TELKOMNIKA Telecommunication, Computing, Electronics and Control
Vol. 18, No. 3, June 2020, pp. 1137~1144
ISSN: 1693-6930, accredited First Grade by Kemenristekdikti, Decree No: 21/E/KPT/2018
DOI: 10.12928/TELKOMNIKA.v18i3.12826

Tractable computation in outage performance analysis of relay selection NOMA

Minh-Sang Van Nguyen, Dinh-Thuan Do
Industrial University of Ho Chi Minh City (IUH), Vietnam

Article Info

Article history:

Received Apr 3, 2019
Revised Jan 13, 2020
Accepted Feb 14, 2020

Keywords:

NOMA
Outage probability
Relay selection

ABSTRACT

In recent years, using full-duplex (FD) transmission model provides enhanced bandwidth efficiency and improved performance for non-orthogonal multiple access (NOMA) system. However, lack of papers have investigated FD relay together with relay selection issue to improve performance of NOMA system. The problems in power allocation for two NOMA users satisfying fairness as well as relay selection strategy are studied in this paper. By considering the outage performance of proposed scheme with its vital result, general NOMA wireless networks can be developed for future networks due to its improved performance. Simulation results show that the relaying selection scheme can achieve a significant performance improvement by increasing required quantity of relay.

Corresponding Author:

Dinh-Thuan Do,
Industrial University of Ho Chi Minh City (IUH),
Ho Chi Minh City, Vietnam.
Email: dodinhthuan@iuh.edu.vn

1. INTRODUCTION

In recent years, non-orthogonal multiple access (NOMA) has attracted a lot of research works due to increasing number of connections. Furthermore, it is considered as one of the modern technologies applied in 5th generation (5G) mobile networks in order to considerably enhance the system spectral efficiency for 5G communication networks [1-4]. In NOMA, multiple users have their signals which are incorporated into mixed signal in power domain. As a result, these users in NOMA are served in the same domain such as time, frequency or code domain. To overcome bad channel condition, NOMA procedure mainly allocates greater transmit power dedicated for users suffering from weak channel conditions. In this scenario, by treating others' signal as noise, these weak users can detect and decode its symbols precisely due to greater power level distributed for far user. On the other hand, based on the successive interference cancellation (SIC) technique, users which have strong channel conditions are capable to detect its own signal. In addition, as compared to the OMA system, there is a significant improvement in NOMA throughput performance [2, 5]. Recently, cooperative networks are introduced as in [6, 7], the author focused on system evaluation related to processing signal at relay and outage probability is guaranteed. Fortunately, such cooperative schemes can be combined with NOMA to reform cooperative NOMA. In particular, it need be investigated performance and it can be enhanced by employing NOMA scheme into system model. In principle, by utilizing SIC, the received message is decoded at the receiver while the transmitter treating interference signal and such NOMA is proposed in NOMA technique as in [8]. Outage probability is main metric to consider in cooperative NOMA network where the message transmission is assisted over an amplify-and-forward (AF) relay from the source node [9]. Moreover, in [10], to increase the system performance NOMA scenario is applied and the mathematical formula in closed form of probability has also been found. In [11], performance of randomly-deployed subscribers of a downlink network are performed in terms of system outage probability and the achievable rate.

To improve the outage performance of all devices in the relay selection (RS) system, the authors in [12] have proposed a two stage RS in cooperative NOMA model. Furthermore, it is similar to [12] that in order to improve system performance, a full-duplex scheme is required to employ in NOMA as considered model by the authors in [13]. Motivated by results in [14-25], this paper targets the concentration on cooperative NOMA integrated with relay selection model and full-duplex scheme employed at relay nodes by inspired by these techniques. In particular, outage and throughput performance are investigated. As main contribution of this paper, we derive the closed-form expression in term of outage event to evaluate system performance.

