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Device-to-Device Relay Cooperative Transmission Based on Network Coding

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Abstract

Due to the advantages of low transmit power consumption, high spectral efficiency and extended system coverage, Device-to-Device (D2D) communication has drawn explosive attention in wireless communication field. Considering that intra-cell interference caused between cellular signals and D2D signals, in this paper, a network coding-based D2D relay cooperative transmission algorithm is proposed. Under D2D single-hop relay transmission mode, cellular interfering signals can be regarded as useful signals to code with D2D signals at D2D relay node. Using cellular interfering signals and network coded signals, D2D receiver restores the D2D signals to achieve the effect of interference suppression. Theoretical analysis shows that, compared with Amplify-and-forward (AF) mode and Decode-and-forward (DF) mode, the proposed algorithm can dramatically increase the link achievable rate. Furthermore, simulation experiment verifies that by employing the proposed algorithm, the interference signals in D2D communication can be eliminated effectively, and meanwhile the symbol error rate (SER) performance can be improved.

Keywords: Device-to-Device (D2D), single-hop relay transmission, network coding, relay cooperative

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1. Introduction

As a novel communication technology [1, 2], Device-to-Device (D2D) communication makes two adjacent terminal users communicate directly without requiring forward through base station. In addition, D2D communication can achieve higher transmission rate with lower transmit power, effectively reducing the burden of base station and improving the network throughput [3]. Jo and Maksymyuk et al. introduce D2D communication to heterogeneous mobile network, achieving a sufficient increase in network capacity [4]. Besides heterogeneous mobile network, D2D communication has been more and more widely applied to cellular network [5, 6]. In cellular network, D2D users need multiplexing the spectrum resources of cellular network to improve the spectral utilization [7, 8], to ease the shortage of spectrum resources of cellular network in a certain extent. Moreover, D2D communication can improve the communication quality of the cell edge users, expand the communication coverage, and improve the robustness of the network infrastructure. For the advantages above, D2D communication has become one of the key techniques in the next generation wireless communication.

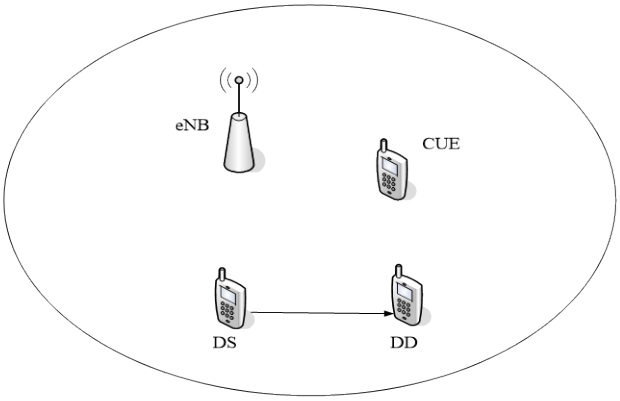
When two D2D devices are far apart, the link between these two D2D devices may suffer from low signal to interference plus noise ratio (SINR), leading to unreliable D2D communication. In this case, relay can be considered to implement cooperative communication during D2D transmission [9-11]. Since the path loss is much smaller for the short range communication, cooperative D2D communication can offer better performances in terms of energy efficiency, throughput and robustness [12, 13]. However, because D2D devices will occupy the spectrum resource of cellular user, cooperative D2D communication causes complex interference among D2D signals and cellular signals, which may decrease the system performance dramatically.

The concept of network coding was first proposed for wired networks to enable the information flow of a multicast graph to reach the maximum capacity, which is defined by the max-flow min-cut theorem [14]. Subsequently, it has been proven that network coding also has the potential to greatly improve the throughput of wireless networks [15]. For cooperative D2D communication, network coding can increase further network performance gain [16, 17], since packets from the same or different information flows at relays can be encoded and transmitted together. Moreover, network coding technology can be used in D2D communication to eliminate signal interference between D2D users and cellular users when spectrum sharing [18].

