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RELAY SELECTION ON DEVICE-TO-DEVICE-ASSISTED FULL-DUPLEX NON-ORTHOGONAL MULTIPLE ACCESS: SYSTEM MODEL AND PERFORMANCE ANALYSIS

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Abstract

In recent year, bandwidth efficiency and performance of Non-Orthogonal Multiple Access (NOMA) system can be enhanced by using a full-duplex transmission model. However, previous papers have not investigated satisfactorily in the full-duplex scenario in which, near device (i.e., so-called as relay) is selected for Device-To-Device (D2D) transmission employing NOMA scheme. The outage performance of Full-Duplex D2D NOMA and relay selection structure for D2D is studied in this paper. By considering the outage and throughput performance of a considered system with its vital result, general wireless networks with various selected devices to help D2D communication in the cellular network. Simulation results show that the device selection scheme can achieve significant performance improvement.

Keywords: D2D, NOMA, Outage probability, Relay selection.

1. Introduction

In recent years, NOMA technology has attracted a lot of attention. It is considered as one of the modern technologies applied in 5^{th} Generation (5G) mobile networks in order to considerably enhance the system spectral efficiency for the next generation communication networks [1-4]. The information of multiple users is incorporated into a mixed signal in the power domain, whereas the users are served in the same domain such as time, frequency or code domain. 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 the 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 Orthogonal Multiple Access (OMA) system, there is a significant improvement in NOMA throughput performance [5].

Chen et al. [6] and Wang et al. [7], focused on the multiple user channel capacity and the spectrum efficiency as well as the number of subscribers under bad channel condition can be enhanced by employing NOMA scheme into the system model. Simultaneously, Gupta and Singer [8] utilized SIC, the received message, in which, is decoded at the receiver while the transmitter treating interference signal applies the NOMA technique. NOMA is known as combination scheme as relaying scheme [9, 10] can be integrated into such a system. Moreover, based on studies by Luan and Do [10], the scenario of impacts on co-channel interference is applied in order to increase the wirelesses power transfer performance and the mathematical formula in the closed form of probability has been found. Nguyen et al. [11] explained that full-duplex are evaluated as architecture to enhance bandwidth usage efficiency. As a result, such full-duplex is conveyed in several NOMA schemes.

For the purpose of improving the outage performance of all devices in the relay selection (RS) system, Ding et al. [12] have proposed a two-stage RS in cooperative NOMA model. Furthermore, similar to studies by Ding et al. [12], in order to improve system performance, a full-duplex NOMA (FD-NOMA) model has been proposed by Zhang et al. [13]. According to Men and Ge [14], Zhong and Zhang [15], NOMA design with a selected cooperative relay node as well as outage probability is examined. Asadi et al. [16] proposed that the Device-To-Device (D2D) communication has shown the possibility of being widely applicable, which based on spectrum sharing with cellular networks. In principle, the equipment in such D2D design can connect directly with another equipment through the control of the base station (BS) and it leads to the result that the end-to-end latency can be descended. It can be proved that the area spectral effectiveness can be enhanced in the D2D scenario and the cellular network is able to accommodate more devices [17]. Motivated by advantages of relay selection [18, 19] and D2D model, this paper aims to combine cooperative NOMA with D2D scheme in full-duplex scenario into considered D2D NOMA system. In particular, outage and throughput performance in such D2D NOMA are investigated. In addition, the D2D transmission with the utilization of full-duplex scenario and relay selection to perform NOMA scheme has been studied by evaluating related parameters.

As the main contribution of this paper, we derive the closed-form expression in term of outage event to evaluate system performance of transmission from the first device in each pair user (so-called near NOMA users), which is treated as relay node to assist forwarding signal to the far NOMA devices.

2. System Model

We consider a downlink system model is shown as Fig. 1, where a base station (BS) would like to send a message to the N near users (NU), which will act as the relay to broadcast BS's data signal to a pair of far users (FU) that set as device 1 (U_1) and device 2 (U_2).

