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PAPERS

Differential STBC NOMA: A new approach to downlink cooperative NOMA

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Due to the ability of massive connectivity, large bandwidth, and low latency, the non-orthogonal multiple access (NOMA) is considered the best approach for the 5th generation and beyond. However, the system performance is declined when the number of users is increased as each user will experience a great number of successive interface cancelations (SIC) in the downlink. To improve system performance, the NOMA is combined with cooperative communication which gives more spectral efficiency and fairness as compared to non-cooperative NOMA. Furthermore, space-time block code (STBC)-cooperative NOMA-based users experienced less SIC as compared to conventional CNOMA. This paper evaluates the performance of differential STBC-CNOMA with keeping in mind the imperfect SIC, channel state information (CSI), and timing synchronization between distributed cooperating users. The simulations results show that differential STBC-CNOMA gives high performance in terms of outage probability and sum rate analysis as compared to simple STBC-NOMA and conventional CNOMA. Hence, the differential STBC-CNOMA seems to be a better and more effective solution to enhance system performance.

K e y w o r d s: CNOMA, differential STBC, SIC, STBC

1 Introduction

Radio access technologies for cellular mobile communications are typically characterized by orthogonal and non-orthogonal multiple access schemes [1–4]. Orthogonal multiple access schemes consist of FDMA, TDMA, CDMA, and OFDMA [1, 2] standardized by the 3rd Generation Partnership Project (3GPP), orthogonal multiple access based on OFDMA or single carrier SC-FDMA is adopted. Orthogonal multiple access was a reasonable choice for achieving good system-level throughput performance in packet-domain services with simple single-user detection. In these conventional multiple access schemes, different users are allocated to orthogonal resources in either the time, frequency, or code domain to avoid or alleviate inter-user interference. In this way, multiplexing gain can be achieved with reasonable complexity [1]. Table 1 presents the orthogonal schemes in detail. The main drawback of these OMA-based systems is the limited number of served users [5] due to dependencies described in Tab. 1.

On the other side, one of the main requirements of the next generation 5G is to increase the spectrum efficiency by at least three times compared to the existing long-term evolution (LTE) [5–7]. This will pose high capacity and data rate requirements on the networks [6]. The researchers and telecommunication regulatory authorities are focusing on 5G to tackle this huge amount of network traffic. So, current OMA schemes cannot cover the massive connectivity requirement of the next generation 5G and beyond technologies B5G. Thus, to support the exponential growth of traffic, multiple access (MA) techniques for 5G are considered as one of the most important research challenges [8].

Therefore, for 5G and B5G, NOMA is considered to be the multiple access technique, which exploits the non-orthogonal resource allocation on the cast of improved receiver ISI, causing a more complex receiver design with successive interference cancellation (SIC) [8, 9]. To mitigate this high ISI, each NOMA receiver uses SIC. Figure 1 shows the working of SIC at the receiver side. As shown by the figure each user detects its signal and forwards the signal to the next user. This process is also called the decoding and subtraction process.

NOMA assigns the same physical resources as OMA but with different powers, the result of which is massive connectivity, high reliability, low latency, high throughput, and improved fairness [9, 10]. To further improve the massive connectivity, spectral efficiency, fairness, and less energy consumption performances of NOMA, it is combined with the cooperative communication concept, known as conventional cooperative NOMA (CCNOMA) [11, 12]. In the CCNOMA system, the user with better channel conditions supports weak channel condition users by serving as relays, since the reliability of the weak user is increased. With all its advantages, the main disadvantage of CNOMA is that it requires more number of SICs at the receiver side, causing computational overhead and

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Table 1.

Generations	Multiple accesss techniques	Nature of resource allocation	Drawbacks
1G	FDMA	Orthogonal	Dependency on frequency
2G	TDMA	Orthogonal	Dependency on time slot
3G	CDMA	Orthogonal	Dependency on code length
4G	OFDMA for downlink	Orthogonal	Dependency on frequency
4G	SC-FDMA for uplink [2]	Orthogonal	and time slots
5G and beyond	NOMA	Non-orthogonal	Discussed in the paper