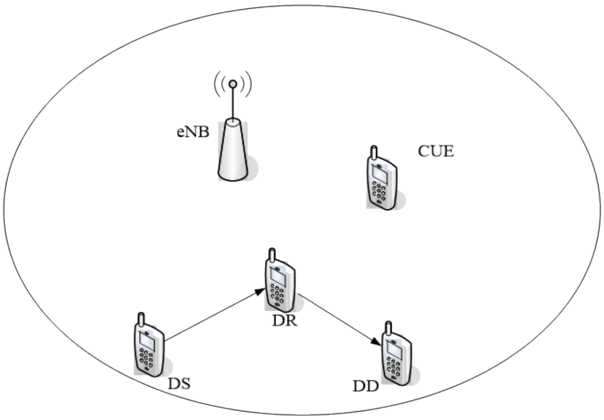
To further eliminate intra-cell interference caused between cellular signals and D2D signals, a D2D relay cooperative transmission algorithm based on network coding is proposed in this paper. Specifically, D2D relay node encodes the received D2D signals and interfering signals of cellular users by network coding [19, 20], and then sends the coded signals to D2D receiver in the next slot. Based on the cellular interference signal and network coded signal, D2D receiver restores the D2D signal. Compared with non-cooperative D2D transmission, the algorithm eliminates the interference of cellular users, and improves the achievable rate of D2D links.

2. Non-cooperative D2D Transmission and Cooperative D2D Transmission

According to whether there is relay cooperation, D2D communication can be divided into non-cooperative and cooperative transmission mode [21, 22], as shown in **Fig. 1**. In particular, DS and DD can be combined as one D2D communication pair as DS denotes D2D sender and DD denotes D2D receiver. As well, CUE is conducted as a cellular user, and DR as a relay node for D2D transmission. When the D2D communication channel conditions are good enough (in a relatively short distance), DS can directly and reliably communicate with DD under the control of the base station, achieving non-cooperative D2D transmission, as shown in **Fig. 1** (a). Alternatively, while the distance of D2D pair is longer, that is the direct communication of DS and DD can not reach the standard of reliable communication, a reliable relay DR is required to carry cooperative communication, as in **Fig. 1** (b).



(a) Non-cooperative D2D transmission mode



(b) Cooperative D2D transmission mode

Fig. 1. D2D communication in cellular network

Based on relay forward mode, traditional cooperative transmission scheme can be divided into amplify-and-forward, decode-and-forward, and encoding-and-forward [23-25]. In cooperative D2D transmission mode of **Fig. 1** (b), D2D relay node DR would inevitably be interfered by cellular signals as adopting amplify-and-forward, decode-and-forward, or encoding-and-forward. It will make the quality of D2D communication decline, meanwhile affecting the achievable rate of D2D link. At the same time, cellular users also would be interfered by D2D signals. If the interference of D2D transmission to cellular communication is controlled through D2D transmitting power, the transmission rate of D2D communication would inevitably be affected, while user experiences will also be affected. Thus in this paper, a D2D relay cooperative transmission algorithm based on network coding is proposed, in which D2D receiver can recover the D2D signal by the cellular interference signal and network coded signal.

3. D2D Relay Cooperative Transmission Algorithm Based on Network Coding

In wireless channel transmission, the path loss will become larger with the increase of transmission distance [26]. As the transmission distance of D2D pair is greater than a certain threshold, the channel condition will be turned into unreliable. Under the circumstances, the D2D relay can be adopted to achieve reliable communication. To be specific, we can use the method introduced in [27] to select the optimal D2D relay DR from the nearby idle CUEs. First set a range around D2D sender DS and D2D receiver DD as a selection area (SA). And then select an idle CUE located inside SA as a D2D relay, to ensure that the D2D cooperative communication between DS and DD can obtain the largest SINR.

In this paper, considering the single-hop relay mode, D2D users multiplex the uplink resources of cellular users. Due to the communication distance of D2D is much less than that among cellular users and base station, and the transmit power of D2D senders is almost the same as that of CUE, the interference of D2D senders can be neglected for base station, besides the interference of CUE to D2D pairs.