This paper develops a system model presented in recent work [13]. Transmission procedure happens in two phases, i.e., at a time t, $t+1$. More specifically, Fig. 1 illustrates the full-duplex D2D devices applying NOMA, which can serve D2D transmission to far devices, for example transferring signalling signal as D2D is underlying with a traditional cellular network. In this model, we denote, D_n, $n = 1,2,...,N$ as D2D devices so-called as NUs. The BS is a single antenna transmission source while the NUs are designed with two separated antennas to serve full-duplex transmission. As a result, self-interference (SI) due to simultaneous operation of two antennas at near devices. We assume that there does not exist a direct link from the BS to FU, h_n and $g_{n,i}$ ($i=1,2$) are denoted the Rayleigh fading channel coefficients of the link BS-NU and NU-FU, respectively.

The random variables $|h_n|^2$ and $|g_{n,i}|^2$ follow the exponential distribution with parameters Φ_{h_n} and $\Phi_{g_{n,i}}$, respectively. Following the principle of normal NOMA, users are distributed in order based on the channel conditions. For example, we assumed that U_1 and U_2 are used for different data transmission, in which, U_1 is used for low-speed applications, while U_2 serves high-speed data rate.

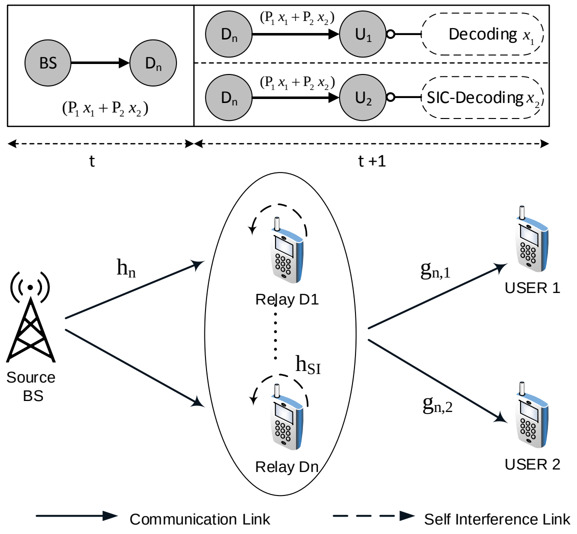

Fig. 1. System model of relay selection D2D NOMA with full-duplex transmission.

The transmission between the *BS* → *NU* and *D$_i$-th* → *U$_i$-th*, $(i=1,2)$ are divided into two phases. In the early phase, the BS sends the superposition signal, $P_1x_1+P_2x_2$, where x_1 and x_2 denotes the message for BS sent forward to first devices and then these signal intend to transmit to U_1 and U_2 in D2D link using the N device considered as cooperative relays, respectively.

In this full-duplex (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 $|h_{SI}|^2$ also follow the exponential distribution with mean value Φ_{SI}, P_i, $(i=1,2)$ is the power allocation coefficients, P_s and P_R (assuming that $P_s=P_R$) are the transmission power at the BS and NU user, respectively. Because it must be satisfied Quality-of-Service (QoS) requirements, we denote $P_1^2+P_2^2=1$ with assumption as $P_1>P_2$. Therefore, the received signal at the NU user, i.e., relay *n-th*, $1\le n\le N$ can be given as

$$y_n^r=h_n\sqrt{P_S}\,(P_1x_1+P_2x_2)+h_{SI}\sqrt{P_R}\,x_{SI}+\delta_n^r \tag{1}$$

where δ_n^r stands for the additive Gaussian noise (AWGN) at *NU-th* user with zero mean and variance N_0.

To successfully decode the signal, which is containing x_1 and x_2, the conditions for relay *n-th* are written as:

$$log_2\left(1+\frac{|h_n|^2P_1^2}{|h_n|^2P_2^2+|h_{SI}|^2+\frac{1}{\varepsilon}}\right)\ge R_1,\quad log_2\Bigl(1+\frac{|h_n|^2P_2^2}{|h_{SI}|^2+\frac{1}{\varepsilon}}\Bigr)>R_2 \tag{2}$$

where ε and R_i, $i=(1,2)$ are the signal-to-noise ratio (SNR) and the target data rate for user *Ui-th*, respectively, $\varepsilon=\frac{P_s}{N_0}=\frac{P_R}{N_0}$.