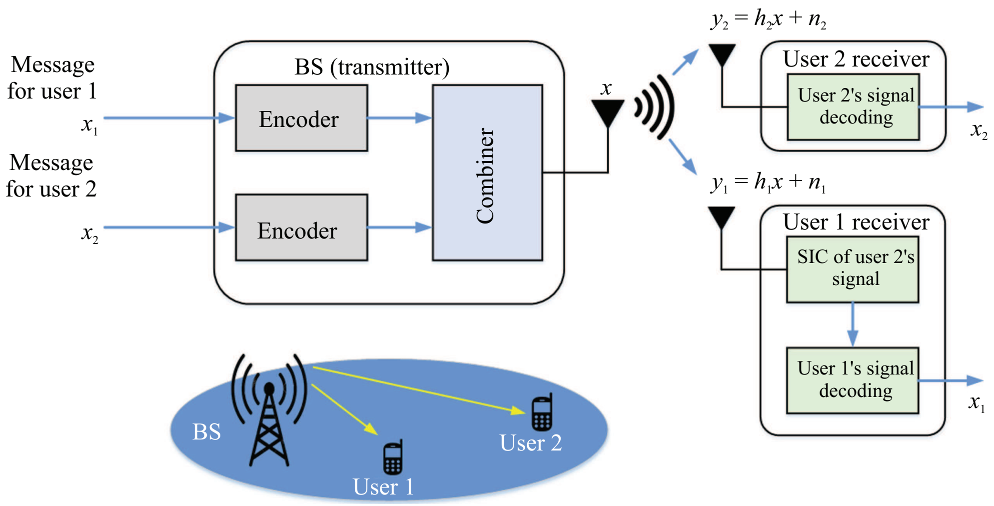

Fig. 1. Working of successive interference cancellation

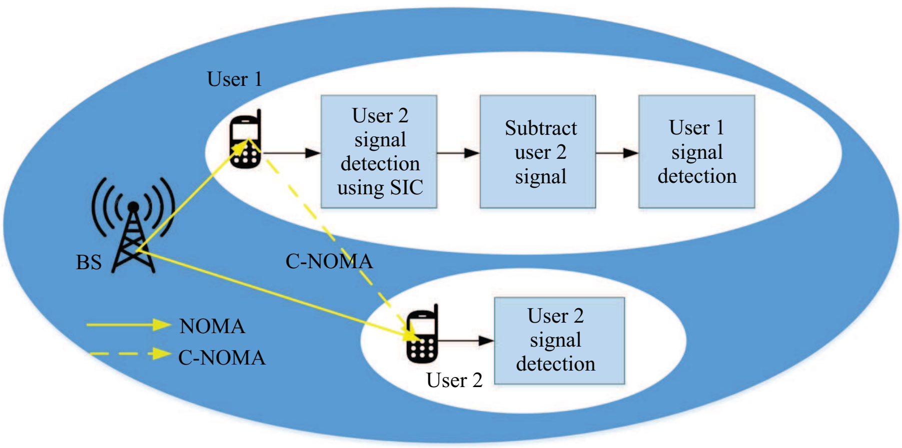

Fig. 2. A two-user downlink NOMA scheme with cooperative phase

complexity [13]. To resolve this issue, an STBC based CNOMA scheme has been presented in [13, 14]. Through STBC in CNOMA, the weak user is cooperated by the strong user, thus reducing the number of SICs, computational overhead, and complexity. Although the timing offsets issue raises by distributed elements, and reliability issues due to imperfect SICs are the issues that still need attention [15, 16].

This paper presents a differentially encoded/decoded STBC coding described in [17]. Further, it used the concept of triple QPSK modulation [18] to achieve full diversity for CNOMA. The main contribution of the paper is as

1) The paper enlightens the timing offsets and imperfect SIC impairment problems.

2) It presents the differential STBC-CNOMA system.

3) Furthermore, it provides the outage probability and sum rates of the SINR for both impairments.

4) Also, the paper derives the expression of pdf of SIR to evaluate the outage probability.

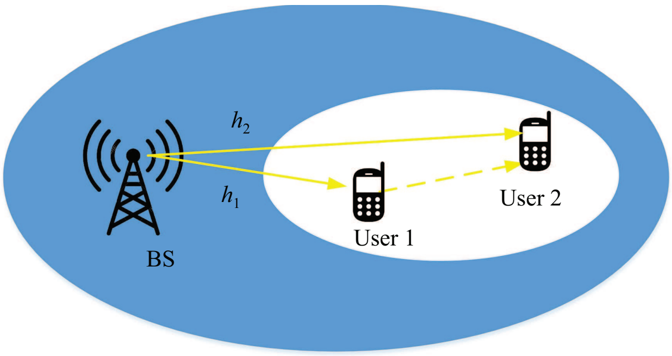

Fig. 3. Channel coefficient of two user downlink NOMA scheme with cooperative phase