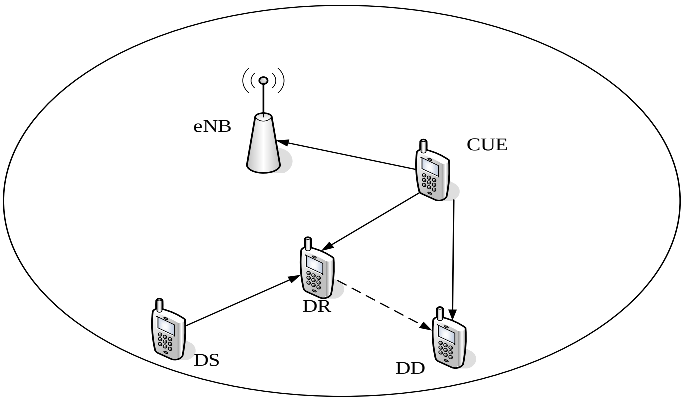


Fig. 2. D2D relay cooperative transmission model in cellular network

Fig. 2 illustrates the D2D relay cooperative transmission model in cellular network. Similarly to traditional cooperative transmission, amplify-and-forward (AF) mode, decode-and-forward (DF) mode and network coding forward (NC forward) mode can all be employed in D2D relay DR of cellular network. As D2D communication multiplexes cellular uplink spectrum resources, D2D relay DR and receiver DD will receive the interference signals of cellular user CUE. In particular, in the first time slot, cellular user CUE sends signal x to base station eNB, and meanwhile DS transmits D2D signal s by using cellular uplink spectrum. Consequently, relay node DR and D2D receiver DD will receive

$$y_{DR} = \sqrt{P_{DS}} h_{DS\_DR} s + \sqrt{P_{CUE}} h_{CUE\_DR} x + n_{DR} \tag{1}$$

$$y_{DD} = \sqrt{P_{CUE}} h_{CUE\_DD} x + n_{DD} \tag{2}$$

where P_{DS} denotes the transmit power of DS, and P_{CUE} the transmit power of CUE. h_{DS_DR}, h_{CUE_DR} and h_{CUE_DD} are the channel fading coefficients of the channel DS to DR, CUE to DR and CUE to DD. n_{DR} and n_{DD} are Gaussian white noise, satisfying $CN\left(0, N_0\right)$ distribution. In the second time slot, relay node DR will have different operation on y_{DR} according to the specific mode adopted. Particularly, D2D relay cooperative algorithm based on network coding is referred to as network coding forward mode briefly.

Amplify-and-forward (AF) mode:

DR amplifies and forwards the received signal y_{DR} to DD. Thus, DD will receive the signal

$$y'_{DD\_AF} = \sqrt{P_{DR}} h_{DR\_DD} \beta y_{DR} + n'_{DD} \tag{3}$$

where P_{DR} is the transmit power of relay DR, and h_{DR_DD} is the channel fading coefficient of DR to DD. Additionally, n'_{DD} means Gaussian noise, and $\beta = \sqrt{P_{DS} \Big/ \left(\left| h_{DS\_DR} \right|^2 P_{DS} + N_0 \right)}$ denotes amplification coefficient. Combining Eqs. (1) and (3), it follows that

$$y'_{DD\_AF} = \beta \sqrt{P_{DS} P_{DR}} h_{DS\_DR} h_{DR\_DD} s + \beta \sqrt{P_{CUE} P_{DR}} h_{CUE\_DR} h_{DR\_DD} x + n \tag{4}$$

where $n = \beta \sqrt{P_{DR}} h_{DR\_DD} n_{DR} + n'_{DD}$.

By maximum likelihood detection, D2D receiver DD can retrieve signal

$$(\hat{s},\ \hat{x})_{DD} = \arg \min_{s \in A_s, x \in A_x} \left\{ \left\| y'_{DD\_AF} - \beta \sqrt{P_{DS} P_{DR}} h_{DS\_DR} h_{DR\_DD} s - \beta \sqrt{P_{CUE} P_{DR}} h_{CUE\_DR} h_{DR\_DD} x \right\|^2 \right\} \tag{5}$$

Decode-and-forward (DF) mode:

In the second time slot, relay node DR will demodulated and decode the signal s, and then re-encode the retrieved information and forward the re-encoded signal s'. DD will receive the signal

$$y'_{DD\_DF} = \sqrt{P_{DR}} h_{DR\_DD} s' + \sqrt{P_{CUE}} h_{CUE\_DR} x + n'_{DD} \tag{6}$$

Similarly, D2D receiver DD employs maximum likelihood detection to recover

$$(\hat{s},\ \hat{x})_{DD} = \arg \min_{s \in A_s, x \in A_x} \left\{ \left\| y'_{DD\_DF} - \sqrt{P_{DR}} h_{DR\_DD} s - \sqrt{P_{CUE}} h_{CUE\_DR} x \right\|^2 \right\} \tag{7}$$

Network coding (NC) forward mode:

Because of fading coefficients $h_{DS\_DR} \neq h_{CUE\_DR}$ and $P_{DS} \neq P_{CUE}$, relay node DR recovers signal $\hat{s}$ and $\hat{x}$ by adopting maximum likelihood detection in the second time slot

$$\left(\hat{s},\ \hat{x}\right)_{DR} = \arg \min_{s \in A_s, x \in A_x} \left\{ \left\| y_{DR} - \sqrt{P_{DS}} h_{DS\_DR} s - \sqrt{P_{CUE}} h_{CUE\_DR} x \right\|^2 \right\} \tag{8}$$

In the meantime, D2D receiver DD can achieve the detected signal

$$(\hat{x})_{DD} = \arg \min_{x \in A_x} \left\{ \left\| y_{DD} - \sqrt{P_{CUE}} h_{CUE\_DD} x \right\|^2 \right\} \tag{9}$$

But if the constraint about the fading coefficients $h_{DS\_DR} \neq h_{CUE\_DR}$ and $P_{DS} \neq P_{CUE}$ cannot be guaranteed, we can employ complex field network coding to ensure that relay node DR can recover the signal $\hat{s}$ and $\hat{x}$ simultaneously. Firstly, the agreed coefficients θ_{DS} and θ_{CUE} drawn from the complex field are assigned to DS and CUE. Then relay node DR and D2D receiver DD will receive

$$y_{DR} = \sqrt{P_{DS}} h_{DS\_DR} \theta_{DS} s + \sqrt{P_{CUE}} h_{CUE\_DR} \theta_{CUE} x + n_{DR} \tag{10}$$

$$y_{DD} = \sqrt{P_{CUE}} h_{CUE\_DD} \theta_{CUE} x + n_{DD} \tag{11}$$

Even though $h_{DS\_DR} = h_{CUE\_DR}$ and $P_{DS} = P_{CUE}$, relay node DR can adopt maximum likelihood detection to recover

$$\left(\hat{s},\ \hat{x}\right)_{DR} = \arg \min_{s \in A_s, x \in A_x} \left\{ \left\| y_{DR} - \sqrt{P_{DS}} h_{DS\_DR} \theta_{DS} s - \sqrt{P_{CUE}} h_{CUE\_DR} \theta_{CUE} x \right\|^2 \right\} \tag{12}$$

Also, D2D receiver DD can recover the detected signal

$$(\hat{x})_{DD} = \arg \min_{x \in A_x} \left\{ \left\| y_{DD} - \sqrt{P_{CUE}} h_{CUE\_DD} \theta_{CUE} x \right\|^2 \right\} \tag{13}$$

Furthermore, relay node DR encodes the detected signal $\hat{s}$ and $\hat{x}$ by network coding to gain the coded signal $\hat{s} + \hat{x}$. In the second time slot, DR transmits the coded signal $\hat{s} + \hat{x}$ to destination node DD

$$y'_{DD\_NC} = \sqrt{P_{DR}} h_{DR\_DD} \left(\hat{s} + \hat{x}\right) + n'_{DD} \tag{14}$$

According to the received signal y'_{DD_NC}, D2D receiver DD achieves the coded signal by maximum likelihood detection

$$(\hat{s}+\hat{x})_{DD} = \arg \min_{s\in A_s, x\in A_x} \left\{ \left\| y'_{DD\_NC} - \sqrt{P_{DR}} h_{DR\_DD} \left(s+x\right) \right\|^2 \right\} \tag{15}$$

Based on the detected signal $\hat{x}$ in the first time slot, D2D receiver DD can recover the D2D signal $\hat{s}$ by encoding signal $\hat{x}$ and $\hat{s}+\hat{x}$ to realize reliable D2D communication.

4. Performance Analysis

In this paper, the link achievable rate, outage probability and symbol error rate (SER) have been simulated as D2D relay node adopts amplify-and-forward and decode-and-forward. Moreover, the performances above will be compared with that as D2D relay node employs D2D relay cooperative algorithm based on network coding.

4.1 Link Achievable Rate

Amplify-and-forward (AF) mode:

Considering the two time slots of AF mode are divided equally during signal transmission, the achievable link rate of D2D transmission [28] can be expressed as

$$R_{AF} = 1/2 \log_2 \left(1+\gamma_{RD\_AF}\right) \tag{16}$$

where γ_{RD_AF} is instantaneous SINR of link DR to DD. According to the interference analysis above, γ_{RD_AF} can be rewritten as

$$\gamma_{RD\_AF} = \frac{\beta^2 P_{DS} P_{DR} \left|h_{DS\_DR}\right|^2 \left|h_{DR\_DD}\right|^2}{\beta^2 P_{CUE} P_{DR} \left|h_{CUE\_DR}\right|^2 \left|h_{DR\_DD}\right|^2 + N_0'} \tag{17}$$

where $N_0' = \left(\beta^2 P_{DR} \left|h_{DR\_DD}\right|^2 + 1\right) N_0$.