During the following time slot, consider that relay *n-th* can successfully decode the signal and is selected to forward the message $P_1x_1+P_2x_2$. In this case, the received signal at far user *Ui-th* are given as the following equation:

$$y_{n,i}^d=g_{n,i}\sqrt{P_R}\,(P_1x_1+P_2x_2)+\delta_{n,i}^d\quad ,i\in\{1,2\} \tag{3}$$

where $\delta_{n,i}^d$ is the AWGN at *FU-th* user with zero mean and variance N_0. It is similar to the first time slot, the condition for User U_1 decodes its message, i.e., x_1

with the $SINR_1 = \frac{|g_{n,1}|^2 P_1^2}{|g_{n,1}|^2 P_2^2 + \frac{1}{\varepsilon}}$ and the other user decodes its own message with $SINR_2 = \varepsilon P_2^2 |g_{n,2}|^2$, provided that $log_2\left(1 + \frac{|g_{n,2}|^2 P_1^2}{|g_{n,2}|^2 P_2^2 + \frac{1}{\varepsilon}}\right) \geq R_1$

Device Selection Scheme

To enhance system performance in such a network, full duplex NOMA cooperates with the device selection model. In this section, we propose a device selection scheme as follow.

For a chosen relay *n-th*, only if the instantaneous rates for U_1 and U_2 are greater or equal to their target data rates R_1 and R_2, respectively, the near user can successfully decode the BS's messages x_1 and x_2, i.e., this condition must be satisfied.

$$log_2\left(1 + \frac{P_1^2 |h_n|^2}{1/\varepsilon + P_2^2 |h_n|^2 + |h_{SI}|^2}\right) \geq R_1 \cup log_2\left(1 + \frac{|h_n|^2 P_2^2}{|h_{SI}|^2 + \frac{1}{\varepsilon}}\right) \geq R_2 \tag{4}$$

This equivalent with the following equation:

$$|h_n|^2 > \frac{max\left\{\frac{(2^{R_1}-1)(1+\varepsilon|h_{SI}|^2)}{P_1^2 - P_2^2\left(2^{R_1}-1\right)}, \frac{(2^{R_2}-1)(1+\varepsilon|h_{SI}|^2)}{P_2^2}\right\}}{\varepsilon} \tag{5}$$

It worth noting that if $|g_{n,1}|^2 > \frac{2^{R_1}-1}{\varepsilon}$ then U_1 needs to be treated first, i.e., the target rate conditions of U_1 need to be satisfied.

The set of selected devices, which can meet the Quality of Service (QoS) requirements of, U_1 can be expressed as follows

$$DS_n = \left\{|h_n|^2 \geq \frac{\xi}{\varepsilon}, |g_{n,1}|^2 \geq \frac{\lambda_1}{\varepsilon}\right\} \tag{6}$$

in which, $\xi = \left(1 + \varepsilon|h_{SI}|^2\right) max\left\{\frac{\lambda_1}{P_1^2 - P_2^2\lambda_1}, \frac{\lambda_2}{P_2^2}\right\}, \lambda_1 = 2^{R_1} - 1, \lambda_2 = 2^{R_2} - 1$. In the other hand, this condition can be happened as the following probability.

$$Pr\left\{|h_n|^2 \geq \frac{\xi}{\varepsilon}, |g_{n,1}|^2 \geq \frac{\lambda_1}{\varepsilon}\right\} = e^{\frac{-\xi-\lambda_1}{\varepsilon\Phi_{h_n}}} = \frac{e^{\frac{-(\lambda_1+m)}{\varepsilon\Phi_{h_n}}}}{\Phi_{SI}m + 1} \tag{7}$$

Noted that it can be chosen $\Phi_{h_n} = \Phi_{g_{n,j}} = 1$

where $m = max\left\{ \dfrac{\lambda_1}{P_1^2 - P_2^2\lambda_1}, \dfrac{\lambda_2}{P_2^2} \right\}$.

In addition, the further criterion for this concerned system for device selection adapting U_2 is:

$$n^* = \underset{n=1,2,\ldots,N}{arg\,max}\left\{ \left|g_{n,2}\right|^2 \right\} \tag{8}$$