2. SYSTEM MODEL

We consider a downlink system model is shown as Figure 1, where a base station (BS) would like to send a message to the N near user (NU) so-called as relay (R) to broadcast BS's data signal to a pair of far users (FU) that set as device 1 (D1) and device 2 (D2). More specifically, Figure 1 illustrates the full-duplex relay in two hop NOMA, which contains one base station (BS), two near NOMA user (strong user) that is capable of the full-duplex transmission, and far NOMA users (weak user). In this model, we denote D_n, $n=$ which exhibit performance gap. The BS is a single antenna transmission source while the NUs are designed with two separated antennas for full-duplex transmission. As a result, self-interference (SI) due to two antennas scheme still exists. We assume that there does not exist a direct link from the BS to FU, h_n and $g_{n,i}$ $(i=\;)$ are denoted the Rayleigh fading channel coefficients of the link BS-NU and NU-FU, respectively. The random variables $|h_n|^2$ and $|g_{n,i}|^2$ are follow the exponential distribution with parameters λ_{hn} and λ $(i=\;)$, respectively. Following principle of normal NOMA, users are distributed in order based on the channel conditions. As show in Figure 1, we assumed that D1 and D2 are used for different data transmission, in which D1 is used for low speed applications, and vice versa for D2 which served high speed data rate.

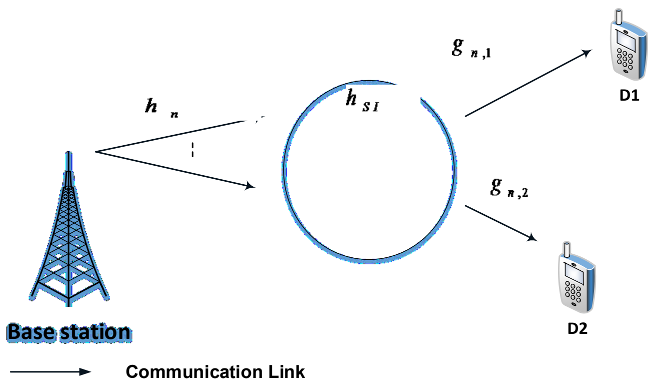

Figure 1. System model of relay selection NOMA with full-duplex transmission

The transmission between the BS-NU and NU-FU are divided into two phases. In the early phase, the BS sends the superposition signal, $a_1x_1 + a_2x_2$ with power allocation factors satisfying $a_1^2 + a_2^2 = 1$, where x_1 and x_2 denotes the message for BS sent to intermediate devices and then these signal intend to transmit to D1 and D2, a_i^2 denotes the power allocation factor for message x_i. In this FD scheme, x_{SI} denotes self-interference signal. In such case, the residual loop self-interference (SI) is set as a Rayleigh fading feedback channel with the coefficient h_{SI}, and random variables $|h_{SI}|^2$ is also follows the exponential distribution with mean value λ_{hsi}. Because of it must be satisfied quality-of-service (QoS) requirements, it is assumed that $a_1 > a_2$.

Therefore, the received signal at the NU user, i.e., *n-th* relay, $1 \le n \le N$ can be given as:

$$y_n^r = \sqrt{P_S} h_n (a_1 x_1 + a_2 x_2) + \sqrt{\varpi P_R} h_{SI} x_{SI} + n_R, \tag{1}$$

where P_S denote the transmission power at the source, n_R stands for the additive Gaussian noise (AWGN) at *n-th* NU user with zero mean and variance N_0.

It need be computed SNR at the relay to detect signal of x_1:

$$\gamma_{SR1,n} = \frac{P_S a_1^2 |h_n|^2}{P_S a_2^2 |h_n|^2 + \varpi P_R |h_{SI}|^2 + N_0}. \tag{2}$$

Then, SNR is computed to decode signal x_2 after requiring SIC procedure:

$$\gamma_{SR2,n} = \frac{P_S a_2^2 |h_n|^2}{\varpi P_R |h_{SI}|^2 + N_0}. \tag{3}$$

We call P_U as transmit power at the selected relay, n_{Di} denotes the AWGN at Di, i.e., $n_{Di} \sim CN(0, N_0)$. In this case, the received signal at far user D1, D2 are given as following equation:

$$y_{n,i}^d = \sqrt{P_U} g_{n,i} (a_1 x_1 + a_2 x_2) + n_{Di} \quad , i \in \{1,2\}. \tag{4}$$

We then compute SNR at user D1 to attain signal x_1:

$$\gamma_{RU1,n} = \frac{P_U a_1^2 |g_{n,1}|^2}{P_U a_2^2 |g_{n,1}|^2 + N_0}. \tag{5}$$

