(11): 2320-2323.
[7] NT Thuong, HT Phong, Dinh Thuan Do, PV Hieu, DT Loc*. Android application for WiFi based indoor position: System design and performance analysis.* Proc. of 2016 International Conference on Information Networking (ICOIN). 2016; 1(1): 1-4.
[8] Y Saito, Y Kishiyama, A Benjebbour, T Nakamura, A Li, K Higuchi. *Non-orthogonal multiple access (NOMA) for cellular future radio access*. Proc. IEEE Veh. Technol. Conf. Dresden, German. 2013.
[9] Z Ding, Y Liu, J Choi, Q Sun, M Elkashlan, H V Poor. Application of non-orthogonal multiple access in LTE and 5G networks. *IEEE Commun. Mag.*, 2017; 55(2): 185-191.
[10] Nguyen Duc Anh, Dinh-Thuan Do. The Maximal SINR Selection Mode for 5G Millimeter-Wave MIMO: Model Systems and Analysis. *Indonesian Journal of Electrical Engineering and Computer Science*. 2017. 7(1): 150-157.
[11] SMR Islam, N Avazov, OA Dobre, KS Kwak. *Powerdomain non-orthogonal multiple access (NOMA) in 5G systems: Potentials and challenges*. IEEE Commun. Surveys Tutorials. 2016; 19(2): 721–742.
[12] Y Saito, A Benjebbour, Y Kishiyama, T Nakamura. *System level performance evaluation of downlink non-orthogonal multiple access (NOMA)*. Proc. IEEE Annu. Symp. Pers. Indoor Mobile Radio Commun. (PIMRC), London, U.K., 2013: 611–615.
[13] Z Ding, Z Yang, P Fan, H V Poor. On the performance of non-orthogonal multiple access in 5G systems with randomly deployed users. *IEEE Signal Process. Lett.*, 2014; 21(12): 1501-1505.
[14] HS Nguyen, AH Bui, Dinh huan Do, M Voznak. *Imperfect Channel State Information of AF and DF Energy Harvesting Cooperative Networks.* China Communications. 2016; 13(10): 11-19.
[15] Dinh Thuan Do, HS Nguyen. *A Tractable Approach to Analyze the Energy-Aware Two-way Relaying Networks in Presence of Co-channel Interference*. EURASIP Journal on Wireless Communications and Networking. 2016.
[16] Tan N. Nguyen, Dinh-Thuan Do, PT Tran, M Voznak. *Time Switching for Wireless Communications with Full-Duplex Relaying in Imperfect CSI Condition.* KSII Transactions on Internet and Information Systems. 2016. 10(9): 4223-4239.
[17] TL Nguyen, Dinh Thuan Do. *A new look at AF two-way relaying networks: energy harvesting architecture and impact of co-channel interference*. Annals of Telecommunications. 2017. 72(11): 669-678.
[18] Dinh-Thuan Do. *Optimal Energy Harvesting Scheme for Power Beacon-Assisted Wireless-Powered Networks*. Indonesian Journal of Electrical Engineering and Computer Science. 2017. 7 (3): 802-808.
[19] I Krikidis, H A Suraweera, P J Smith, C Yuen. Full-duplex relay selection for amplify-and-forward cooperative networks. IEEE Trans. Wireless Commun., 2012; 11(12): 4381-4393.

[20] B Zhong, Z Zhang, X Chai, Z Pan, K Long, H Cao. Performance analysis for opportunistic full-duplex relay selection in underlay cognitive networks. *IEEE Trans. Veh. Technol.*, 64(10): 4905-4910.
[21] P Xu, Z Yang, Z Ding, Z Zhang. *Optimal relay selection schemes for cooperatie NOMA*. Trans on Vehicular Tech. 2018; 67(8): 7851-7855.
[22] S Lee, DB da Costa, QT Vien, TQ Duong, RT de Sousa. *Non-orthogonal multiple access schemes with partial relay selection*. IET Communications. 2017. 11(6): 846-854.
[23] D Wan, M Wen, F Ji, Y Liu, Y Huang. Cooperative NOMA Systems with Partial Channel State Information Over Nakagami- $m$ Fading Channels. in IEEE Transactions on Communications, 2018; 66(3): 947-958.
[24] S Lee, D Benevides da Costa, TQ Duong. Outage probability of non-orthogonal multiple *access schemes with partial relay selection*. 2016 IEEE 27th Annual International Symposium on Personal, Indoor, and Mobile Radio Communications (PIMRC), Valencia, 2016: 1-6.
[25] TM Hoang, NT Tan, NH Hoang. *Performance analysis of decode-and-forward partial relay selection in NOMA systems with RF energy harvesting*. Springer Wireless Networks. 2018.