**Device-to-Device Link with Best Helping Base Station: Non-Orthogonal Multiple Access Schemes and Performance Analysis**

***Abstract***

It can be studied in this paper that a cooperative non-orthogonal multiple access (NOMA) helps device-to-device (D2D) communication system through base station (BS). In particular, we investigate relay selection scheme as a best channel condition for dedicated devices where a different data transmission demand on each device. The analysis on amplifying-and forward (AF) relay is proposed to evaluate system performance of the conventional cooperative NOMA scheme. Under the realistic assumption of perfect channel estimation, the achievable outage probability of both devices is investigated, and several impacts on system performance are presented. The mathematical formula in closed form of probability has also been found. By implementing Monte-Carlo simulation, the simulation results confirm the accuracy of the derived analytical results. Also, the proposed D2D cooperative NOMA system introduces expected performance on reasonable selected parameters in the moderate signal to noise ratio (SNR) regime.

***Keywords****:* Outage probability, D2D, NOMA, Relay Selection

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**1. Introduction**

In recent times, non-orthogonal multiple access **(**NOMA) has attracted a lot of attention as interesting candidate for 5th generation (5G) networks. It is considered as one of the modern technologies applied in mobile networks for the purpose of improving spectral efficiency (SE). NOMA can be used in a wide variety of areas, especially in the Internet of Things (IoT) applications or wireless sensor networks, where wireless signal processing techniques are required. One of the biggest advantages of NOMA is that it allows multiple devices concurrently severed with the same bandwidth resources, e.g., time slots, frequency or spreading codes, but the power of the devices in the NOMA system must be different.

With a specific goal to enhance the system capacity and improve the dependability of NOMA, cooperative NOMA (C-NOMA) systems have drawn in a few considerations [1]– [4]. The authors in [1] considered the average normal rate for C-NOMA networks. In order to improve the performance of the system, the authors in [2] have studied the technique of combining NOMA with multiple antenna network. In [3], the spectral efficiency is enhanced by the application of NOMA technology to the relay transmission and coordinated directed. In [4], the C-NOMA network was recommended as a new detection scheme. Besides, the value of optimal and near optimal power division parameters was also proposed.

There are a number of studies to improve the transmission power in collaborative communication networks, which indicated in [5] - [7], due to the diversity of radio channels that the devices or relays can be exploited. In fact, the LTE system or other systems are indispensable modern techniques such as device selection techniques, relay selection techniques and scheduling techniques. Therefore, some authors in [8-10] have done research on relay selection techniques that based on the NOMA principle. Results demonstrate that the blending scheme of helpful cooperative relay and NOMA can incredibly enhance the system’s performance. Furthermore, the outage probability in closed-form equation was also found by the authors in [8], and they also proposed a decode-and-forward (DF) relay selection in the two-stage scheme. Also related to the relay selection associated with NOMA, the research works in [9] have achieved good results in finding the asymptotic and approximation equation of the average sum rate in AF mode. In addition, another relay selection method has been applied in [10], which relies on partial channel state information (CSI). The results of the study are shown by the analysis of the outage probability and its asymptotic form. In this way, it is possible to evaluate the influence of the partial relay selection technique on the system’s performance.

It can be seen as a modern technique to make the mobile data offloading for wireless networks, device-to-device (D2D) scheme is proposed to proximity communication. D2D devices deploy in the same frequency band with cellular devices (CUs) under control of the base station (BS) in the cellular network and hence effectively suscess transmission probability can be seen and the pectral efficiency can be improved [11], [12]. Due to limited resource of the battery lifetime budget of devices, it can be affected to the system throughput in D2D underlaying networks. Fortunately, to prong the lifetime of networks, D2D underlaying networks can be used energy harvesting via radio frequency as in works [13]–[14].