We then consider SNR at user D2 to eliminate interference signal x_1 and it can be computed by:

$$\gamma_{RU12,n} = \frac{P_U a_1^2 |g_{n,2}|^2}{P_U a_2^2 |g_{n,2}|^2 + N_0}. \tag{6}$$

Similarly, at relay, SIC is performed at user D2 to decode its own signal x_2:

$$\gamma_{RU2,n} = \frac{P_U a_2^2 |g_{n,2}|^2}{N_0}. \tag{7}$$

Then, we consider on criteria to relay selected to signal forwarding to far users. In particular, the index of best relay n^1* is selected to provide a maximum end-to-end SNR among the BS-NU-D1 links as:

$$n^1* = \underset{n=1,2,\cdots}{\arg\max} \left\{ \min\left(\gamma_{SR1,n}, \gamma_{RU1,n} \right) \right\}. \tag{8}$$

Similarly, the index of best relay n^2* is selected to provide a a maximum end-to-end SNR among the S-NU-D2 links as:

$$n^2* = \underset{n=1,2,\cdots}{\operatorname{argmax}} \left\{ \min\left(\gamma_{SR2,n}, \gamma_{RU12,n}, \gamma_{RU2,n} \right) \right\}. \quad (9)$$

3. SYSTEM PERFORMANCE ANALYSIS

3.1. Performance of user D1

In the scenario of FD mode, we provide following results:

Proposition 1: The closed-form expression of outage probability at user D1

$$\begin{aligned} OP_1^{FD} &= \min_{n=1,\ldots} \left(\Pr\left(\gamma_{SR1,n} < \lambda_1^{FD} \cup \gamma_{RU1,n} < \lambda_1^{FD} \right) \right) \\ &= \prod_{n=1}^{N} \left(1 - \underbrace{\Pr\left(\gamma_{SR1,n} \geq \lambda_1^{FD}, \gamma_{RU1,n} \geq \lambda_1^{FD} \right)}_{A} \right) \end{aligned} \quad (10)$$

Proof:

In which, it can be computed components as:

$$\begin{aligned} A &= \Pr\left(\gamma_{SR1,n} \geq \lambda_1^{FD}, \gamma_{RU1,n} \geq \lambda_1^{FD} \right) \\ &= \Pr\left(P_S a_1^2 \left| h_n \right|^2 \geq \lambda_1^{FD} \left(P_S a_2^2 \left| h_n \right|^2 + \varpi P_R \left| h_{SI} \right|^2 + N_0 \right), P_U a_1^2 \left| g_{n,1} \right|^2 \geq \lambda_1^{FD} \left(P_U a_2^2 \left| g_{n,1} \right|^2 + N_0 \right) \right). \end{aligned} \quad (11)$$

Then it is rewritten as:

$$\begin{aligned} A &= \Pr\left(\left| h_n \right|^2 \geq \frac{\lambda_1^{FD} \varpi P_R \left| h_{SI} \right|^2 + \lambda_1 N_0}{P_S \left(a_1^2 - \lambda_1^{FD} a_2^2 \right)} \right) \times \Pr\left(\left| g_{n,1} \right|^2 \geq \frac{\lambda_1^{FD} N_0}{P_U \left(a_1^2 - \lambda_1^{FD} a_2^2 \right)} \right) \\ &= A_1 \times A_2. \end{aligned} \quad (12)$$

In this case, we have two calcualations as below:

$$\begin{aligned} A_1 &= \Pr\left(\left| h_n \right|^2 \geq \frac{\lambda_1^{FD} \varpi P_R \left| h_{SI} \right|^2 + \lambda_1^{FD} N_0}{P_S \left(a_1^2 - \lambda_1^{FD} a_2^2 \right)} \right); if: a_1^2 > \lambda_1^{FD} a_2^2 \\ &= \exp\left(-\frac{\lambda_1^{FD} N_0}{P_S \left(a_1^2 - \lambda_1^{FD} a_2^2 \right) \lambda_{hn}} \right) \frac{P_S \left(a_1^2 - \lambda_1^{FD} a_2^2 \right) \lambda_{hn}}{\lambda_1^{FD} \varpi P_R \lambda_{hsi} + P_S \left(a_1^2 - \lambda_1^{FD} a_2^2 \right) \lambda_{hn}}, \end{aligned} \quad (13)$$

and

$$A_2 = \Pr\left(\left| g_{n,1} \right|^2 \geq \frac{\lambda_1^{FD} N_0}{P_U \left(a_1^2 - \lambda_1^{FD} a_2^2 \right)} \right) = \exp\left(-\frac{\lambda_1^{FD} N_0}{P_U \left(a_1^2 - \lambda_1^{FD} a_2^2 \right) \lambda_{gn,1}} \right). \quad (14)$$