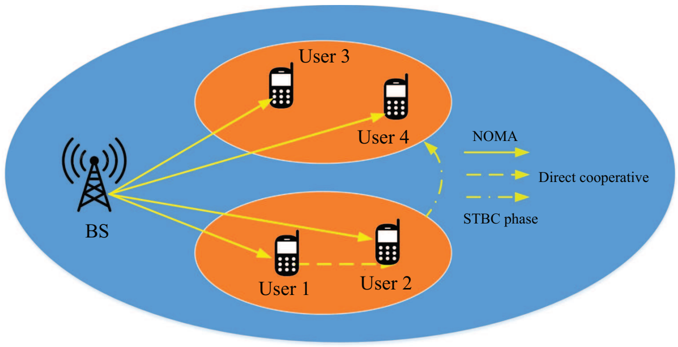

Fig. 4. "Illustration of the direct and STBC cooperative NOMA schemes

5) The analysis shows that the proposed differential STBC-CNOMA outperforms the conventional CNOMA scheme.

2 System model

In the cooperative-NOMA system shown in Fig. 2, the superimposed signal is transmitted by the base station (BS). Now, we considered a channel between the BS and users and between users in Rayleigh fading channel. As we know a user who is near to BS, experienced a high signal level and quality (strong user) as compared to the far user with a weak signal. Therefore, a user with a weak signal condition is assigned the high powers. If there are K users in the user set as $U \in \{U_1, U_2, U_3, \ldots, U_K\}$ where U_1 has the strongest channel condition, and U_K possess the lowest channel conditions, then the power will be allocated as $P \in \{P_K, P_{K-1}, P_{K-2}, \ldots, P_1\}$ where P_K is the minimum power and P_1 is the highest power. Now in the conventional C-NOMA scheme, there are two phases. In the first phase, the BS sends a superimposed signal to all U users. All the receivers will decode their own message by SIC if it is a strong user, or by treating other user signals as noise if it is a weak user. In the second phase, also known as cooperative NOMA (C-NOMA), there are $U-1$ time slots, now in each time slot the i-th user broadcasts a new superimposed message consisting of $U - i$ superimposed messages. Suppose that $i \in U$ but not equal to U, for example, for $i = 2$, the second user transmits a superimposed message to $U - 2$ users. The whole process is shown in Fig. 3. Now at the receiver side, each i-th receiver will receive i superimposed signals. Each receiver will apply SIC on each signal and collect different observations of the same message. Then all observations are combined through Maximum Ratio Combining (MRC) [19].

As we discussed above the main disadvantage of C-NOMA is the higher number of SICs at the receiver side, which causes an increased computational complexity of the overall system. Since there is limited power at each user equipment (UE), the high computational complexity causes the energy consumptions [20, 21]. STBC-NOMA overcome the problems of cooperative NOMA, by using STBC cooperation. The U_1, and U_2 which are strong users make an STBC pair and transmits the weak users' U_3 and U_4 signals by distributing 2×2 transmission. The process is continued until the weakest user U_K is reached.

In the proposed differential STBC-NOMA scheme, as discussed in the last paragraph, the strong user performs differential STBC coding to cooperate with the weak user instead of sending the superimposed signal. Same as C-NOMA, there are two phases in the differential C-NOMA scheme.

In the first phase, just like conventional NOMA where a superimposed signal S_s is sent by the base station to all users U such that

$$S_s = \sum_{i}^{U} \sqrt{u_i P} \cdot s_i \,, \tag{1}$$

where s_i is the message signal and u_i is the power coefficient of the i-th user and P is the total power of the BS. $\sqrt{u_i P}$ is approximately equal to $\sqrt{P_i}$ which is the power allocated to user i from the total transmission power P of the BS. Now the received signal by the User K is as follows

$$Y_s = h_k \sum_{i=1}^{U} \sqrt{P_i} \cdot s_i + n_k \,, \tag{2}$$

where n_k is the Gaussian noise, and h_k is the Rayleigh fading channel coefficient of the i-th user. The channel coefficients of K users are in ascending order as $h_K^2 \leq h_{K-1}^2 \leq \cdots \leq h_2^2 \leq h_1^2$, this equation assumes that user 1 has the strongest channel coefficient h_1^2, while User K is the weakest channel coefficient h_K^2. The power coefficient is assigned based on NOMA as $u_K \geq u_{K-1} \geq \cdots \geq u_2 \geq u_1$, where u_K is the strongest power coefficient assigned to the weakest channel coefficient user U_K and vice versa. The power coefficient of all users is $\sum_{i=1}^{U} u_i = 1$.

