

Exploiting outage performance in device-to-device for user grouping

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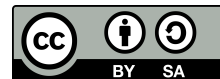
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ABSTRACT

The spectrum efficiency and massive connections are joint designed in new form of device-to-device for user grouping. A pair of users is implemented with non-orthogonal multiple access (NOMA) systems. Although NOMA benefits to such system in term of the serving users, device to device (D2D) faces the interference from normal cellular users (CUE). In particular, we derive exact formulas of outage probability to show system performance. In this article, we compare two schemes to find relevant scheme to implement in practice. The frame structure is designed with two timeslot related to uplink and downlink between the base station and D2D users. We confirm the better scheme in numerical result by considering the impacts of many parameters on outage performance.

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1. INTRODUCTION

To implement multiple access schemes in cellular networks for current wireless systems, orthogonal multiple access (OMA) systems is deployed most of systems, e.g., frequency division multiple access (FDMA), time division multiple access (TDMA), and orthogonal frequency division multiple access (OFDMA). In OMA, exclusive resources are allocated to users. Although OMA has advantages such as low complexity receivers and no intracell interference, it suffers from two main disadvantages such as limited number of users and low spectral efficiency. In the perspective of demand of massive connections, non-orthogonal multiple access (NOMA) is promising candidate for multiple access scheme. In the principle of NOMA, it employs different power levels to multiplex multiple users at the same frequency, time and code resources [1]-[7].

The work [8] studied downlink NOMA by examining joint optimization of power factors assigned to users and secure performance was also evaluated. The current communication systems may also get benefits by enabling NOMA for multiple access. The NOMA massive MIMO was presented in [9], [10] to explore antennas diversity. The work in [11] compared NOMA transmissions between multiple antennas case and single antenna case. The near optimal sum-rate (SR) performance was explored in MIMO-NOMA system and a high-complexity beamforming was recommended in such multiple antennas NOMA approach [12].

It is further necessary to study device-to-device (D2D) communications in the heterogeneous nature of 5G cellular NOMA -aided systems. The base station (BS) normally wants to exchange their controlling signal while D2D communications enable proximate cellular users [13], [14]. Especially, the spectrum band is reused for pair of D2D users in the cellular systems [15], [16]. However, as the main disadvantage, D2D users

meet mutual interference among D2D and normal cellular links. The authors in [17] deployed D2D for the applications of NOMA networks by allowing one D2D transmitter send signals to multiple D2D receivers with assistance of NOMA. The other promising applications of D2D can be seen in [18]-[24]. As main benefit, D2D enables users to communicate effectively at close distance, especially processing multiple access with NOMA scheme. Motivated by recent studies [18]-[24] and [25], we develop two practical schemes of D2D-NOMA system along with system performance analysis.

2. SYSTEM MODEL

Consider uplink and downlink transmission in D2D-NOMA system which consists of groups of paired user under the impacts of BS and conventional user (CUE), as shown in Figure 1 [25]. It is assumed that the BS, and all users are equipped with single antenna. In each group, two users need two time slots for signal processing. The relay is assumed to decode signal perfectly, which exhibit two schemes.

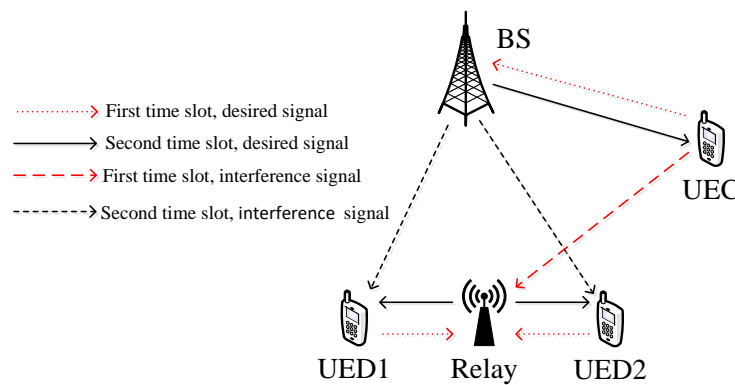


Figure 1. Enabling D2D in NOMA

First, P_{iT} is transmit power at the source, here we denote ($i = 1, 2, c, b, r$). We characterize h_{ij} as Raleigh fading channels to reflect gains of $i - j$ link ($j = 1, 2, c, b, r$). It is assumed that $h_{ij} = h_{ji}$. The additive complex Gaussian noise is assumed fro noise n_i ($i = 1, 2, c, b, r$), i.e. $n_i \sim \mathcal{CN}(0, N_0)$:

$$P_{i,j} = P_{iT}d_{ij}^{-\alpha} \tag{1}$$

where α is the path-loss exponent.