Then A is rewritten as:

$$\begin{aligned} A &= \exp\left(-\frac{\lambda_1^{FD} N_0}{P_S \left(a_1^2 - \lambda_1^{FD} a_2^2 \right) \lambda_{hn}} \right) \frac{P_S \left(a_1^2 - \lambda_1^{FD} a_2^2 \right) \lambda_{hn}}{\lambda_1^{FD} \varpi P_R \lambda_{hsi} + P_S \left(a_1^2 - \lambda_1^{FD} a_2^2 \right) \lambda_{hn}} \exp\left(-\frac{\lambda_1^{FD} N_0}{P_U \left(a_1^2 - \lambda_1^{FD} a_2^2 \right) \lambda_{gn,1}} \right) \\ &= \frac{P_S \left(a_1^2 - \lambda_1^{FD} a_2^2 \right) \lambda_{hn}}{\lambda_1^{FD} \varpi P_R \lambda_{hsi} + P_S \left(a_1^2 - \lambda_1^{FD}{}_1 a_2^2 \right) \lambda_{hn}} \exp\left(-\frac{\lambda_1^{FD} N_0}{P_S \left(a_1^2 - \lambda_1^{FD} a_2^2 \right) \lambda_{hn}} - \frac{\lambda_1^{FD} N_0}{P_U \left(a_1^2 - \lambda_1^{FD} a_2^2 \right) \lambda_{gn,1}} \right). \end{aligned} \quad (15)$$

Therefore, such outage probability for user D1 is given by:

$$OP_1^{FD} = \prod_{n=1}^{N} \left(\begin{array}{l} 1 - \dfrac{P_S\left(a_1^2 - \lambda_1^{FD} a_2^2\right)\lambda_{hn}}{\lambda_1^{FD} \varpi P_R \lambda_{hsi} + P_S\left(a_1^2 - \lambda_1^{FD} a_2^2\right)\lambda_{hn}} \\ \times \exp\left(-\dfrac{\lambda_1^{FD} N_0}{P_S\left(a_1^2 - \lambda_1^{FD} a_2^2\right)\lambda_{hn}} - \dfrac{\lambda_1^{FD} N_0}{P_U\left(a_1^2 - \lambda_1^{FD} a_2^2\right)\lambda_{gn,1}} \right) \end{array} \right), \tag{16}$$

where $\lambda_1^{FD} = 2^{R_1} - 1$.

Similarly, in HD mode, such outage performance can be shown as:

$$OP_1^{HD} = \prod_{n=1}^{N} \left(1 - \exp\left(-\frac{\lambda_1^{HD} N_0}{P_S\left(a_1^2 - \lambda_1^{HD} a_2^2\right)\lambda_{hn}} - \frac{\lambda_1^{HD} N_0}{P_U\left(a_1^2 - \lambda_1^{HD} a_2^2\right)\lambda_{gn,1}} \right) \right), \tag{17}$$

where $\lambda_1^{HD} = 2^{2R_1} - 1$.

3.2. Performance of user D2

To consider performance of user of D2, the related outage probability can be given by:
Proposition 2: The closed-form expression of outage probability at user D2 can be given by:

$$\begin{aligned} OP_2^{FD} &= \min_{n=1,\dots} \left(\Pr\left(\gamma_{SR2,n} < \lambda_2^{FD} \cup \gamma_{RU12,n} < \lambda_1^{FD} \cup \gamma_{RU2,n} < \lambda_2^{FD}\right)\right) \\ &= \prod_{n=1}^{N} \left(1 - \underbrace{\Pr\left(\gamma_{SR2,n} \geq \lambda_2^{FD}, \gamma_{RU12,n} \geq \lambda_1^{FD}, \gamma_{RU2,n} \geq \lambda_2^{FD}\right)}_{B} \right) \end{aligned} \tag{18}$$