Now the k-th user (where k not equal to U) detects the m-th user signal (suppose that $m < k$). SIC is performed after the detection m-th user signal and then subtracts the signal from the received superimposed signal. The k-th user signal-to-interference-plus-noise ratio (SINR) is given by

$$SINR_k = \frac{h_k^2 \cdot P_k}{\sum_{i=1}^{I} h_k^2 \cdot P_i + \sigma^2}, \tag{3}$$

where σ^2 is the identical noise variance to all users, and I is the number of total interfering signals to the user such that $1 \leq I \leq k-1$.

There are further two parts of the second phase of the proposed system *ie*, direct cooperation and STBC cooperation. The strong user uses $U-1$ timeslots to cooperate with the weak users. In the direct cooperative part, user 1 cooperates with user 2 by directly sending the copy of the user 2 signal. The process is shown in Fig.4. Now the user 2 has two copies of the signal, which is combined through MRC.

In the differential STBC based cooperative NOMA transmission phase, with reference to their channel condition, the first two strongest users form the first pair, while the second and third strongest users form 2nd pair. The process is continued till the data is received by U_{K-1} and U_K users. There are total Z User pairs where $Z = \frac{K}{2}$, and Z is even. In case if K is odd, U_{K-1} and U_{K-2} forms the $Z-th$ user pair, here $Z = \frac{K-1}{2}$. The $Z-1$ user directly cooperates with the last odd user. In STBC cooperative part, cooperation is done between all the users by applying differential 2×2 STBC transmission. At the receiver end, each receiver receives two message signals, one is its own and the second is its neighbors' signal. The STBC receiver, keep its own signal, and discarded the other signal as noise.

The performance of STBC coding is sensitive to channel state information (CSI). If CSI is not accurate or it is not completely known to the receiver, a differential STBC encoding/ decoding is applied to the receiver to reduce the CSI dependency. The transmitter of differently encoded STBC system, an identity matrix containing no information is transmitted to initialized the transmission such that $A_0 = I_{NT}$. Now the data matrices are differentially encoded and transmitted. At t time slot, the transmitted matrix is a $p \times p$ matrix written as

$$A_t = V_t \hat{A}_t - 1, \tag{4}$$

where $V_t = \frac{1}{\sqrt{B}} G_e$. Here G_e is an STBC transmission matrix and B is the number of non-zero elements in each column of G_e. $\hat{A}_t - 1$ is the normalized version of $A_t - 1$ and written as $\hat{A}_t - 1 = \frac{1}{a_{t-1}}(A_t - 1)$.

The receiver of differentially encoded STBC takes two consecutively received signal matrices as

$$Y_{t-1} = \sqrt{\frac{\rho}{N_T}} A_{t-1} H^T + W_{t-1} \,, \tag{5}$$

$$Y_t = \sqrt{\frac{\rho}{N_T}} A_t H^T + W_t \,. \tag{6}$$

Now substituting (4) into (6) and apply (5) we get

$$Y_t = a_{t-1}^{-1} V_t Y_{t-1} - a_{t-1}^{-1} V_t W_{t-1} + W_t \,. \tag{7}$$

As we know the noise matrices IID (independent and identically distributed) elements are at different time slots, (eq7) can be rewritten as,[17]

$$Y_t = a_{t-1}^{-1} V_t Y_{t-1} + \sqrt{1 + a_{t-1}^{-2} a_t^2 W_t'} \,. \tag{8}$$

Here W_t' is a noise matrix whose elements are IID Gaussian distributed random variable with zero mean and unit variance, is equal to the n_k part of (2). $a_{t-1}^{-1} V_t Y_{t-1}$ is the signal part of the equation and equal to s_i of (2). a_{t-1}^{-1} is the channel coefficient and equal to h_k part of the (2). Now from (8) if we ignore the dependent equivalent noise variance of the transmitted signal, the near-optimal differential decoding rule becomes as

$$(\hat{V}_t)_{n-o} = \arg\min_V \|Y_t - a_{t-1}^{-1} V_t Y_{t-1}\|^2. \tag{9}$$

This equation requires accurate knowledge of the previous signal a_{t-1}. The SNR loss of the near-optimal differential equation is very small (0.1 dB) as compared to the optimal differential rule. Furthermore, this differential detection rule has linear complexity [22].