3. System Performance Analysis

In this section, in order to determine whether or not the outage ability occur on the whole system, we denote Ψ_1 is the outage ability that relay n^* is unable to decode x_1, or both of the FUs and selected NU cannot decode x_1 successfully, Ψ_2 denotes the outage ability that x_2 cannot be decoded successfully by relay n^* and by U_2. Hence, the outage ability of the entire system can be expressed as follows:

$$\Psi = \Psi_1 \cup \Psi_2 \tag{9}$$

Consequently, the overall outage probability can be given as:

$$Pr(\Psi) = Pr(\Psi_1) + Pr(\Psi_2) \tag{10}$$

in which, $Pr(\Psi_1)$ can be calculated as follows:

$$\begin{aligned} Pr(\Psi_1) = \prod_{n=1}^{N}\Bigg[1 - \Bigg\{ & \underbrace{Pr\left(\left|h_n\right|^2 \geq \left(\left|h_{SI}\right|^2 \varepsilon + 1\right)\gamma\right)}_{A_1} \\ & \times \underbrace{Pr\left(\left|g_{n,1}\right|^2 \geq \omega_1\right)}_{A_2} \times \underbrace{Pr\left(\left|g_{n,2}\right|^2 \geq \omega_1\right)}_{A_3} \Bigg\} \Bigg] \end{aligned} \tag{11}$$

where $\omega_1 = \dfrac{\lambda_1}{\varepsilon\left(P_1^2 - \lambda_1 P_2^2\right)}$, $\gamma = max\left\{ \dfrac{2^{R_2} - 1}{\varepsilon\left(P_2^2 - P_1^2\left(2^{R_2} - 1\right)\right)}, \dfrac{2^{R_1} - 1}{P_1^2\varepsilon} \right\}$. It is worth noting that using exponent distribution we obtain $A_1 = \dfrac{\Phi_{h_n}}{\Phi_{h_n} + \varepsilon\gamma\Phi_{SI}} e^{-\gamma/\Phi_{h_n}}$, and $A_2 = e^{-\frac{\omega_1}{\Phi_{g_{n,1}}}}, A_3 = e^{-\frac{\omega_1}{\Phi_{g_{n,2}}}}$.

The second term $Pr(\Psi_2)$ can be derived as follows:

$$Pr(\Psi_2) = Pr\left(Q_1, \left|DS_n\right| = n\right) + Pr\left(Q_2, \bar{Q}_1, \left|DS_n\right| = n\right) \tag{12}$$

where Q_1 is the case that relay n^* is unable to decode x_2, $\bar{Q}_1$ stands for the complementary circumstance of Q_1, and Q_2 denotes when x_2 cannot be decoded at U_2. The previous equation can be denoted as follows:

$$Pr(\Psi_2) = \underbrace{Pr\left(Q_1, |DS_n| = n\right)}_{A} + \underbrace{Pr\left(Q_2, \bar{Q}_1, |DS_n| = n\right)}_{B} \tag{13}$$

Next, we consider the first term of Eq. (13) as below:

$$\begin{aligned} A &= Pr\left(Q_1, |DS_n| = n\right) \\ &= Pr\left(log_2\left(1 + \frac{|h_{n*}|^2 P_2^2}{|h_{SI}|^2 + \frac{1}{\varepsilon}}\right) < R_2, |DS_n| = n \right) \\ &= \left[1 - Pr\left(|h_{n*}|^2 \geq \frac{\lambda_2 \varepsilon |h_{SI}|^2 + \lambda_2}{\varepsilon P_2^2}\right)\right] \times Pr\left(|DS_n| = n\right) \end{aligned} \tag{14}$$

It is worth noting that the probability for the n relay devices, which it is selected in DS_n, can be expressed as follows [18]

$$Pr(|DS_n| = n) = \binom{N}{n} \left(\frac{e^{\frac{-(\lambda_1 + m)}{\varepsilon}}}{\Phi_{SI} m + 1} \right)^n \left(1 - \frac{e^{\frac{-(\lambda_1 + m)}{\varepsilon}}}{\Phi_{SI} m + 1} \right)^{N-n} \tag{15}$$

From Eq. (14) and Eq. (15), the expected result for Eq. (14) can be rewritten as follow:

$$\begin{aligned} A = &\left(1 - \sum_{n=1}^{N} \binom{N}{n} (-1)^{n-1} \frac{\Phi_{h_n} \varepsilon P_2^2}{\Phi_{SI} n \lambda_2 \varepsilon + \Phi_{h_n} \varepsilon P_2^2} exp\left(-\frac{n\lambda_2}{\Phi_{h_n} \varepsilon P_2^2} \right) \right) \\ &\times \binom{N}{n} \left(\frac{e^{\frac{-(\lambda_1 + m)}{\varepsilon}}}{\Phi_{SI} m + 1} \right)^n \left(1 - \frac{e^{\frac{-(\lambda_1 + m)}{\varepsilon}}}{\Phi_{SI} m + 1} \right)^{N-n} \end{aligned} \tag{16}$$