Proof:
It can be computed that:

$$\begin{aligned} B &= \Pr\left(\gamma_{SR2,n} \geq \lambda_2^{FD}, \gamma_{RU12,n} \geq \lambda_1^{FD}, \gamma_{RU2,n} \geq \lambda_2^{FD}\right) \\ &= \Pr\left(\frac{P_S a_2^2 \left|h_n\right|^2}{\varpi P_R \left|h_{SI}\right|^2 + N_0} \geq \lambda_2^{FD} \right) \times \Pr\left(\frac{P_U a_1^2 \left|g_{n,2}\right|^2}{P_U a_2^2 \left|g_{n,2}\right|^2 + N_0} \geq \lambda_1^{FD}, \frac{P_U a_2^2 \left|g_{n,2}\right|^2}{N_0} \geq \lambda_2^{FD} \right) \\ &= B_1 \times B_2. \end{aligned} \tag{19}$$

We can computed each part as follows:

$$\begin{aligned} B_1 &= \Pr\left(\frac{P_S a_2^2 \left|h_n\right|^2}{\varpi P_R \left|h_{SI}\right|^2 + N_0} \geq \lambda_2^{FD} \right) \\ &= \frac{P_S a_2^2 \lambda_{hn}}{\lambda_2^{FD} \varpi P_R \lambda_{hsi} + P_S a_2^2 \lambda_{hn}} \exp\left(-\frac{\lambda_2^{FD} N_0}{P_S a_2^2 \lambda_{hn}} \right), \end{aligned} \tag{20}$$

and

$$\begin{aligned} B_2 &= \Pr\left(\left|g_{n,2}\right|^2 \geq \frac{N_0 \lambda_1^{FD}}{P_U\left(a_1^2 - a_2^2 \lambda_1^{FD}\right)}, \left|g_{n,2}\right|^2 \geq \frac{N_0 \lambda_2^{FD}}{P_U a_2^2} \right); if: a_1^2 > a_2^2 \lambda_1^{FD} \\ &= \exp\left(-\frac{\theta^{FD}}{\lambda_{gn,2}} \right), \end{aligned} \tag{21}$$

Then, we have:

$$OP_2^{FD} = \prod_{n=1}^{N}\left(1-\frac{P_S a_2^2 \lambda_{hn}}{\lambda_2^{FD}\varpi P_R \lambda_{hsi} + P_S a_2^2 \lambda_{hn}} \exp\left(-\frac{\lambda_2^{FD} N_0}{P_S a_2^2 \lambda_{hn}} - \frac{\theta^{FD}}{\lambda_{gn,2}}\right)\right), \quad (22)$$

where

$$\lambda_2^{FD} = 2^{R_2} - 1,\ \theta^{FD} = \max\left(\frac{N_0 \lambda_1^{FD}}{P_U\left(a_1^2 - a_2^2 \lambda_1^{FD}\right)}, \frac{N_0 \lambda_2^{FD}}{P_U a_2^2}\right).$$

Similarly, in HD mode such outage metric for user D2 is formulated by:

$$OP_2^{HD} = \prod_{n=1}^{N}\left(1-\exp\left(-\frac{\lambda_2^{HD} N_0}{P_S a_2^2 \lambda_{hn}} - \frac{\theta^{HD}}{\lambda_{gn,2}}\right)\right), \quad (23)$$

where

$$\lambda_2^{HD} = 2^{R_2} - 1,\ \theta^{HD} = \max\left(\frac{N_0 \lambda_1^{HD}}{P_U\left(a_1^2 - a_2^2 \lambda_1^{HD}\right)}, \frac{N_0 \lambda_2^{HD}}{P_U a_2^2}\right).$$

4. SIMULATION RESULT

In this section, we present numerical results to evaluate analytical expressions calculated in previous part. The power allocation coefficients of NOMA is $a_1 = 0.8$ for D1. As the observation, Figure 2 and Figure 3 plot the outage probability for proposed NOMA for two far NOMA users described as in figures. In this scenario, relay selection scheme is applied for further improvement of outage behavior. Observing the Figure 2, one can conclude that much power allocated to user D1 results in better outage performance. In addition, both Figure 2 and Figure 3 manifest that RS NOMA can remarkably increase the outage performance as if reasonable selection of FD/HD mode is given. Moreover, when we change transmit power at relay, the gap performance regarding the outage probabilities achieved by RS NOMA can be seen clearly at such high transmit power at relay.

