

Interference Canceling Improvement using Symbol Misalignment in 5G NOMA downlink transmission

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Abstract - In this paper, we introduce the method for reducing the interference power using symbol misalignment in NOMA downlink transmission. Unlike other papers about the asynchronous NOMA downlink transmission using symbol misalignment, we provide the symbol misalignment when two and over use one orthogonal source. Here, we solve the intended asynchronous problem to get the minimum interference power between several users in PD-NOMA downlink transmission.

Keywords - NOMA Downlink Transmission, SINR Analysis, Symbol Misalignment.

I. INTRODUCTION

NOMA is the main technology for 5th and next generation mobile communication because the services for more wireless devices are possible. In 5th generation mobile communication for the 100~1000 times speed of 4G and diverse QoS, NOMA is the bright technology with the high spectrum efficiency, use of different channel conditions, user fairness and etc. In fact, NOMA is not the technology for feature, in 3GPP-LTE-A, it is used by MUST(MultiUser Superposition Transmission), and in the digital TV standard ATSC3.0, it is used by LDM(Layered Division Multiplexing).[12]

In [6], the existing NOMA technologies are divided by 2 parts - Code Domain Multiplexing(CDM) and power Domain Multiplexing(PDM) CDM-NOMA includes LDS(Low-Density Spreading)[7,8,9], SCMA(Sparse Code Multiple Access)[10],PDMA(Pattern Division Multiple Access)[11] and etc and they are to get the redundancy using Coding and spreading. Then PDM-NOMA provides the multiuser services in equal DoF(Degrees of Freedom).

Here, several users use one orthogonal source, so the interference between users certainly happen, and for removing the interference, it uses SIC(Successive Interference Cancellation).

CDM-NOMA improves the spectrum efficiency with potential symbol gain, and then PDM-NOMA can make without the big changes of 4G physical layer. Furthermore, it can improve the main features of 5G such as spectrum efficiency, energy efficiency and user fairness through the flexible data allocation, so it is better than CDM-NOMA. The CR wireless can see one variety of simple PD-NOMA.[12]

But NOMA has some disadvantages that a BS requires the complex SIC and it has high calculation complexity, receiver delay, error due to wrong SCI, increase of system signal or symbol and interference between cells.

It is very important problem to progress the correct SCI because SCI is the main part of receiver signal process in PDM-NOMA.

The one method to improve the properties of SCI is to reduce the interference power. For this, in [4], it introduces that the symbol misalignment that two users use one orthogonal source increases the BER property and improves the system property, and when symbol misalignment is equal to the half of symbol interval, BER is minimum.

In [1], NOMA with the intended symbol offset for reducing the interference between users defines ANOMA(Asynchronous NOMA), and it introduces to reduce the interference power in downlink transmission using this. In [2] and [3], it provides the

SIC in ANOMA. In the most papers for reducing the interference power using symbol offset, it refers to the case of two users.[1,4] In [2,3], it refers to the case of several users with one orthogonal source, but, here, it describes the new SCI called Triangular SIC(T-SIC).

For the large diverse QoS, it must allocate $M > 2$ users in one orthogonal source.

In this paper, it provides the symbol offset problem to minimum the interference power, BER and stop probability when $M > 2$ users use one orthogonal source in downlink NOMA communication system.

The rest of this paper is as follow; Section 2 introduces the system model, SINR analysis and optimal symbol offset. In section 3, it introduces the simulation result and Section 4 provides the results.

II. CONVERGENCE OF THE GENERALIZED DFE WITH ERROR FEEDBACK FILTER

System Model

Similarly to [2,3,4], here, we use the downlink NOMA communication system for $M(M > 2)$ users with the same BS.

To simplify, we refer to SISO-NOMA with one transceiver antenna.

The BS transmits a signal with the transmission

$$\text{power } P_i \text{ for User } i \text{ and } \sum_{i=1}^M p_i = P \text{ (P:Total}$$

transmission power).