In the first phase, two users send their signals (s_1 and s_2) to the relay. The relay needs the second phase to send back its signal s_r to the two destinations (D1 and D2). We treat the received signal as collection of three components of signals as below:

$$y_r^{DF} = \sqrt{a_1 P_{1r}} h_{1r} s_1 + \sqrt{a_2 P_{2r}} h_{2r} s_2 + \sqrt{P_{cr}} h_{cr} s_c + n_r \tag{2}$$

In the second phase, the relay sends signal s_r to destinations. By treating signal s_b from the base station. The received signal at user D1 and D2 are given by [25]:

$$y_{r1}^{DF} = \sqrt{P_{rT}} h_{r1} s_r + \sqrt{P_{bT}} h_{b1} s_b + n_1 \tag{3}$$

and

$$y_{r2}^{DF} = \sqrt{P_{rT}} h_{r2} s_r + \sqrt{P_{bT}} h_{b2} s_b + n_2 \tag{4}$$

In Scheme I, it is assumed that to decode D1's signal the relay can eliminate interference from D2 perfectly. For the first phase, the signal to interference plus noise ratio (SINR) at relay to detect signal s_1 is given by:

$$\gamma_{1r} = \frac{\bar{P}_{1r} |h_{1r}|^2}{P_{cr} |h_{cr}|^2 + N_0} \tag{5}$$

where $\bar{P}_{1r} = a_1 P_{1r}$. Similarly, to help the relay decode D2's signal, SINR is given by:

$$\gamma_{2r} = \frac{\bar{P}_{2r} |h_{2r}|^2}{P_{cr} |h_{cr}|^2 + N_0} \tag{6}$$

where $\bar{P}_{2r} = a_2 P_{2r}$. In the second phase of Scheme I, the SINRs are computed at two destinations D1, D2 respectively:

$$\gamma_{r1} = \frac{P_{r1} |h_{r1}|^2}{P_{cr} |h_{b1}|^2 + N_0} \tag{7}$$

and

$$\gamma_{r2} = \frac{P_{r2} |h_{r2}|^2}{P_{cr} |h_{b2}|^2 + N_0} \tag{8}$$

In Scheme II, by treating interference from the CUE, SINR in the first phase is given by [25]:

$$\gamma_{up} = \frac{\bar{P}_{1r} |h_{1r}|^2 + \bar{P}_{2r} |h_{2r}|^2}{P_{cr} |h_{cr}|^2 + N_0} \tag{9}$$

The other computations of SINRs in the second phase at Scheme II are similar as one in Scheme I.

3. ANALYSIS OF OUTAGE PROBABILITY

The main system performance metric, namely outage probability, which is defined as probability to SINR less than the required thresholds γ_{th} . Such outage probability corresponding SINR γ is given by:

$$P_{out} = Pr(\gamma \leq \gamma_{th}) \tag{10}$$

3.1. Scheme I: ideal NOMA

Proposition 1: The outage probability at relay R in phase I or at device at phase II to detect signal from each device is given by [25]:

$$P_{out,ij} = 1 - \frac{Q_{ij}}{P_{kj} \gamma_{th} + Q_{ij}} e^{-\frac{N_0}{Q_{ij}} \gamma_{th}}, \quad Q_{ij} = \begin{cases} \bar{P}_{ij}, & i \in \{1, 2\}; j \in \{r\} \\ P_{ij}, & otherwise \end{cases} \tag{11}$$