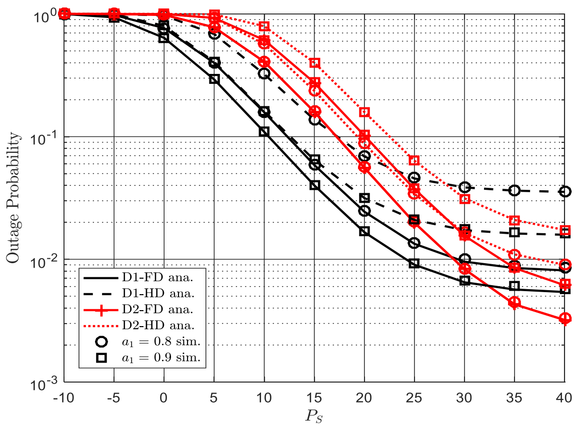

Figure 2. Comparison on FD and HD of both far users versus transmit SNR at the BS as varying a_1 ($\lambda_{hn} = \lambda_{gn,1} = 1$, $\lambda_{gn,2} = 10$, $\lambda_{hsi} = 0.01$, $P_R = P_U = 20(dB)$, $R_1 = 0.5$, $R_2 = 1$, $N_0 = 1$, $N = 1$)

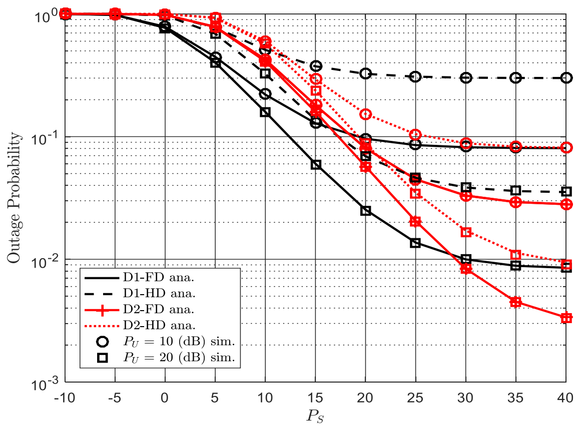

Figure 3. Outage performance comparison on FD and HD of both users versus transmit power at relay as varying P_U ($\lambda_{hn} = \lambda_{gn,1} = 1$, $\lambda_{gn,2} = 10$, $\lambda_{hsi} = 0.01$, $P_R = 20(dB)$, $R_1 = 0.5$, $R_2 = 1$, $N_0 = 1$, $N = 1$)

In Figure 4, it can be observed that the outage probability varies according to the different values of self-interference channel. The exact outage probability curves of proposed RS NOMA with higher level of SI will be resulted in worse outage performance. It is observed that the superiority of full duplex function in RS NOMA is no longer apparent with the very large values of SI (i.e. as $\lambda_{hsi} = 1$ (dB)). Therefore, it is essential to consider the influence of SI when designing practical full duplex antenna in such NOMA systems.

In Figure 5, we evaluate impact of the number of relay at relay selected. Better performance can be observed at higher number of relay selected. We compare the outage behavior of different cases considering the number of relay. It can be observed from Figure 5 that for the proposed scheme, the analytical outage is improved at $N = 2$. In addition, Figure 5 also shows that the proposed scheme can obtained clear outage performance gap as higher SNR raised.

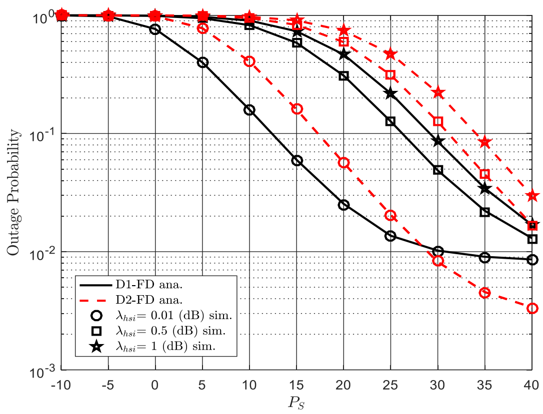

Figure 4. Outage performance comparison in case of FD mode for both far users versus transmit power at the BS as varying λ_{hsi} ($\lambda_{hn} = \lambda_{gn,1} = 1$, $\lambda_{gn,2} = 10$, $\lambda_{hsi} = 0.01$, $P_R = P_U = 20(dB)$, $R_1 = 0.5$, $R_2 = 1$, $N_0 = 1$, $N = 1$).