The signal x_i is as follow;

$$x_i = \sum_{n=1}^N b_i(n)s(t-nT-\tau_i) \quad (1)$$

where N is the number of transmission symbols, $b_i(n)$ is the transmitted symbols,

$$s(t) = \begin{cases} 1/T & 0 \leq t \leq T \\ 0 & \text{otherwis} \end{cases} \text{ is the rectangle pulse}$$

shaping filter, τ_i is the intended delay of BS.

Then, the symbol synchronization is $0 < \tau_i < T(i = \overline{1, M})$.

In NOMA downlink transmission, x is the linear combination of BS transmission signal $x_i (i = \overline{1, M})$.

$$x = \sum_{i=1}^M \sqrt{p_i} x_i = \sum_{i=1}^M \sqrt{p_i} \sum_{n=1}^N b_i(n)s(t-nT-\tau_i) \quad (2)$$

The received signal y_i of user i is as follow:

$$y_i = h_i x + n_i \quad (3)$$

where h_i is the complex channel coefficient between BS and User i and n_i is AWGN and $n_i \sim N(0, \delta_i^2)$.

We assume that the system transmission bandwidth is W and the noise PSD of all users without loss of generality δ_i^2 is constant.

$$\text{So } \delta_i^2 = \delta^2.$$

Then we also assume that if $i < j$, $p_i < p_j$.

SINR analysis and symbol offset with maximum SINR

For SINR analysis of each user, we firstly analyze SINR of users with power P_1 .

The receive signal $y_1(t)$ of user 1 is as follow;

$$\begin{aligned} y_1(t) &= h_1 x + n_1 = \sum_{i=1}^M h_1 \sqrt{p_i} \sum_{n=1}^N b_i(n)s(t-nT-\tau_i) + n_1 \\ &= h_1 \sqrt{p_1} \sum_{n=1}^N b_1(n)s(t-nT-\tau_1) + \\ &h_1 \sum_{i=2}^M \sqrt{p_i} \sum_{n=1}^N b_i(n)s(t-nT-\tau_i) + n_1 \end{aligned} \quad (4)$$

When the traditional SIC is processed in the receiver, the first UE passes the received wave through the match filter and the sampled discrete signal at each interval T is as follow:

$$\begin{aligned} y_{1,M}(k) &= \int_{kT+\tau_1}^{(k+1)T+\tau_1} y_1(t)s(t-kT-\tau_M)dt \\ &= \sqrt{P_M} h_1 b_M(k) + \end{aligned}$$

$$\begin{aligned}
 & \sum_{i=1}^M h_1 \sqrt{P_i} \sum_{n=1}^N b_i(k) \int_{kT+\tau_1}^{(k+1)T+\tau_1} s(t-nT-\tau_i) \cdot s(t-kT-\tau_M) dt \\
 & + \int_{kT+\tau_1}^{(k+1)T+\tau_1} n_1(t) s(t-kT-\tau_M) dt \\
 & = \sqrt{P_M} h_1 b_M(k) + \\
 & \sum_{i=1}^M h_1 \sqrt{p_i} (\rho_M b_i(k-0.5-0.5\text{sgn}(\tau_M-\tau_i)) + \\
 & \rho_{iM} b_i(k+0.5-0.5\text{sgn}(\tau_M-\tau_i))) + n_{1M}(n)
 \end{aligned}$$

(5)

$$\begin{aligned}
 & 1 \quad x > 0 \\
 & \text{where } \text{sgn}(x) = 0 \quad x = 0 \text{ is the complex} \\
 & 1 \quad x < 1
 \end{aligned}$$

function, $n_{1M}(n)$ is AWGN and $n_{1M}(n) \sim N(0, w\delta^2)$.