Proof: We denote $X = P_{ij} |h_{ij}|^2$, $Y = P_{kj} |h_{kj}|^2 + N_0$ and $Z = X/Y$. The PDFs of these denotations are represented as $f_X(x) = 1/P_{ij} e^{-x/P_{ij}}$ and $f_Y(y) = 1/P_{kj} e^{-y/P_{kj}} e^{N_0/P_{kj}}$. We have PDF $f_Z(x)$:

$$\begin{aligned} f_Z(x) &= \int_{N_0}^{\infty} y f(z y, y) dy \\ &= \frac{N_0}{P_{kj} z + P_{ij}} e^{-\frac{N_0}{P_{ij}} z} + \frac{P_{ij} P_{kj}}{(P_{kj} z + P_{ij})^2} e^{-\frac{N_0}{P_{ij}} z} \end{aligned} \tag{12}$$

In particular, $f_Z(\gamma_{th})$ is given by [25]:

$$f_Z(\gamma_{th}) = \underbrace{\int_0^{\gamma_{th}} \frac{N_0 e^{-\frac{N_0}{P_{ij}} z}}{(P_{kj} z + P_{ij})^2} dz}_{F_{Z1}} + \underbrace{\int_0^{\gamma_{th}} \frac{N_0 e^{-\frac{N_0}{P_{ij}} z}}{P_{kj} z + P_{ij}} dz}_{F_{Z2}} \tag{13}$$

$$F_{Z1} = 1 - \frac{P_{ij}}{P_{kj} \gamma_{th} + P_{ij}} e^{-\frac{N_0}{P_{ij}} \gamma_{th}} - \int_0^{\gamma_{th}} \frac{N_0 e^{-\frac{N_0}{P_{ij}} z}}{P_{kj} z + P_{ij}} dz + \int_0^{\gamma_{th}} \frac{N_0 e^{-\frac{N_0}{P_{ij}} z}}{P_{kj} z + P_{ij}} dz \tag{14}$$

Then, we have outage probability for uplink:

$$F_Z(\gamma_{th}) = 1 - \frac{P_{ij}}{P_{kj} \gamma_{th} + P_{ij}} e^{-\frac{N_0}{P_{ij}} \gamma_{th}} \tag{15}$$

Similarly, we have outage probability for downlink, then we achieve final P_{out} . This completes the proof. Therefore, we examine outage performance of whole system D2D which is formulated by:

$$P_{D2D,out,I} = 1 - (1 - P_{out,1r})(1 - P_{out,2r})(1 - P_{out,r1})(1 - P_{out,r2}) \quad (16)$$

3.2. Scheme II

Proposition 2: In Scheme 2, considering uplink from D2D users to the relay, the outage probability at relay in phase I is given by:

$$\begin{aligned} P_{out,up} &= F(\gamma_{up} \leq \gamma_{thm}) \\ &= 1 + \frac{\bar{P}_{1r}^2}{(\bar{P}_{2r} - \bar{P}_{1r})(P_{cr}\gamma_{thm} + \bar{P}_{1r})} e^{-\frac{N_0}{\bar{P}_{1r}}\gamma_{thm}} \\ &\quad - \frac{\bar{P}_{2r}^2}{(\bar{P}_{2r} - \bar{P}_{1r})(P_{cr}\gamma_{thm} + \bar{P}_{2r})} e^{-\frac{N_0}{\bar{P}_{2r}}\gamma_{thm}} \end{aligned} \quad (17)$$

Proof: We denote $S = \bar{P}_{1r}|h_{1r}|^2 + \bar{P}_{2r}|h_{2r}|^2$, $T = P_{cr}|h_{cr}|^2 + N_0$ and $U = S/T$. We have PDFs ad below:

$$f_S(s) = 1/(\bar{P}_{2r} - \bar{P}_{1r}) e^{-s/\bar{P}_{2r}} - 1/(\bar{P}_{2r} - \bar{P}_{1r}) e^{-s/\bar{P}_{1r}} \quad (18)$$

and

$$f_T(t) = 1/P_{cr}T e^{-t/P_{cr} + N_0/P_{cr}} \quad (19)$$

It is noted that $f_U^{asy}(u)$ is computed by [25]:

$$\begin{aligned} f_U^{asy}(u) &= \int_{N_0}^{\infty} t f(ut, t) dt \\ &= \frac{e^{\frac{N_0}{P_{cr}}}}{P_{cr}(\bar{P}_{2r} - \bar{P}_{1r})} \frac{\bar{P}_{2r}}{u + \frac{\bar{P}_{2r}}{P_{cr}}} n e^{-\frac{u}{\bar{P}_{2r}} - \frac{N_0}{P_{cr}}} + \frac{e^{\frac{N_0}{P_{cr}}}}{P_{cr}(\bar{P}_{2r} - \bar{P}_{1r})} \left(\frac{\bar{P}_{2r}}{u + \frac{\bar{P}_{2r}}{P_{cr}}} \right)^2 e^{-\frac{u}{\bar{P}_{2r}} - \frac{N_0}{P_{cr}}} \\ &\quad - \frac{e^{\frac{N_0}{P_{cr}}}}{P_{cr}(\bar{P}_{2r} - \bar{P}_{1r})} \frac{\bar{P}_{1r}}{u + \frac{\bar{P}_{1r}}{P_{cr}}} N_0 e^{-\frac{u}{\bar{P}_{1r}} - \frac{N_0}{P_{cr}}} - \frac{e^{\frac{N_0}{P_{cr}}}}{P_{cr}(\bar{P}_{2r} - \bar{P}_{1r})} \left(\frac{\bar{P}_{1r}}{u + \frac{\bar{P}_{1r}}{P_{cr}}} \right)^2 e^{-\frac{u}{\bar{P}_{1r}} - \frac{N_0}{P_{cr}}} \end{aligned} \quad (20)$$

Then, $f_U^{asy}(u)$ is rewritten by:

$$\begin{aligned} f_U^{asy}(u) &= \frac{\bar{P}_{2r}N_0}{P_{cr}(\bar{P}_{2r} - \bar{P}_{1r})} \left(\frac{1}{u + \frac{\bar{P}_{2r}}{P_{cr}}} \right) e^{-\frac{N_0}{\bar{P}_{2r}}u} + \frac{\bar{P}_{2r}^2}{P_{cr}(\bar{P}_{2r} - \bar{P}_{1r})} \left(\frac{1}{u + \frac{\bar{P}_{2r}}{P_{cr}}} \right)^2 e^{-\frac{N_0}{\bar{P}_{2r}}u} \\ &\quad - \frac{\bar{P}_{1r}N_0}{P_{cr}(\bar{P}_{2r} - \bar{P}_{1r})} \left(\frac{1}{u + \frac{\bar{P}_{1r}}{P_{cr}}} \right) e^{-\frac{N_0}{\bar{P}_{1r}}u} - \frac{\bar{P}_{1r}^2}{P_{cr}(\bar{P}_{2r} - \bar{P}_{1r})} \left(\frac{1}{u + \frac{\bar{P}_{1r}}{P_{cr}}} \right)^2 e^{-\frac{N_0}{\bar{P}_{1r}}u} \end{aligned} \quad (21)$$

For uplink, we have $P_{out,up}$ as:

$$\begin{aligned} P_{out,up} &= F(\gamma_{up} \leq \gamma_{thm}) = 1 + \frac{\bar{P}_{1r}^2}{(\bar{P}_{2r} - \bar{P}_{1r})(P_{cr}\gamma_{thm} + \bar{P}_{1r})} e^{-\frac{N_0}{\bar{P}_{1r}}\gamma_{thm}} \\ &\quad - \frac{\bar{P}_{2r}^2}{(\bar{P}_{2r} - \bar{P}_{1r})(P_{cr}\gamma_{thm} + \bar{P}_{2r})} e^{-\frac{N_0}{\bar{P}_{2r}}\gamma_{thm}} \end{aligned} \quad (22)$$

This completes the proof. By combining both uplink and downlink between the relay and D2D users, we can achieve the outage probability as below for Scheme II:

$$P_{D2D,out,II} = 1 - (1 - P_{out,up})^2(1 - P_{out,r1})^2(1 - P_{out,r2})^2 \quad (23)$$

4. NUMERICAL RESULTS

We conduct 10^6 iterations for realizing independent channels. The path loss exponent setting to be $\alpha = 4$. We set the distances $d_{12} = 1, d_{1r} = 0.7$ and $d_{2r} = 0.3, \gamma_{th} = \gamma_{thm} = \{3, 5, 7\}$. The power allocation coefficients for NOMA scheme $a_1 = 0.2$ and $a_2 = 0.8$.