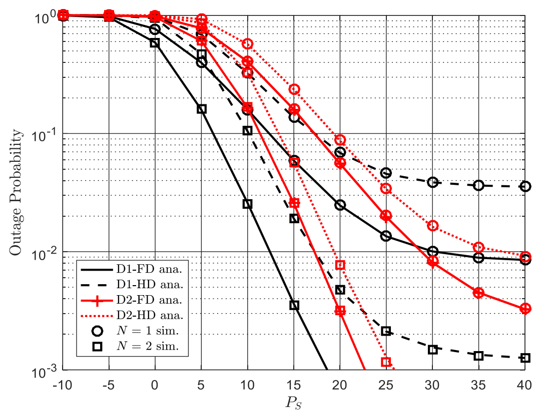

Figure 5. Outage performance comparison on FD and HD of both far users versus transmit power at the BS as varying N ($\lambda_{hn} = \lambda_{gn,1} = 1$, $\lambda_{gn,2} = 10$, $\lambda_{hsi} = 0.01$, $P_R = P_U = 20(dB)$, $R_1 = 0.5$, $R_2 = 1$, $N_0 = 1$).

5. CONCLUSION

In this study, we suggested applying relay selection scheme in NOMA scheme to evaluate system outage performance. As most important thing, full-duplex scheme is also studied. The considered NOMA scheme is assessed and compared with the different scenarios in terms of system outage. By achieving outage with appropriate selection of number of relay, it can be observed from the simulation result that the proposed NOMA with improved performance can be applied in real NOMA design. For further research topics, with more than two users we may consider a generalization of relay selection policies and performance investigation for randomly distributed NOMA users.

REFERENCES

[1] T. L. Nguyen, Dinh-Thuan Do, "Exploiting Impacts of Intercell Interference on SWIPT-assisted Non-orthogonal Multiple Access," *Wireless Communications and Mobile Computing,* vol. 17, pp. 1-12, 2018.

[2] Y. Saito, et al., "Non-orthogonal multiple access (NOMA) for cellular future radio access," *Proc. IEEE Veh. Technol. Conf. (VTC Spring),* 2013.

[3] Dinh-Thuan Do and C. B. Le, "Application of NOMA in Wireless System with Wireless Power Transfer Scheme: Outage and Ergodic Capacity Performance Analysis," *Sensors,* vol. 18, no. 10, pp. 3501, 2018.

[4] Dinh-Thuan Do, M. S. Van Nguyen, T. A. Hoang and M. Voznak, "NOMA-Assisted Multiple Access Scheme for IoT Deployment: Relay Selection Model and Secrecy Performance Improvement," *Sensors,* vol. 19, no. 3, pp. 736, 2019.

[5] Z. Ding, et al., "On the performance of non-orthogonal multiple access in 5G systems with randomly deployed users," *IEEE Signal Process. Lett. Dec.,* vol. 21, no. 12, pp. 1501-1505, 2014.

[6] Dinh-Thuan Do, H. S. Nguyen, M. Voznak and T. S. Nguyen, "Wireless powered relaying networks under imperfect channel state information: system performance and optimal policy for instantaneous rate," *Radioengineering,* vol. 26, no. 3, pp. 869-877, 2017.

[7] X. X. Nguyen and Dinh-Thuan 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,* vol. 2017, no, 1, pp. 1-16, 2017.

[8] A. S. Gupta, and A. Singer, “Successive Interference Cancellation Using Constellation Structure,” *IEEE Trans. Signal Process*, vol. 55, no. 12, pp. 5716–5730, 2007.

[9] X. S. Liang, Y. P. Wu, D. W. K. Ng, Y. P. Zuo, S. Jin, and H. B. Zhu, “Outage Performance for Cooperative NOMA Transmission with an AF Relay,” *IEEE Commun. Lett.,* vol. 21, no. 11, pp. 2428-2431, 2017.