The correlation functions ρ_{Mi}, ρ_{iM} are as follow:

$$\begin{aligned}
 \rho_{Mi} &= \int_0^T s(t) s(t+0.5T+0.5T \text{sgn}(\tau_M-\tau_i) + \tau_i - \tau_M) dt = \\
 & \frac{|\tau_M - \tau_i|}{T} \quad \tau_M \geq \tau_i \\
 & = \frac{T - |\tau_M - \tau_i|}{T} \quad \tau_M < \tau_i \\
 & = 0.5 - (0.5 - \frac{|\tau_M - \tau_i|}{T}) \text{sgn}(\tau_M - \tau_i)
 \end{aligned}$$

(6)

$$\begin{aligned}
 \rho_{iM} &= \int_0^T s(t) s(t-0.5T+0.5T \text{sgn}(\tau_m-\tau_i) + \tau_i - \tau_m) dt = \\
 & \frac{|\tau_m - \tau_i|}{T} \quad \tau_m \geq \tau_i \\
 & = \frac{T - |\tau_m - \tau_i|}{T} \quad \tau_m < \tau_i \\
 & = 0.5 + (0.5 - \frac{|\tau_m - \tau_i|}{T}) \text{sgn}(\tau_m - \tau_i)
 \end{aligned}$$

(7) For the sake of convenience, we assume

$$\delta_{kj} = \frac{|\tau_k - \tau_j|}{T}, \text{ then when the first user decodes the}$$

signal of user M, the interference power $P_{I(1,M)}$ is as follow;

$$\begin{aligned}
 P_{I(1,M)} &= \\
 & E[\sum_{i=1}^M h_1 \sqrt{p_i} (\rho_M b_i(n-0.5-0.5\text{sgn}(\tau_M-\tau_i)) + \\
 & \rho_{iM} b_i(n+0.5-0.5\text{sgn}(\tau_M-\tau_i)))^2] = \\
 & = |h_1|^2 \sum_{i=1}^{M-1} p_i (2\delta_{Mi}^2 - 2\delta_{Mi} + 1)
 \end{aligned}$$

From equ 5 and 8, when the first user decodes the signal of user M, the SINR is as follow:

$$\begin{aligned}
 \text{SINR}_{1,M} &= \frac{p_M |h_1|^2}{|h_1|^2 \sum_{i=1}^{M-1} p_i (2\delta_{Mi}^2 - 2\delta_{Mi} + 1) + W\delta^2} \\
 &= \\
 &= \frac{1}{\sum_{i=1}^{M-1} \frac{p_i}{p_M} (2\delta_{Mi}^2 - 2\delta_{Mi} + 1) + \frac{W\delta^2}{p_M |h_1|^2}}
 \end{aligned}$$

To be similar to Equ 9, when the first user decodes the signal of user ℓ , the SINR is as follow:

$$\begin{aligned}
 \text{SINR}_{1,\ell} &= \frac{1}{\sum_{i=1}^{\ell-1} \frac{p_i}{p_\ell} (2\delta_{\ell i}^2 - 2\delta_{\ell i} + 1) + \frac{W\delta^2}{p_\ell |h_1|^2}}
 \end{aligned}$$

(10)

Likewise, when the User m decodes the signal of user ℓ ($\ell > m$), the SINR is as follow;

$$\begin{aligned}
 \text{SINR}_{m,\ell} &= \frac{1}{\sum_{i=1}^{\ell-1} \frac{p_i}{p_\ell} (2\delta_{\ell i}^2 - 2\delta_{\ell i} + 1) + \frac{W\delta^2}{p_\ell |h_m|^2}}
 \end{aligned}$$

(11)

The denominator of Equ (9),(10),(11) is the interference and noise power when the signal power is 1, that is normalized interference and noise power and the first term is the normalized interference power.

Like in [4], these normalized interference powers have the minimum value at $\delta_{\ell i} = 0.5$.

But for all users ℓ, i ($\ell > i$), Setting the time offset $\delta_{\ell i} = 0.5$ is impossible.

Consider $p_\ell > p_i (\ell > i)$ and the big part of interference power is at $i = \ell - 1$.

That is, When the time offset between users with adjacent index is about $0.5T$, SINR has the maximum value.

It means that the time offset between users with adjacent index is equal and it sets the maximum values. Then weights of the time offset between user $\ell, \ell - 1$ and the time offset between user $j, j - 1$ is equal.

Because two parameters that determine the interference power are $\frac{P_{\ell-1}}{P_\ell}, (2\delta_{li}^2 - \delta_{li} + 1)$ and

$\frac{P_{\ell-1}}{P_\ell}$ has the different values according to the choice of ℓ , but, the expected value is the constant.