Similarly, it can be expressed in the second term of Eq. (13) as below

$$\begin{aligned} B &= Pr\left(Q_2, \bar{Q}_1, |DS_n| = n\right) \\ &= Pr\left(log_2(1 + \varepsilon |g_{n*,2}|^2 P_2^2) < R_2, log_2\left(1 + \frac{|h_{n*}|^2 P_2^2}{|h_{SI}|^2 + \frac{1}{\varepsilon}}\right) > R_2, |DS_n| = n \right) \\ &= \left(1 - \sum_{n=1}^{N} \binom{N}{n} (-1)^{n-1} exp\left(-\frac{n\lambda_2}{\Phi_{g_{n,2}} \varepsilon P_2^2} \right) \right) \\ &\times \left(\sum_{n=1}^{N} \binom{N}{n} (-1)^{n-1} \frac{\Phi_{h_n} \varepsilon P_2^2}{\Phi_{SI} n \lambda_2 \varepsilon + \Phi_{h_n} \varepsilon P_2^2} exp\left(-\frac{n\lambda_2}{\Phi_{h_n} \varepsilon P_2^2} \right) \right) \\ &\times \binom{N}{n} \left(\frac{e^{\frac{-(\lambda_1 + m)}{\varepsilon}}}{\Phi_{SI} m + 1} \right)^n \left(1 - \frac{e^{\frac{-(\lambda_1 + m)}{\varepsilon}}}{\Phi_{SI} m + 1} \right)^{N-n} \end{aligned} \tag{17}$$

After some manipulations, we obtain:

$$\begin{aligned}
Pr(\Psi_2) &= A+B \\
&= \Bigg(1-\sum_{n=1}^{N}\binom{N}{n}(-1)^{n-1}\frac{\Phi_{h_n}\varepsilon P_2^2}{\Phi_{SI}n\lambda_2\varepsilon+\Phi_{h_n}\varepsilon P_2^2}exp\Bigg(-\frac{n\lambda_2}{\Phi_{h_n}\varepsilon P_2^2}\Bigg)\Bigg) \\
&\quad\times\binom{N}{n}\Bigg(\frac{e^{\frac{-(\lambda_1+m)}{\varepsilon}}}{\Phi_{SI}m+1}\Bigg)^{n}\Bigg(1-\frac{e^{\frac{-(\lambda_1+m)}{\varepsilon}}}{\Phi_{SI}m+1}\Bigg)^{N-n} \\
&\quad+\Bigg(1-\sum_{n=1}^{N}\binom{N}{n}(-1)^{n-1}exp\Bigg(-\frac{n\lambda_2}{\Phi_{g_{n,2}}\varepsilon P_2^2}\Bigg)\Bigg) \\
&\quad\times\Bigg(\sum_{n=1}^{N}\binom{N}{n}(-1)^{n-1}\frac{\Phi_{h_n}\varepsilon P_2^2}{\Phi_{SI}n\lambda_2\varepsilon+\Phi_{h_n}\varepsilon P_2^2}exp\Bigg(-\frac{n\lambda_2}{\Phi_{h_n}\varepsilon P_2^2}\Bigg)\Bigg) \\
&\quad\times\binom{N}{n}\Bigg(\frac{e^{\frac{-(\lambda_1+m)}{\varepsilon}}}{\Phi_{SI}m+1}\Bigg)^{n}\Bigg(1-\frac{e^{\frac{-(\lambda_1+m)}{\varepsilon}}}{\Phi_{SI}m+1}\Bigg)^{N-n}
\end{aligned} \tag{18}$$