Decode-and-forward (DF) mode:

In the first time slot, when DS transmits the D2D signal s to DR, cellular user CUE also sends a signal to eNB. During the signal transmission, since CUE share the cellular spectrum resources with the D2D user pair, DR and DD will receive the interference signal from CUE. Via analysis, the instantaneous SINR of link DS to DR can be expressed as

$$\gamma_{SR\_DF} = \frac{P_{DS} \left|h_{DS\_DR}\right|^2}{P_{CUE} \left|h_{CUE\_DR}\right|^2 + N_0} \tag{18}$$

In the second time slot, when DR sends a signal to DD, DD also receives the interference signal from CUE. The instantaneous SINR of link DR to DD can be expressed as

$$\gamma_{RD\_DF} = \frac{P_{DR} \left|h_{DR\_DD}\right|^2}{P_{CUE} \left|h_{CUE\_DD}\right|^2 + N_0} \tag{19}$$

Thus in DF mode, the link achievable rate of D2D transmission can be written as

$$R_{DF} = \min\left\{1/2\log_2\left(1+\gamma_{SR\_DF}\right),\ 1/2\log_2\left(1+\gamma_{RD\_DF}\right)\right\} \tag{20}$$

Network coding (NC) forward mode:

In this mode, the operation of network coding is carried out at DR to make the interference signal effective. At the same time, the cellular signal is eliminated at DD, which virtually eliminates the interference of cellular signals to improve SINR significantly. In the first time slot, the instantaneous SINR of link DS to DR can be expressed as

$$\gamma_{SR\_NC} = \frac{P_{DS}\left|h_{DS\_DR}\right|^2 + P_{CUE}\left|h_{CUE\_DR}\right|^2}{N_0} \tag{21}$$

In the second time slot, the instantaneous SINR of link DR to DD can be written as

$$\gamma_{RD\_NC} = \frac{P_{DR}\left|h_{DR\_DD}\right|^2}{N_0} \tag{22}$$

Thus, in NC forward mode, the link achievable rate of D2D transmission can be calculated as

$$R_{NC} = \min\left\{1/2\log_2\left(1+\gamma_{SR\_NC}\right),\ 1/2\log_2\left(1+\gamma_{RD\_NC}\right)\right\} \tag{23}$$

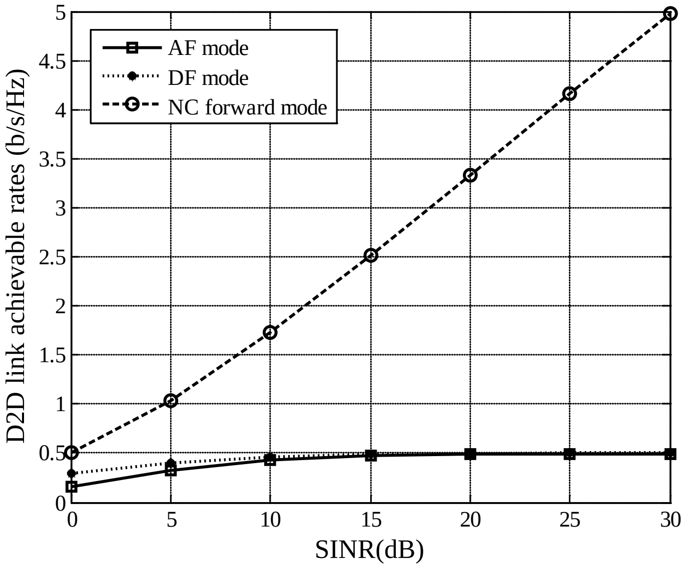


Fig. 3. D2D link achievable rates of the three forward modes

During the simulation, we choose $P_{DS} = P_{CUE} = P_{DR} = 1$. The D2D link achievable rates under AF mode, DF mode and NC forward mode are shown in **Fig. 3**. Obviously, with better link conditions (larger SINR), D2D link rate under NC forward mode is significantly higher than that of AF mode and DF mode, which indicates that NC forward mode has great advantages in improving D2D link rate.