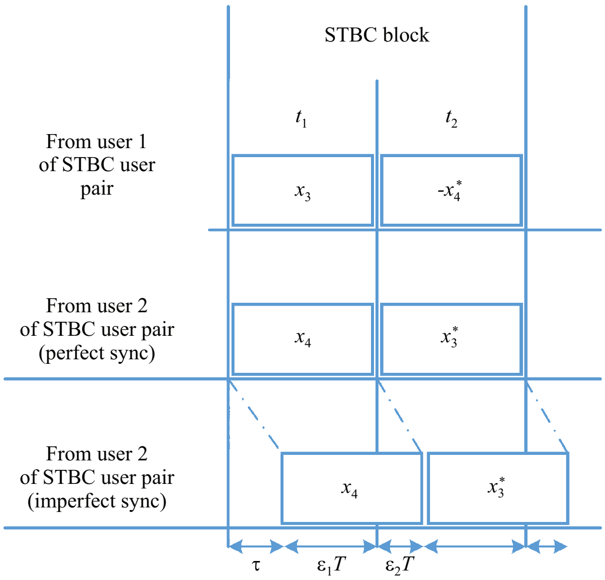

Fig. 5. Timing synchronization issue

Now consider the SNR of user 1 and SINR of user 2 as (if $K = 1$)

$$SNR_1 = \frac{h_1^2 \times P_1}{\sigma^2} \,. \tag{10}$$

While for $K = 2$

$$SINR_2 = \frac{h_2^2 \times P_2}{(h_2^2 \times P_1) + \sigma^2} + \frac{g_{1,2}^2 \times \hat{P}}{\sigma^2} \,, \tag{11}$$

where $g_{1,2}^2$ is the channel gain between user 1 and user 2, and $\hat{P}$ represents the power assigned to the single direct communication from the total transmission power.

For $2 < k \le U$ users, SINR is given by

$$SINR_k = \frac{h_k^2 \times P_k}{\sum_{i=1}^{I}(h_k^2 \times P_i) + \sigma^2} + \frac{g_{k-n-1,k}^2 + g_{k-n-2,k}^2 \times \hat{P}}{\sigma^2} \,. \tag{12}$$

Here $\hat{P}$ represents the power assigned to the single STBC communication from the total STBC cooperation phase, and $n = \{0, 1\}$ is the first and second receiver of the STBC phase.

For $K = U$ (all users till the last user) and when U is odd, the SINR will be

$$SINR_k = \frac{h_k^2 \times P_k}{\sum_{i=1}^{I}(h_k^2 \times P_i) + \sigma^2} + \frac{g_{k-1,k}^2 \times \hat{P}}{\sigma^2} \,. \tag{13}$$

3 The impairments in communication

There are three practical impairments an STBC based CNOMA system can face, imperfect synchronization, imperfect CSI, and imperfect SIC. The detail of all three problems is given below.

Figure 5 shows the imperfect synchronization issue. At the time t_0, each user receives their NOMA message from BS. User 1 and user 2 decode their own and also user 3 and user 4 messages, then they send the messages to corresponding user 3 and user 4 through STBC transmission. Figure 5 shows the process as at time t_1 user 1 and 2 send messages x_3 and x_4 to users 3 and 4 respectively. At the time t_2 they also send messages $-x_4^*$ and x_3^* to users 3 and 4 respectively so that the STBC receiver detects their message signal. This process is perfect synchronization. If we focus on the third row of Fig. 5, a timing mismatch event will be observed. The symbol duration is T seconds while the STBC message duration with offsets $\tau = \varepsilon_2 T$. Due to this timing offset the receiver (user 3 and 4) does not receive the signal at the perfect time and causes ISI. This will cause reduced SINR.

Now the equations for users 3 and 4 of the STBC pair will be

$$r_{3,1} = g_{3,1}x_3 + g_{3,2}\varepsilon_1 x_3 + \beta_{3,1} \,, \tag{14}$$

$$r_{3,2} = -g_{3,1}x_4^* + g_{3,2}\varepsilon_1 x_3^* + g_{3,2}\varepsilon_2 x_4 + \beta_{3,2} \,, \tag{15}$$

$$r_{4,1} = g_{4,1}x_3 + g_{4,2}\varepsilon_1 x_4 + \beta_{4,1} \,, \tag{16}$$

$$r_{4,2} = -g_{4,1}x_4^* + g_{4,2}\varepsilon_1 x_3^* + g_{4,2}\varepsilon_2 x_4 + \beta_{4,2} \,, \tag{17}$$

where $r_{k,t}$ is the received signal and $\beta_{k,t}$ is the additive noise of the k-th at time slot t.