From Eqs. (11) to (18), the required probability in Eq. (10) can be calculated in the closed-form as:

$$\begin{aligned}
Pr(\Psi) &= \prod_{n=1}^{N}\left[1-\frac{\Phi_{h_n}}{\Phi_{h_n}+\varepsilon\gamma\Phi_{SI}}e^{-\gamma/\Phi_{h_n}}e^{-\frac{\omega_1}{\Phi_{g_{n,1}}}}e^{-\frac{\omega_1}{\Phi_{g_{n,2}}}}\right] \\
&\quad+\Bigg(1-\sum_{n=1}^{N}\binom{N}{n}(-1)^{n-1}\frac{\Phi_{h_n}\varepsilon P_2^2}{\Phi_{SI}n\lambda_2\varepsilon+\Phi_{h_n}\varepsilon P_2^2}exp\Bigg(-\frac{n\lambda_2}{\Phi_{h_n}\varepsilon P_2^2}\Bigg)\Bigg) \\
&\quad\times\binom{N}{n}\Bigg(\frac{e^{\frac{-(\lambda_1+m)}{\varepsilon}}}{\Phi_{SI}m+1}\Bigg)^{n}\Bigg(1-\frac{e^{\frac{-(\lambda_1+m)}{\varepsilon}}}{\Phi_{SI}m+1}\Bigg)^{N-n} \\
&\quad+\Bigg(1-\sum_{n=1}^{N}\binom{N}{n}(-1)^{n-1}exp\Bigg(-\frac{n\lambda_2}{\Phi_{g_{n,2}}\varepsilon P_2^2}\Bigg)\Bigg) \\
&\quad\times\Bigg(\sum_{n=1}^{N}\binom{N}{n}(-1)^{n-1}\frac{\Phi_{h_n}\varepsilon P_2^2}{\Phi_{SI}n\lambda_2\varepsilon+\Phi_{h_n}\varepsilon P_2^2}exp\Bigg(-\frac{n\lambda_2}{\Phi_{h_n}\varepsilon P_2^2}\Bigg)\Bigg) \\
&\quad\times\binom{N}{n}\Bigg(\frac{e^{\frac{-(\lambda_1+m)}{\varepsilon}}}{\Phi_{SI}m+1}\Bigg)^{n}\Bigg(1-\frac{e^{\frac{-(\lambda_1+m)}{\varepsilon}}}{\Phi_{SI}m+1}\Bigg)^{N-n}
\end{aligned} \tag{19}$$

Remark 1: Here, it is assumed that channel gain of each link in the first hop and self-interference channel are similar value and equals to Φ_{h_n}, Φ_{SI}, respectively. This is an important contribution of this paper to evaluate device selection scheme in D2D NOMA.

In this paper, it can calculate the throughput from the obtainable sum rate of the system. Particularly, the BS sends the message at a fixed target rate R_0, which is subject to the impact of outage probability because of random wireless fading channels. The overall FD NOMA sum throughput can be given as

$$\Gamma = 1-Pr(\Psi)\ R_0 \tag{20}$$

4. Simulation Result

In this section, we present numerical results to evaluate analytical expressions calculated in the previous part. Without loss of generality, it can be pretended that the distance from BS to near users-*th*, which is standardised to the unit, and average channel power gains are assumed that $\Phi_{SI} = \Phi_{h_n} = \Phi_{g_{n,1}} = \Phi_{g_{n,2}} = 1$. The power allocation coefficients of NOMA are $P_1^2 = 0.75$ and $P_2^2 = 0.25$ for U_1 and U_2, respectively. Note that the simulation results are done with the help of Matlab.

As the observation, Figs. 2 and 3 plot the outage probability for proposed NOMA with two scenarios described as in figures, where the relay selection scheme is applied. Observing Fig. 2, one can conclude that more relay brings better outage performance. Besides, in studies by Ding et al. [19], we also compared our system's outage performance with the max-min relay selection criterion, in which, can be seen in Fig. 2 that at SNR from 0 dB to 20 dB, our system's performance is better than max-min relay selection criterion.

However, at the high SNR, i.e., SNR from 25 dB to 40 dB, the performance is better than our system model.

This could be explained because of our system is FD, so when the SNR is high, the self-interference is also stronger and it crucial affects the system's performance. In addition, both Figs. 2 and 3 manifest that D2D NOMA can remarkably increase the outage performance as if a reasonable selection of number of device is given.

Moreover, when the number of the NUs, i.e., N is increased, the performance gap regarding the outage probabilities achieved by D2D NOMA can be seen clearly at high transmit SNR.