4.2 Outage Probability and Symbol Error Rate

When the instantaneous channel capacity, i.e., the link achievable rate is less than the information rate *R*, the D2D transmission will be interrupted. Define $\gamma_1 = \left|h_{DS\_DR}\right|^2 \Big/ N_0$, $\gamma_2 = \left|h_{DR\_DD}\right|^2 \Big/ N_0$, $\gamma_3 = \left|h_{CUE\_DR}\right|^2 \Big/ N_0$, $\gamma_4 = \left|h_{CUE\_DD}\right|^2 \Big/ N_0$, and also assume $P_{DS} = P_{CUE} = P_{DR} = 1$. In this section, the outage probabilities of three forward modes are analyzed, and the simulation experiments of SER are carried out.

AF mode:

The outage probability of D2D user pair is

$$P_{AF}^{out} = P\left(R_{AF} < R\right) = P\left[1/2\log_2\left(1+\gamma_{RD\_AF}\right) < R\right] \tag{24}$$

which can be reduced as

$$P_{AF}^{out} = P\left(R_{AF} < R\right) = P\left[\gamma_{RD\_AF} < 2^{2R} - 1\right] \tag{25}$$

Combining Eqs. (17) with (25), we can obtain that

$$\begin{aligned} P_{AF}^{out} &= P\left(\frac{\gamma_1\gamma_2}{\gamma_2\gamma_3 + \gamma_1 + \gamma_2 + 1} < 2^{2R} - 1\right) \\ &= \int_0^\infty N_0 e^{-N_0\gamma_3} \int_a^a N_0 e^{-N_0\gamma_2} \int_0^{\frac{a(\gamma_2\gamma_3+\gamma_2+1)}{\gamma_2-a}} N_0 e^{-N_0\gamma_1} d\gamma_1 d\gamma_2 d\gamma_3 \\ &\quad + \int_0^\infty N_0 e^{-N_0\gamma_3} \int_0^a N_0 e^{-N_0\gamma_2} d\gamma_2 d\gamma_3 \\ &= \int_0^\infty N_0 e^{-N_0\gamma_3} \int_0^a N_0 e^{-N_0\gamma_2} d\gamma_2 d\gamma_3 \end{aligned} \tag{26}$$

where $a = 2^{2R} - 1$.

DF mode:

The outage probability of D2D terminal is given by

$$\begin{aligned} P_{DF}^{out} &= P\left(R_{DF} < R\right) \\ &= P\left[\min\left\{1/2\log_2\left(1+\gamma_{SR\_DF}\right),\ 1/2\log_2\left(1+\gamma_{RD\_DF}\right)\right\} < R\right] \\ &= 1 - P\left[\min\left\{1/2\log_2\left(1+\gamma_{SR\_DF}\right),\ 1/2\log_2\left(1+\gamma_{RD\_DF}\right)\right\} \geq R\right] \\ &= 1 - P\left[1/2\log_2\left(1+\gamma_{SR\_DF}\right) \geq R \text{ and } 1/2\log_2\left(1+\gamma_{RD\_DF}\right) \geq R\right] \\ &= 1 - P\left[1/2\log_2\left(1+\gamma_{SR\_DF}\right) \geq R\right] P\left[1/2\log_2\left(1+\gamma_{RD\_DF}\right) \geq R\right] \end{aligned} \tag{27}$$

Take γ_{SR_DF} of Eq. (18) and γ_{RD_DF} of Eq. (19) into Eq. (27), we can obtain that

$$
\begin{aligned}
P_{DF}^{out} &= 1-P\left(\frac{\gamma_1}{\gamma_3+1}\geq 2^{2R}-1\right)P\left(\frac{\gamma_2}{\gamma_4+1}\geq 2^{2R}-1\right)\\
&= P\left(\frac{\gamma_1}{\gamma_3+1}< 2^{2R}-1\right)+P\left(\frac{\gamma_2}{\gamma_4+1}< 2^{2R}-1\right)-P\left(\frac{\gamma_1}{\gamma_3+1}< 2^{2R}-1\right)P\left(\frac{\gamma_2}{\gamma_4+1}< 2^{2R}-1\right)\\
&= \int_0^a N_0 e^{-N_0\gamma_3}\int_0^{a(\gamma_3+1)} N_0 e^{-N_0\gamma_1}d\gamma_1 d\gamma_3+\int_0^a N_0 e^{-N_0\gamma_4}\int_0^{a(\gamma_4+1)} N_0 e^{-N_0\gamma_2}d\gamma_2 d\gamma_4\\
&\quad -\int_0^a N_0 e^{-N_0\gamma_3}\int_0^{a(\gamma_3+1)} N_0 e^{-N_0\gamma_1}d\gamma_1 d\gamma_3\int_0^a N_0 e^{-N_0\gamma_4}\int_0^{a(\gamma_4+1)} N_0 e^{-N_0\gamma_2}d\gamma_2 d\gamma_4
\end{aligned}
\tag{28}
$$