The second important impairment is the imperfect channel state information (CSI). CSI is the channel estimation available at the receiver to detect the correct message signal. If the CSI is corrupted or not estimated correctly, the channel estimation between k-th and j-th user is $g_{k,j}$, and w_j is estimation error between k-th and j-th users' channel, then $\hat{g}_{k,j} = g_{k,j} + w_j$ will be the channel estimation. The w_j is a complex Gaussian RV with zero mean and σ_w^2 variance. $\hat{g}_{k,j}$ is also a function of RV with zero mean and $\sigma_{\hat{g}}^2 = \sigma_g^2 + \sigma_w^2$ variance. Let $\partial = \frac{\sigma_g^2}{\sigma_g^2 + \sigma_w^2}$ is the correlation coefficient between estimated and real channels, since $g_{k,j} = \hat{g}_{k,j} + \xi_{k,j}$, where $\xi_{k,j}$ is a complex independent RV with $\sigma_\xi^2 = \frac{\sigma_g^2 \sigma_w^2}{\sigma_g^2 + \sigma_w^2}$ variance [15].

The third impairment of NOMA based system is imperfect SIC. SIC plays an important role in perfectly decoding the high interface signals. But if the SIC is not perfectly designed, then it will allow some interferences in the desired signal at the receiver. Many things affect the performance of SIC *eg*, imperfect CSI, imperfect design, imperfect power allocation concerning phase and amplitude [20, 23]. Due to imperfect SIC, the SINR at k-th and

k-th+1 user will be

$$\gamma_k^\mu = \frac{|h_k|^2 p_k}{\mu |g_\mu|^2 p_\mu + \sum_{i=1}^{k-1} |h_k|^2 p_i + \sigma^2} - \frac{(|g_{k,k-1}|^2 + |g_{k,k-2}|^2)\rho_s}{\sigma^2}, \tag{18}$$

$$\gamma_{k+1}^\mu = \frac{|h_{k+1}|^2 p_{k+1}}{\mu |g_\mu|^2 p_\mu + \sum_{i=1}^{(k+1)-1} |h_{k+1}|^2 p_i + \sigma^2} + \frac{(|g_{k+1,(k+1)-2}|^2 + |g_{k+1,(k+1)-3}|^2)\rho_s}{\sigma^2}. \tag{19}$$

Here $\mu \in \{0,1\}$, where 0 corresponds to a perfect SIC and 1 corresponds to an imperfect SIC for the corresponding user.

4 Performance analysis

This section discusses the sum rate and outage probability analysis of the system. The interference is considered to be limited hence noise can be ignored.

4.1 Outage probability analysis

The outage probability of U_k where $k < K$ is defined as

$$P_{out} = P_r(SIR < \gamma_{th}) = 1 - \int_{\gamma_{th}}^{\infty} f_A(a)\, da\,, \tag{20}$$

where γ_{th} is the SIR threshold. In (20), A is the combination of the SIR of the k-th user (described as $Q = \frac{X}{Y}$) and the STBC gain after cooperation phase known as R, which can be described as

$$A = Q + R\,. \tag{21}$$

Remember that Q and X are two distinct random variables of the desired signals exponentially distributed and its PDF is given as, $F_X(x) = \frac{1}{\varphi}\exp\big(-\frac{x}{\varphi}\big)$ where φ is the mean power of the desired signal X, while Y is the sum of $(k-1)$ RVs which are exponentially distributed, hence

$$F_Y(y) = \sum_{i=1}^{I} C_i \frac{1}{\Omega_i} \exp(-\frac{y}{\Omega_i}), \tag{22}$$

where Ω_i is the mean power of the i-th interferer, I is the total number of interferences such that $1 \le I \le (k-1)$ and $C_i = \prod_{j\neq i} \frac{1/\Omega_j}{1/\Omega_j - 1/\Omega_i}$. R in (21) is the gamma distribution such that $f_R(r) = \frac{r}{\delta^2}\exp(-\frac{r}{\delta})$, where δ is the mean power of the received signal in cooperative mode.