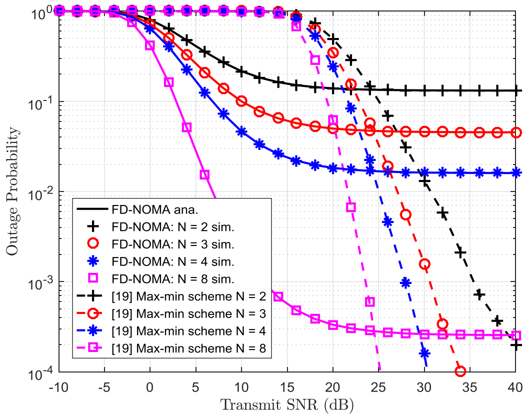

Fig. 2. Outage probability with different number of NU nodes and comparison with the max-min relay selection criterion [19]. Key parameters $R_1 = 0.5$, $R_2 = 2$.

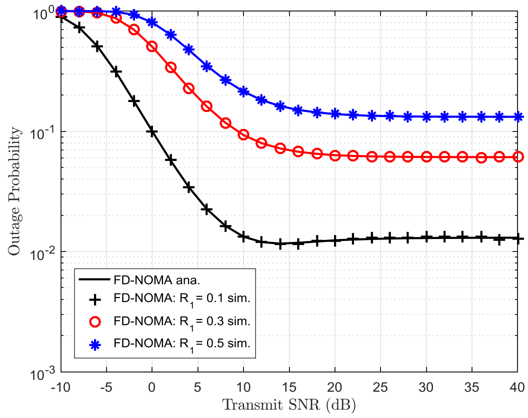

Fig. 3. Outage probability with number of NUs, $N=2$ and different target rates are $R_1=\{0.1;0.3;0.5\}$ and $R_2=2$.

In Fig. 4, it can be observed that the outage probability varies according to the different values of SI. In this figure, we set different self-interference ratios are $\Phi_{SI} \triangleq E\left\{\left|h_{SI}\right|^2\right\} = \{0.6;0.8;1\}$. The exact outage probability curves of proposed D2D NOMA with a higher level of SI will result in worse outage performance. It is observed that the superiority of full duplex function in D2D NOMA is no longer appear with the very large values of SI (i.e., $E\left\{\left|h_{SI}\right|^2\right\} = 1\ dB$). Therefore, it is essential to consider the influence of SI when designing practical full duplex antenna in such NOMA systems. Besides, the perfect combination of analytical lines and simulation lines has confirmed the accuracy of our analytical expressions.

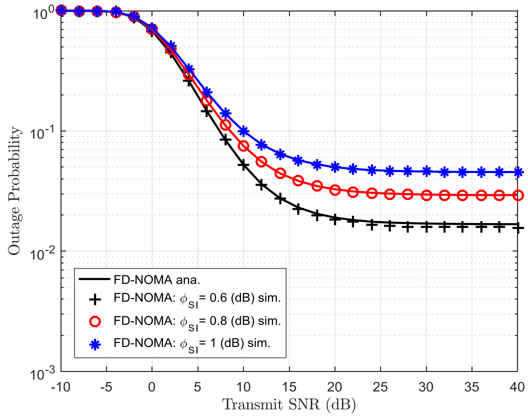

Fig. 4. Outage probability with number of NUs, $N=3$, $R_1=0.5$, $R_2=2$, $\Phi_{h_n}=\Phi_{g_{n,1}}=\Phi_{g_{n,2}}=1$ and $\Phi_{SI}=0.6;0.8;1$.

In Fig. 5, we compare the throughput of four different cases considering the number of relay. Our setting are $R_1 = 1\,(b/s/Hz)$, $R_2 = 2\,(b/s/Hz)$, $R_0 = 2(b/s/Hz)$ and $P_2^2 = 0.25$. It can be observed from Fig. 5 that for the proposed scheme, the analytical throughput remains at the maximal level at high transmit SNR, i.e. transmit SNR is greater than approximately 20 (dB). In addition, Fig. 5 also shows that the proposed scheme can obtain clear throughput performance gap as SNR between 5dB and 20 dB. For the case that the value of SNR is low, the throughput in this NOMA scheme becomes very small and the proposed scheme almost works in low quality.