Figure 2 and Figure 3 demonstrate the trends of outage probability of Scheme I and Scheme II versus transmit SNR respectively. It can be seen clearly that better outage probability occurs at high SNR region. The lower required threshold $\gamma_{th} = 3$ is reported as the better case. as shown in Figure 2.

Main precise result is recognized when Monte-Carlo and analytical curves are matched very well, which confirm the exactness of derivations. Figure 4 and Figure 5 compare performance of two schemes in terms of outage probability and throughput respectively. It is noted that throughput at the fixed rate R is computed by $T = R(1 - P_{out})$.

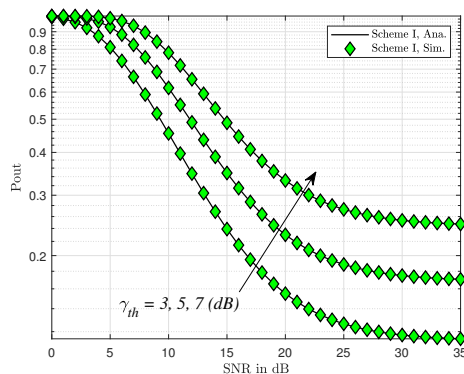


Figure 2. Scheme I: D2D-NOMA's outage performance when varying transmit SNR, with $d_{1r} = 0.7$ and $d_{2r} = 0.3$

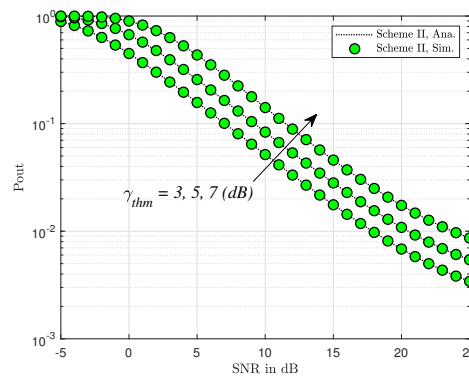


Figure 3. Scheme II: D2D-NOMA's outage performance when varying transmit SNR, with $d_{1r} = d_{2r} = 0.5$

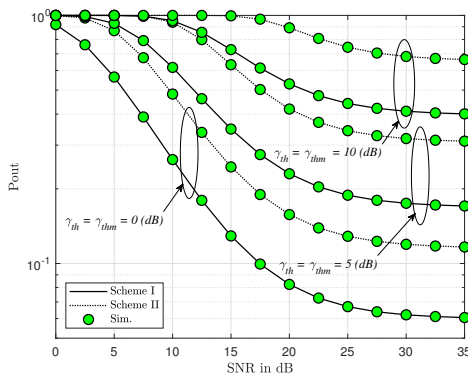


Figure 4. Comparison of outage probability between Scheme I and Scheme II, with $d_{1r} = 0.7$ and $d_{2r} = 0.3$

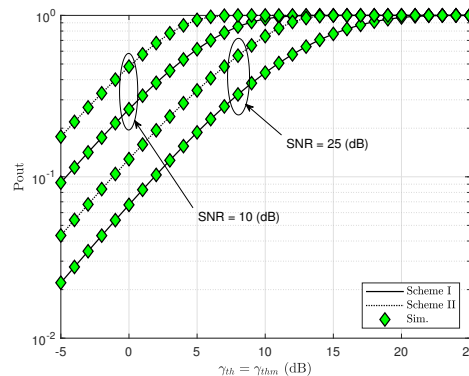


Figure 5. Comparison of throughput between Scheme I and Scheme II, with $d_{1r} = 0.7$ and $d_{2r} = 0.3$

5. CONCLUSION

In this paper, we have studied a D2D based NOMA transmission scheme in the existence of traditional cellular user. To evaluate the proposed schemes, we computed SINRs and then expressions of outage probability are presented. For the two scenarios, we provided comprehensive analysis of the system performances metrics, and derive the closed-form expressions of the outage probability. In the following, we concluded that system performance of D2D-NOMA system relying on Scheme I is better than that using Scheme II. More paired users are employed in D2D-NOMA systems in the future work.

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