NC forward mode:

$$
\begin{aligned}
P_{NC}^{out} &= P\left(R_{NC}<R\right)\\
&= P\left[\min\left\{1/2\log_2\left(1+\gamma_{SR\_NC}\right),\ 1/2\log_2\left(1+\gamma_{RD\_NC}\right)\right\}<R\right]\\
&= 1-P\left[1/2\log_2\left(1+\gamma_{SR\_NC}\right)\geq R\right]P\left[1/2\log_2\left(1+\gamma_{RD\_NC}\right)\geq R\right]
\end{aligned}
\tag{29}
$$

Take γ_{SR_NC} of Eq. (21) and γ_{RD_NC} of Eq. (22) into Eq. (29), the outage probability in NC forward mode can be given as

$$
\begin{aligned}
P_{NC}^{out} &= 1-P\left(\gamma_1+\gamma_3\geq 2^{2R}-1\right)P\left(\gamma_2\geq 2^{2R}-1\right)\\
&= \int_0^a N_0 e^{-N_0\gamma_1}\int_0^{a-\gamma_1} N_0 e^{-N_0\gamma_3}d\gamma_3 d\gamma_1+\int_0^a N_0 e^{-N_0\gamma_2}d\gamma_2\\
&\quad -\int_0^a N_0 e^{-N_0\gamma_1}\int_0^{a-\gamma_1} N_0 e^{-N_0\gamma_3}d\gamma_3 d\gamma_1\int_0^a N_0 e^{-N_0\gamma_2}d\gamma_2
\end{aligned}
\tag{30}
$$

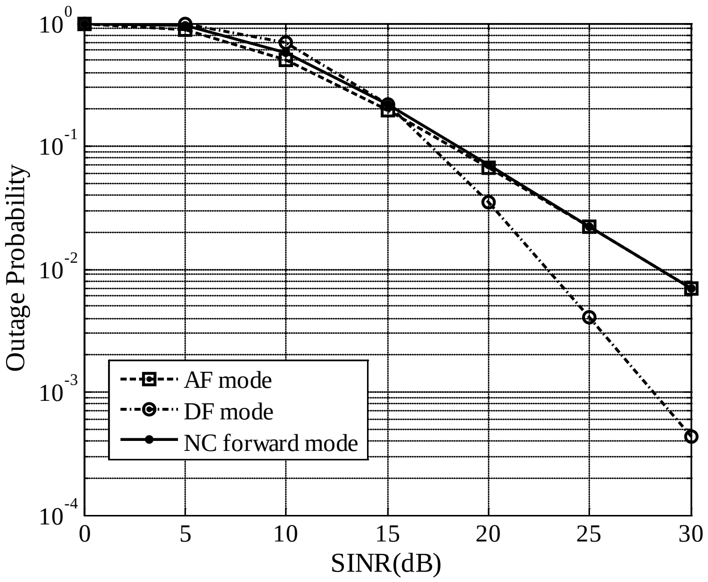


Fig. 4. Outage Probability of the three forward modes

According to Eqs. (26), (28) and (30), the numerical values of the outage probabilities of three forward modes can be calculated by MATLAB. Concretely, the information rate $R = 1.5$ bps is employed in our simulation. Upon the numerical values, the corresponding figure of outage probability vs. SINR can be plotted, as shown in **Fig. 4**. No matter how large SINR is, NC forward mode almost has the same outage probability as AF mode. However, under better link conditions (larger SINR than 15dB), the outage probabilities of NC forward mode and AF mode are larger than that of DF mode obviously.

Finally, SER performances are compared as D2D relay node adopts AF mode, DF mode and NC forward mode separately. The SER comparison of NC forward mode is shown in **Fig. 5**, as using modulations of different orders. To achieve the same SER performance (e.g., 10^{-2} SER), the required SINR values under BPSK, QPSK, 8PSK and 16PSK modulations with NC forward mode are 19.8 dB, 26.88 dB, 33.85 dB, and 40.96 dB, respectively. As seen, NC forward mode with BPSK modulation can reach better SER performance. For these reasons, BPSK modulation is adopted to compare SER performances of AF mode, DF mode and NC forward mode.