Now as we know X and Y are RV and mutually independent, the CDF of k is as follows

$$P_r\{K > k\} = \int_{x=0}^{\infty} (\int_{y=0}^{x/k} f_Y(y)\, dy\,) f_X(x)\, dx\,, \tag{23}$$

where $\int_{y=0}^{x/k} f_Y(y)\, dy = \sum_{i=1}^{I} C_i |1 - \exp(-\frac{x}{k\Omega_i})|$ is the CDF of the hypoexponential RV in (23). So (23) becomes

$$P_r\{K > k\} = \int_{x=0}^{\infty} (\sum_{i=1}^{I} C_i |1 - \exp(-\frac{x}{k\Omega_i})|) \frac{1}{\lambda} \exp(-\frac{x}{\lambda})\, dx\,, \tag{24}$$

$$P_r\{K > k\} = \sum_{i=1}^{I} C_i \frac{\lambda}{\lambda + k\Omega_i}\,, \tag{25}$$

Now the PDF of K is $f_K(k) = \sum_{i=1}^{I} C_i \Omega_i \frac{\lambda}{\lambda + k\Omega_i^2}$. So by convolving the PDF of K and R, the PDF of A will be found. From the PDF of A we can find the outage probability of the k-th user in STBC-NOMA is

$$P_{r(out)}(\tau) = \sum_{i=1}^{I} \frac{C_i}{\Omega_i^2 \delta^2} \exp(-\frac{\lambda + \tau\Omega_i}{\delta\Omega_i}) \times \Big\{ \exp(\frac{\lambda}{\delta\Omega_i}) \delta\Omega_i (e^{\frac{a}{\delta}} (\lambda + \delta\Omega_i) - \Omega_i(\delta + \tau) - \lambda) + \lambda(\lambda + \tau\Omega_i)[E_i|\frac{\lambda}{\delta\Omega_i}| - E_i|\frac{\lambda + \tau\Omega_i}{\delta\Omega_i}|] \Big\}\,. \tag{26}$$

4.2 Sum rate analysis

For the user whose SIR is less than the threshold τ, the rate outage probability is given by $P_r(\zeta) = P_{r(out)}(2^{\frac{\zeta}{B}} - 1)$, where B is the bandwidth, and ζ is the rate threshold. It is the probability that the rate of a user is less than some threshold ζ, given that the SIR outage probability is less than a threshold τ, $P_{r(out)}(\tau)$.

5 Results and discussions

This section discusses the results and discussion of the proposed system. Simulation were carried out using the MATLAB simulation tool. The proposed system is compared with the traditional cooperative NOMA and STBC NOMA in terms of sum rates outage probability. The communication system is considered to be a single BS and multi-users $(k = 4)$. The channel is considered to be Rayleigh flat faded between BS and users. The transmission power is kept the same for all three schemes. The user maximum transmission power in cooperation mode is kept at 1 W. If the rate threshold of a user is less than the user rate, he can participate in cooperation.

The PDF of SINR for different timing offsets is shown in Fig. 6. In this case, the CSI and SIC are assumed perfect. It is clear from the figure that with increasing timing offsets (τ), the SINR of a user decreases. Since it is derived that, outage probability is an increasing function of timing offsets.

Figure 7 compares the outage probability of DSTBC-CNOMA, with STBC-CNOMA, CNOMA, and NOMA schemes respectively for $\tau = \{0, 0.5\}$. The horizontal

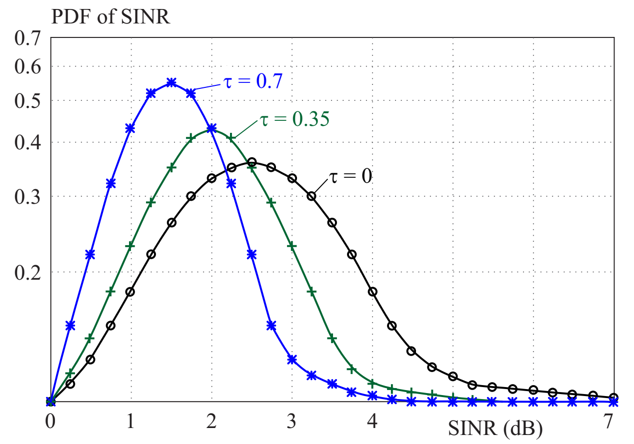

Fig. 6. PDF of SINR for DSTBC-CNOMA with timing offsets

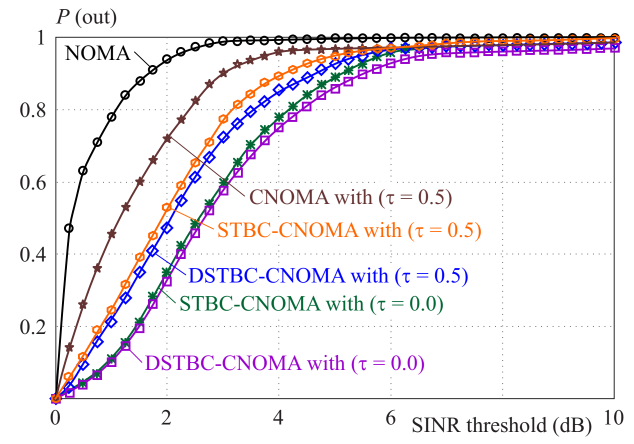

Fig. 7. Outage probability comparison with imperfect synchronization, perfect SIC, and perfect CSI