But, if the time offset for making the time offset between users with adjacent index about $0.5T$ and equal value is $\frac{T}{M}$, the big interference power is produced.

In this paper, we provide the method to reduce the interference power by providing the equal time offset $(0.5 - \alpha)T$ between users with adjacent indices.

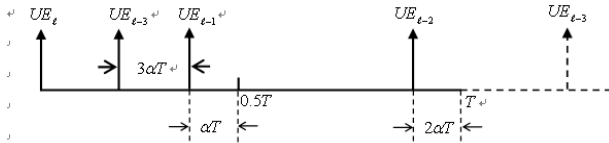


Fig 1. Time offset between users in this paper (Without the loss of generality, time offset of UE_ℓ is settled by 0.)

In Fig 1, the time offset between $UE_{\ell-2}$ and $UE_{\ell-3}$ seems $(0.5 + \alpha)T$, but in fact, $UE_{\ell-3}$ has the time offset in solid line distance and it only moves to time T by the symbol misalignment.

Here, $0 < \alpha < 0.5$ is selected for making the time offset between users with adjacent index and then when the synchronization is provided, it reduces the effect of $\frac{P_{\ell-1}}{P_\ell}$ for the maximum interference power

and it also reduces the effect of $\frac{P_{\ell-2}}{P_\ell}$.

In the normalized interference power of Eq.(11), it puts $(0.5 - \alpha)(\ell - i) - \text{int}(0.5 - \alpha)(\ell - i)$ instead of δ_{li} and consider $p_\ell > p_{\ell-1} > p_{\ell-2} > \dots > p_1$, then if the $\ell - 5$ element is ignored, and when the third user decodes the signal of user $\ell (\ell > m)$, the normalized interference power is as follow:

$$P_{Norl}^{m,\ell} = \frac{P_{\ell-1}}{P_\ell} (0.5 + 2\alpha^2) + \frac{P_{\ell-2}}{P_\ell} (0.5 + 2(0.5 - \alpha)^2) + \frac{P_{\ell-3}}{P_\ell} (0.5 + 18\alpha^2) + \frac{P_{\ell-4}}{P_\ell} (0.5 + 2(0.5 - 4\alpha)^2) \quad (12)$$

where $3(0.5 - \alpha) > 1$.

As shown in Eq.(12), if α is almost small - the time offset is almost same to $0.5T$, the interference between user $\ell - 1, \ell - 3$ is reduced, but the interference between users $\ell - 2, \ell - 4$ is increased. Without the loss of generality, we assume that $P_\ell, P_{\ell-1}, P_{\ell-2}, P_{\ell-3}, P_{\ell-4}$ is known, and then α for minimum of $P_{Norl}^{m,\ell}$ is as follow;

$$\frac{\partial P_{Norl}^{m,\ell}}{\partial \alpha} = 0 \Rightarrow \frac{P_{\ell-1}}{P_\ell} 2\alpha - \frac{P_{\ell-2}}{P_\ell} 2(1 - 4\alpha) + \frac{P_{\ell-3}}{P_\ell} 18\alpha - \frac{P_{\ell-4}}{P_\ell} 4(1 - 8\alpha) = 0$$

$$\alpha \left(\frac{P_{\ell-1}}{P_\ell} + 4 \frac{P_{\ell-2}}{P_\ell} + 9 \frac{P_{\ell-3}}{P_\ell} + 16 \frac{P_{\ell-4}}{P_\ell} \right) = \frac{P_{\ell-2}}{P_\ell} + \frac{P_{\ell-4}}{P_\ell}$$

$$\alpha_{opt}(\ell) = \frac{P_{\ell-2} + P_{\ell-4}}{P_{\ell-1} + 4P_{\ell-2} + 9P_{\ell-3} + 16P_{\ell-4}} \quad (13)$$

As shown in Eq.(13), when $P_{\ell-2}, P_{\ell-4}$ is increased, α_{opt} is increased, and when $P_{\ell-1}, P_{\ell-3}$ is increased, it is reduced.