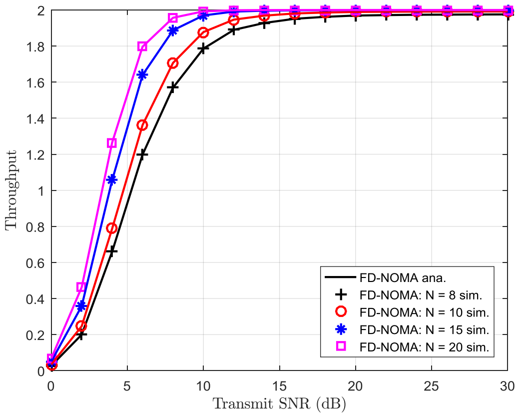

Fig. 5. System throughput with different numbers of relay. $R_0 = 2$**,** $R_1 = 1$**,** $R_2 = 2$**.**

5. Conclusion

In this study, we suggested a device selection scheme integrated with NOMA scheme to evaluate system outage performance for a D2D transmission with multiple devices. The considered NOMA scheme is assessed and compared with the different scenarios in terms of outage behaviour and throughput. By achieving outage with appropriate selection of the number of device, it can be observed from the simulation result that the proposed NOMA can be applied in real NOMA design, then such NOMA scheme can achieve outage and throughput criteria for each user in pair of NOMA users. 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.

Nomenclatures

$D_1 \ldots D_n$	NUs user
DS_n	Set of selected devices for U_1
$E\{.\}$	Expectation operation, dB
$\Phi_{g_{n,1}}$	Mean of $\lvert g_{n,1} \rvert^2$, dB

$\Phi_{g_{n,2}}$	Mean of $\lvert g_{n,2}\rvert^2$, dB
Φ_{h_n}	Mean of $\lvert h_n\rvert^2$, dB
Φ_{SI}	Mean of $\lvert h_{SI}\rvert^2$, dB
Γ	System throughput, b/s/Hz
$g_{n,1}$	Rayleigh fading channel coefficient of the link relay-U_1
$g_{n,2}$	Rayleigh fading channel coefficient of the link relay-U_2
$\lvert g_{n,1}\rvert^2$	Channel power gain of the link relay-U_1, dB
$\lvert g_{n,2}\rvert^2$	Channel power gain of the link relay-U_2, dB
h_n	Rayleigh fading channel coefficient of the link BS-relay
h_{SI}	Rayleigh fading channel self-interference coefficient
$\lvert h_n\rvert^2$	Channel power gain of the link BS-relay, dB
$\lvert h_{SI}\rvert^2$	Channel power gain of the self-interference, dB
m	Temporary coefficient in calculation (7)
N_0	Noise power of AWGN δ_n^r, dB
$n;N$	Number of relay
$n*$	Selected relay in the set of relays
P_1	Power allocation coefficient of U_1, dB
P_2	Power allocation coefficient of U_2, dB
Pr(.)	Probability operator
P_S	Power of BS, dB
P_R	Power of Relay, dB
Q_1	Outage ability that relay n^* is unable to decode x_2
$\bar{Q}_1$	Complementary circumstance of Q_1
Q_2	Outage ability when x_2 cannot be decoded at U_2
R_0	Fixed target rate of BS, b/s/Hz
R_1	Target data rate for U_1, b/s/Hz
R_2	Target data rate for U_2, b/s/Hz
$SINR_1$	Condition of signal-to-noise ratio for user U_1 decodes its message
$SINR_2$	Condition of signal-to-noise ratio for user U_2 decodes its message
t	Time, s
U_1	User device 1
U_2	User device 2
x_1	Source message of U_1

x_2	Source message of U_2
x_{SI}	Self-interference signal of relay *n-th*
y_n^r	Received signal at the relay *n-th*

Greek Symbols

γ	Temporary coefficient in calculation (11)
δ_n^r	Additive white Gaussian noise, dB
ε	Signal-to-noise ratio ($P_s / N_0 = P_R / N_0$), dB
λ_1	SNR threshold of U_1 ($2^{R_1} - 1$), dB
λ_2	SNR threshold of U_2 ($2^{R_2} - 1$), dB
ξ	Temporary coefficient in calculation (6)
Ψ	Outage ability of the entire system
Ψ_1	Outage ability to decode x_1
Ψ_2	Outage ability to decode x_2
ω_1	Temporary coefficient in calculation (11)

Abbreviations

AWGN	Additive White Gaussian Noise
BS	Base Station
D2D	Device-to-Device
FD	Full-Duplex
FU	Far Users
NOMA	Non-Orthogonal Multiple Access
NU	Near Users
OMA	Orthogonal Multiple Access
QoS	Quality-of-Service
RS	Relay Selection
SI	Self-Interference
SIC	Successive Interference Cancellation
SNR	Signal-to-Noise

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