[10] L. Lv, J. Chen, Q. Ni, and Z. G. Ding, “Design of cooperative non orthogonal multicast cognitive multiple access for 5g systems: user scheduling and performance analysis,” *IEEE Trans. Commun. Jun.* vol. 65, no. 6, pp. 2641–2656, 2017.

[11] Z. G. Ding, Z. Yang, P. Z. Fan, and H. V. Poor, “On the performance of non-orthogonal multiple access in 5G systems with randomly deployed users,” *IEEE Signal Process. Lett. Dec.,* vol. 21, no. 12, pp. 1501–1505, 2014.

[12] Z. Ding, H. Dai, and H. V. Poor, “Relay selection for cooperative NOMA,” *IEEE Commun. Lett. Aug*., vol. 5, no. 4, pp. 416– 419, 2016.

[13] Z. Zhang, Z. Ma, M. Xiao, Z. Ding, and P. Fan., “Full-duplex device-to-device aided cooperative non-orthogonal multiple access,” *IEEE Trans. on Vehicular Technology,* vol. 66, no. 5, pp. 4467–4471, 2017.

[14] J. Gong and X. Chen, “Achievable rate region of non-orthogonal multiple access systems with wireless powered decoder,” *IEEE J. Sel. Areas Commun.*, vol. 35, no. 12, pp. 2846–2859, Dec. 2017.

[15] Y. Liu, Z. Ding, M. Elkashlan, and H. V. Poor, “Cooperative non-orthogonal multiple access with simultaneous wireless information and power transfer,” *IEEE J. Sel. Areas Commun.*, vol. 34, no. 4, pp. 938–953, Apr. 2016.

[16] Dinh-Thuan Do and M.-S. Van Nguyen, "Device-to-device transmission modes in NOMA network with and without Wireless Power Transfer," *Computer Communications*, Vol. 139, pp. 67-77, May 2019.

[17] D. T. Do, M. Vaezi and T. L. Nguyen, “Wireless Powered Cooperative Relaying using NOMA with Imperfect CSI,” *Proc. of IEEE Globecom Workshops (GC Wkshps), Abu Dhabi, UAE*, pp. 1-6, 2018.

[18] D. T. Do and A. T. Le, “NOMA based cognitive relaying: Transceiver hardware impairments, relay selection policies and outage performance comparison,” *Computer Communications*, vol. 146, pp. 144-154, 2019.

[19] S. Lee, D. B. da Costa, Q. T. Vien, T. Q. Duong, and R. T. de Sousa, ‘‘Non-orthogonal multiple access schemes with partial relay selection,’’ *IET Commun.*, vol. 11, no. 6, pp. 846–854, 2017.

[20] S. Lee, D. B. da Costa, T. Q. Duong, “Outage probability of Non-Orthogonal Multiple Access Schemes with partial Relay Selection,” *Proc. IEEE PIMRC*, pp. 1–6, 2016.

[21] D. T. Do et al. “Wireless power transfer enabled NOMA relay systems: two SIC modes and performance evaluation,” *TELKOMNIKA Telecommunication Computing Electronics and Control*, vol. 17, no. 6, pp. 2697-2703, 2019.

[22] Dinh-Thuan Do, Chi-Bao Le, A. T. Le, "Cooperative underlay cognitive radio assisted NOMA: secondary network improvement and outage performance, " *TELKOMNIKA Telecommunication Computing Electronics and Control*, vol. 17, no. 5, pp. 2147-2154, 2019

[23] Dinh-Thuan Do, T. T. Thi Nguyen, "Exact Outage Performance Analysis of Amplify and Forward-Aware Cooperative NOMA," *TELKOMNIKA Telecommunication Computing Electronics and Control*, vol. 16, no. 5, pp. 1966-1973, 2018.

[24] Dinh-Thuan Do, C. B. Le, "Exploiting Outage Performance of Wireless Powered NOMA," *TELKOMNIKA Telecommunication Computing Electronics and Control*, vol. 16, no. 5, pp. 1907-1917, 2018.

[25] D.-T. Do, A.-T. Le and B.-M. Lee, “On Performance Analysis of Underlay Cognitive Radio-Aware Hybrid OMA/NOMA Networks with Imperfect CSI,” *Electronics*, vol. 8, no. 7, pp. 1-21, 2019.