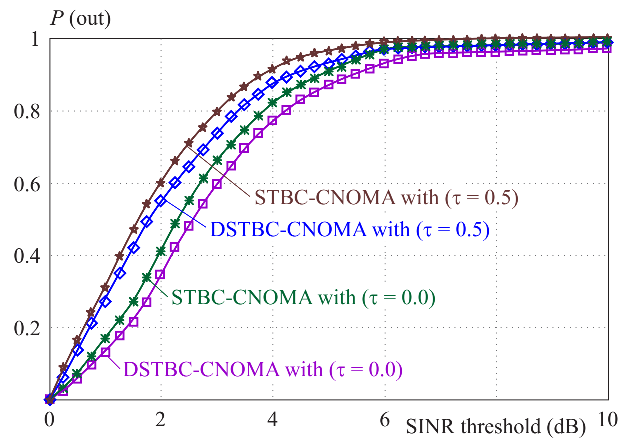

Fig. 8. Outage probability comparison with imperfect synchronization, and imperfect SIC

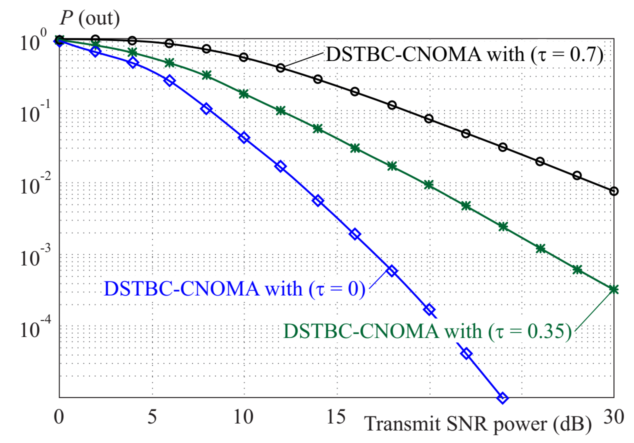

Fig. 9. Sum rate analysis of DSTBC-CNOMA with imperfect timing $\tau = \{0, 0.35, 0.7\}$

axis represents the SINR threshold in dB, while the vertical axis shows the outage probability $P_{r(out)}$. It can be observed that $P_{r(out)}$ of NOMA is the highest for a given threshold. Also, it can be noted that differential STBC-CNOMA outperforms STBC-CNOMA, CNOMA, and NOMA schemes with both perfect and imperfect timing offsets. Although the performance of both DSTBC-CNOMA, and STBC-NOMA approaches to NOMA performance when τ approaches to 1. Since for $\tau < 0.5$ and low SINR, the DSTBC-CNOMA is an attractive scheme.

Figure 8 again discusses the outage probability for the proposed system, but imperfect synchronization $\tau = \{0, 0.5\}$ and imperfect SIC (-dB). As the previous figures described that STBC based NOMA schemes outperformed the Cooperative NOMA, therefore Fig.8 only compares DSTBC-CNOMA and STBC-CNOMA schemes. It is observed that due to imperfect SIC (-5 dB), the performance of both DSTBC and STBC NOMA schemes is degraded a bit. But still, it is very attractive. Furthermore, in both timing offsets the performance of DSTBC-CNOMA is better than that of STBC-NOMA.

The sum rate analysis of DSTBC-CNOMA is described in Fig. 9. The horizontal axis shows the transmit SNR power in dB, while the vertical axis shows the outage probability. It is shown in the figure that the rate outage degrades with increasing timing offsets. It is obvious that with imperfect timing the performance of the receiver will be degraded due to a lack of orthogonality.

6 Conclusion

Paper discusses the differential cooperative NOMA scheme. In this scheme, the strong user cooperates with the weak user through differential STBC. The outage probability and SIR are obtained through the received SIR of the k-th user. The paper also describes the NOMA impairment *eg*, the imperfect synchronization, imperfect SIC, and imperfect CSI. It is derived that Imperfect CSI and Synchronization may cause the interferences in SIC. The simulation results show that cooperative NOMA and simple STBC NOMA are outperformed by differential STBC NOMA in terms of outage probability and sum rate. In the near future, we will discuss the BER analysis of differential STBC NOMA in the presence of all three NOMA transmission impairments.

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