That is, if the power with odd index is bigger, α_{opt} is reduced and if the power with even index is bigger, α_{opt} is increased.

But with Eq.(13), we don't calculate the complex optimal value α_{opt} .

Because it ignores $p_{\ell-k} (k \geq 5)$, and consider $p_{\ell} \geq p_{\ell-5} \geq p_{\ell-6} \dots$, then you can see that α_{opt} has the enough correctness.

The optimal α given by Equ(13) is the function of ℓ , so in practice, α_{opt} is calculated by the weighted average of $\alpha_{opt}(\ell)$.

The optimal α is calculated as follow;

$$\alpha_{opt} = \frac{\sum_{\ell=2}^M (\ell-1) \alpha_{opt}(\ell)}{\sum_{\ell=2}^M (\ell-1)} \quad (14)$$

The reason that the weight of $\alpha_{opt}(\ell)$ is ℓ that $\alpha_{opt}(\ell)$ is the value that is calculated by ℓ interferences. The $\ell-1$ normalized interference power elements $\frac{P_i}{P_{\ell}} (2\delta_{li}^2 - 2\delta_{li} + 1)$ is not all used for calculation of $\alpha_{opt}(\ell)$, so α_{opt} is calculated by the following equation.

$$\alpha_{opt} = \frac{\sum_{\ell=2}^M N\ell \alpha_{opt}(\ell)}{\sum_{\ell=2}^M N\ell} \quad (15)$$

where $N\ell$ is the number of normalized interference power for calculation of $\alpha_{opt}(\ell)$ and if $\ell \geq 5$, $N\ell = 4$ and if $\ell < 4$, $N\ell = \ell - 1$.

Simulation Results

In this section, we present numerical simulation results to illustrate the effect of symbol asynchronous, i.e., δ on the BER performance of downlink NOMA system. In Fig. 2, we show the BER performance under different settings of SIR (P_2/P_1) and symbol misalignment (δ) when the SNR ($h_{12}P_2/\sigma^2$) is fixed to 10dB.

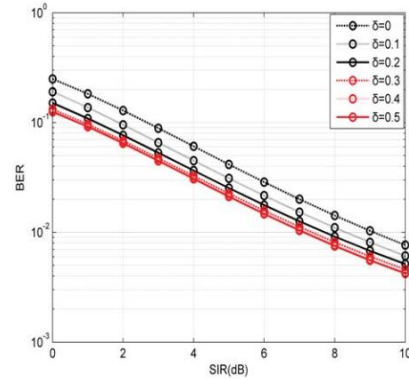


Fig. 2 BER versus SIR when SNR is 10 dB

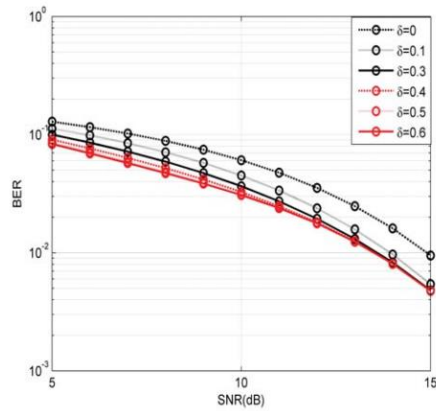


Fig. 3. BER versus SNR when SIR is 4dB

In Fig. 3, we present the BER performance under different setting of SNR and symbol misalignment (δ) when the SIR is fixed to 4dB. From both figures, we can see that the BER performance improves significantly as the symbol misalignment (δ) increases from 0 to 0.5.

III. CONCLUSIONS

In this paper, we have investigated the effect of symbol misalignment to the performance of downlink NOMA. Also, we derive the channel mode of asynchronous NOMA where SIC is applied at UEs. Furthermore, the result shows that symbol misalignment between the two signals can actually improve the BER performance and boost the system capacity, which is contrary to the traditional cognition that asynchrony is harmful and unnecessary to the downlink NOMA system. And when the misalignment is 0.5 symbol period, the

minimum BER and the maximum capacity are obtained.

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