Motivated by advantage of D2D and NOMA [15], in this paper, it can be considered that a D2D NOMA in specific mode, where device transfer signal to other device via base station (BS), with relay selection and the influence of Rayleigh fading channels is determined. The primary contributions of this paper are summarized as follows:

* We analyzed and evaluated the performance of the system which incorporated NOMA with relay selection to enhance network performance and spectral efficiency.
* Exact expressions for the outage probability are obtained in closed-form. Also, it can be used as a theoretical basis for the actual NOMA system design.
* These derived expressions are checked via simulation to corroborate the exactness of analysis in NOMA

**2. System model**

The basic model of a downlink cooperative NOMA system is shown in Fig. 1, which includes one mobile device (), two far devices ( and ) and  AF relays node that acts as a base station (BS) (  with ), in which  would like to send its data to and  with the assistance of a relay that it belongs to the set of  AF relays because there is no immediate way among the  with two devices  and , because of they are covered or in a very distant position. We considered all the devices that are equipped with only one antenna, this means that they work in half-duplex (HD) mode. The scheme of cooperative NOMA comprises of two successive equivalent length time slots. As previously mentioned, the selected relay can be resolved through some selection criteria. In this paper, we denote the fading channel coefficient and the additive white Gaussian noise (AWGN) between  and  are and , respectively, the fading channel coefficient and the AWGN between and, are indicated by  and , respectively.  and  are combined together to perform NOMA cooperative system.



*Fig.1. System model of Non-Orthogonal Multiple Access Schemes with Relay Selection*

In the first timeslot, will send its data to all relays node, which is given by as follows:

  (1) in which  and are the power allocation coefficients, and  and  are the data for  and , respectively,  denote the transmit power at . Based on the working fundamental of NOMA, it can be assumed that  with . The received signal at  is given by

  (2)

It can be assumed that the transmit power of  and all relay devices is the same, i.e., . Furthermore, we defined that the average transmit SNR, and the random variables  and  stand for the SNRs of the links  and  , in which  and , respectively.

In the second stage, the signal to interference and noise ratio (SINR) at  of the chosen link for detecting signal  can be communicated as

  (3)

Likewise, the SINR at  for detecting signal  can be computed by applying successive interference cancelation (SIC) and it can be expressed as

  (4)

After receiving the signal from , the relay transmits the signal to  and , in the second stage, where  is the gain factor of the AF relay mode, it can be expressed as

  (5)

Without loss of generality, the received signals at  and  which forwarded by  as follows:

  (6)

  (7)

It is similar to the first time slot, the SINR at  of the link  can be shown as

  (8)

 Considering on the link, the instantaneous SINR at  to remove  and the SINR at  to get its own data, respectively, are given by

  (9)

  (10)

**3. Outage Performance Consideration**

Because it must be satisfied quality-of-service (QoS) requirements, it require consideration on outage performance. So, the devices in the system will be provided a separated SNR threshold, ,. Remembering this, next it will be derived the outage probabilities for the two paired devices  and . For straightforwardness, it can be assumed that all the SINRs threshold of  and are the same, i.e.,.

## 3.1. Outage Probability at D1 for detecting signal

 It can be initially determined the outage probability at the chosen relaying noderelated the signal and, respectively.

The cumulative distribution functions (CDFs) of the random variables and  are, respectively, given by [10]

  (11)

  (12)

where  and  stand for the average SNRs of the links and , respectively.

In light of the NOMA scheme, an outage event occurs if neither the direct transmission nor the relaying transmission succeeds. Therefore, the outage probability (OP) at  can be expressed as

  (13)

where,

  (14)

From (11), it can be also seen that if  the outage always happens, whereas if or  then the outage may occur or not. Accordingly, it can be shown that

  (15)

Note that  denotes as the probability density functions (PDF) of the channel , i.e., .

By displacing (11) and (12) into (15), can be got as in (16) where  indicates the first order modified Bessel function of the second kind [16, eq. (9.6.22)]

  (16)

where 

At the end, the outage probability at  for detecting signal can be achieved as

  (17)

## 3.2.Outage Probability at D2 for detecting signal

Since  requires to get and then remove the signal of  first, the outage probability at  will be occur if the outage probability of the first state and the second state occurred. In this manner, the outage probability at  can be shown as

  (18)

From the outage probability of  for detecting signal , it can be computed that the outage probability for  for detecting signal as follows [10]

  (19)

where 

  (20)

where,

  ( 21)

where .