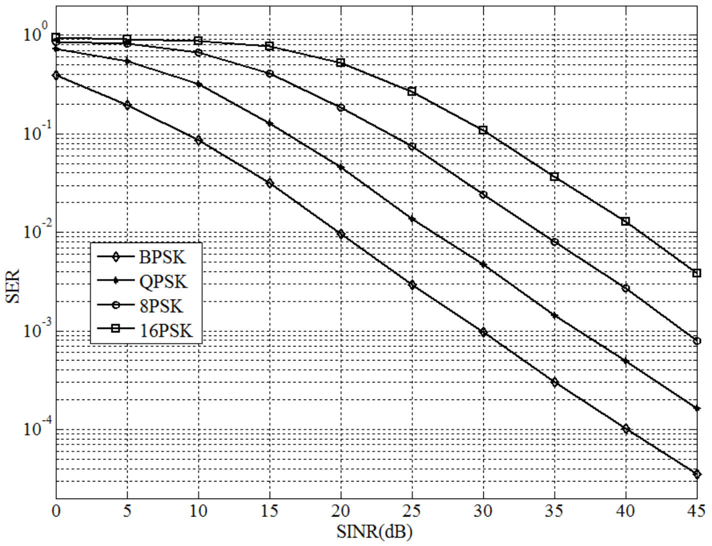


Fig. 5. SER Performances of NC forward mode as adopting BPSK, QPSK, 8PSK and 16PSK modulation

In NC forward mode and DF mode, D2D relay node will decode the received symbols to recover the D2D information bits. In contrast, AF mode only amplifies and forwards the received symbols at D2D relay node, meanwhile inevitably amplifying symbol errors and noises. So theoretically, NC forward mode and DF mode have better performances in SER. SER performance comparison of AF mode, DF mode and NC forward mode is shown in **Fig. 6**. As seen, AF mode has larger SER except under very small SINR condition, and alternatively compared with AF mode, NC forward mode and DF mode have advantages in SER performances. The simulation results verify the correctness of the theoretical analysis above.

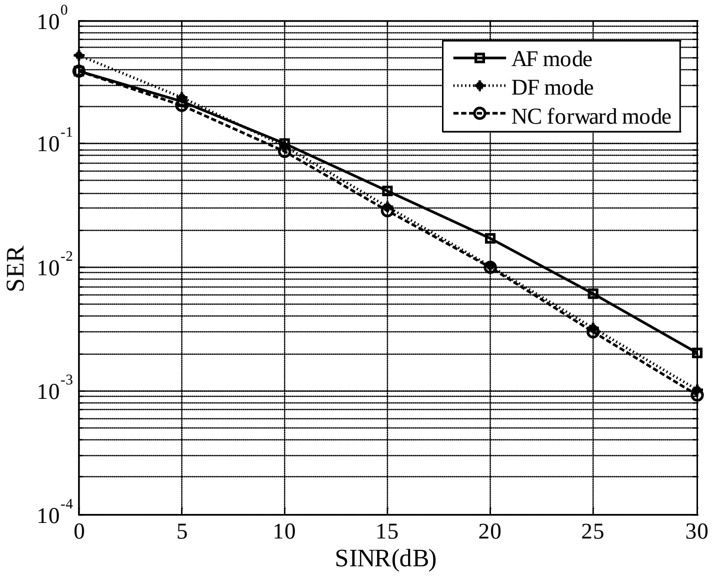


Fig. 6. SER Performances of the three forward modes

5. Conclusion

In this paper, the D2D relay cooperative transmission algorithm based on network coding is proposed, in which using cellular interfering signals and network coded signals, D2D receiver restores the D2D signals to achieve the effect of interference suppression. Theoretical analysis shows that compared with AF mode and DF mode, the proposed algorithm can increase the link achievable rate dramatically. Furthermore, simulation experiment verifies that by employing the proposed algorithm, the interference signals in D2D communication can be eliminated effectively, and meanwhile its SER performance can be improved.

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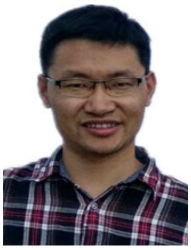

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