In next step, the mathematics expression in closed-form for is provided as

  (22)

## 3.3.Best relay selection scheme

In case of detecting  at , it can initially detach signal for and afterward applying SIC for detecting the remaining signal. Accordingly, the outage for collecting  at  can be communicated as below

  (23)

**4. System Performance Analysis**

In this section, to confirm the outage performance, the proposed BS selection strategy for D2D transmission is verified and several corresponding simulations are conducted. The specific values of the adopted simulation parameters are summarized in speciffic result. In this paper, all simulation results are performed by averaging over  random trials, unless mentioned otherwise. Particularly, in this part, our numerical results are provided to evaluate the outage performance of two far devices in NOMA scheme and in several scenarios. The simulation results obtained, which based on the Monte Carlo simulation, in which BPCU is denoted for bit per channel use.



*Fig.2. Outage probability of* , , .

In Fig. 2, the outage performance of the proposed scheme is shown versus the SNR  when varying number of relay node which is in role of helping relay for the near device can be communicatted with the far device. We set power allocation for two far devices in NOMA scheme. From Fig. 1, one can see that the proposed schemes with high number of relay node significantly outperform the scheme use only relay. The performance gap is large when SNR large. As can be seen from such simulation, the proposed optimal scheme has the similar performance as the number of relay is 5 or 15, and this situation confimed that floor outage occure at limited number of relay . Furthermore, Fig. 2 manifest that D2D NOMA can remarkably enhance the outage performance at high transmit SNR at the first device. More importantly, the analytical curves match very well with Monte-Carlo results.



*Fig. 3. Outage probability of* , , .

Similarly in Fig. 3, the outage performance for detecting signal of D2 and performance gap provide the enhanced performance at high number of relay in all values of SNR regime. This is because more relays bring higher diversity gains, which improves the reliability of the cooperative networks. In the low to moderate SNR range, the performance of the proposed scheme declines sharply.



*Fig. 4. Outage probability of detecting* *’s signal as varying threshold SNR,* , .

In Fig. 4 shows outage performance of detecting signal of far device denoted as  as changing the threshold SNR. In this case, the analysis lines of the outage probability match coincides with the simulation lines. It can be seen that the performance of such D2D NOMA with low data rate produce lower outage event. Similarly trend can be seen in Fig. 5 for detecting signal of .



*Fig.5. Outage probability of detecting ’s signal as varying threshold SNR,* , .



*Fig.6. Comparison of probability between  and ,* , .

It is shown that the number of relay node in the considered networks which strongly affect on the outage performance at all values of SNR regime. With the number of relay node is selected and at specific SNR at source device, the outage probability for  and  is the same. Another observation is that the performance of two far device is differ value at high SNR.

Fig. 7 plots the outage probability of overal D2D system as considering detection of two signal for two devices with different number of relay node. One can observe that adjusting the number of relay node in D2D NOMA will affect the outage behaviors of overall system. As the value of SNR increases, the outage will be improved remarkably. It is worth noting that based on the application requirements of different scenarios, the setting of reasonable number of relay in D2D NOMA is prerequisite.



*Fig.7. Outage event of overall D2D NOMA,* , .

**5. Conclusion**

In this paper, a cooperative non-orthogonal multiple access (NOMA) helps device-to-device (D2D) communication system. Besides, the relay selection scheme as a best channel condition for dedicated devices was also investigated. The performance of the proposed model is evaluated by considerations on the outage probability in closed-form expressions, the power distribution coefficient and the system outage. Our results are verified by simulation results. From the exact outage probability expression and simulation results, it is easy to realize that the quantity of relay node and the threshold rate have consequences on system performance. Our suggested scheme can dramatically increase the spectral efficiency of the system via a cooperative D2D-NOMA scheme.

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