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Performance Enhancement Using Receive Diversity With Power Adaptation in the NOMA System

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ABSTRACT This paper proposes receive diversity with power adaptation for a non-orthogonal multiple access (NOMA) system in a multi-user circumstance. Since the basic concept of power domain NOMA divides user data by the difference of power, successive interference cancellation (SIC) is necessary to extract user data. In the process of SIC calculation, the error propagation has occurred. Therefore, signal-to-interference-plus-noise ratio (SINR) decreases as the number of user entity increases in a power domain NOMA system. In order to mitigate the inter-user interference, data are allocated to subcarriers with an instantaneous user grouping scheme. With the subcarrier structure of the instantaneous user grouping scheme, this paper proposes receive diversity to improve the bit error rate (BER). However, since the diversity method decreases the sum capacity of the system, a power adaptation method is also proposed to compensate the sum capacity. The simulation results show that the proposed method improves the BER performance than the conventional scheme and increases sum capacity that is decreased by the receiver diversity scheme.

INDEX TERMS NOMA, SIC, power adaptation, receive diversity, user grouping, MRC.

I. INTRODUCTION

For the last 30 years, wireless communication has been evolved in the needs of faster data transmission and larger user capacity. Therefore there have been several user multiplexing technologies for the base station (BS) to accommodate multiple users [1], [2]. Frequency division multiple access (FDMA) and time division multiple access (TDMA) were the key multiplexing technologies for 1G and 2G communication. For 3G communication, it was code division multiple access (CDMA). Finally for 4G communication, it is orthogonal frequency division multiple access (OFDMA). Most of these multiplexing technologies are known as orthogonal multiple access (OMA) since user data are multiplexed with orthogonality.

However, for the 5G communication, new multiplexing technology called NOMA has emerged to meet the demands for data rate and capacity [3]–[6]. Numerous NOMA schemes exist and are categorized into two different domains of power and code domain NOMA [7]–[9]. This paper focuses on the power domain NOMA since it is a main research topic of the NOMA.

The representative method for the power domain NOMA is a basic NOMA with a SIC receiver shown in Fig. 1 [10], [11]. Power domain NOMA is one of a non-orthogonal multi-user superposition transmission (MUST) techniques. However, the basic power domain NOMA has problems such as error propagation and inter-user interference which degrades BER. There were previous works to increase BER performance or capacity of the power domain NOMA. M.B.Shahab suggested time sharing NOMA (TS-NOMA) to increase capacity [12]. There are situations which users cannot be paired with the user grouping scheme due to random cellular deployment. Therefore, TS-NOMA accommodates users which have similar channel gain to improve sum capacity. I.A.Mahady suggested improper Gaussian signaling (IGS) based NOMA to increase sum capacity under imperfect SIC calculation [13]. IGS looses the power constraint of the signal

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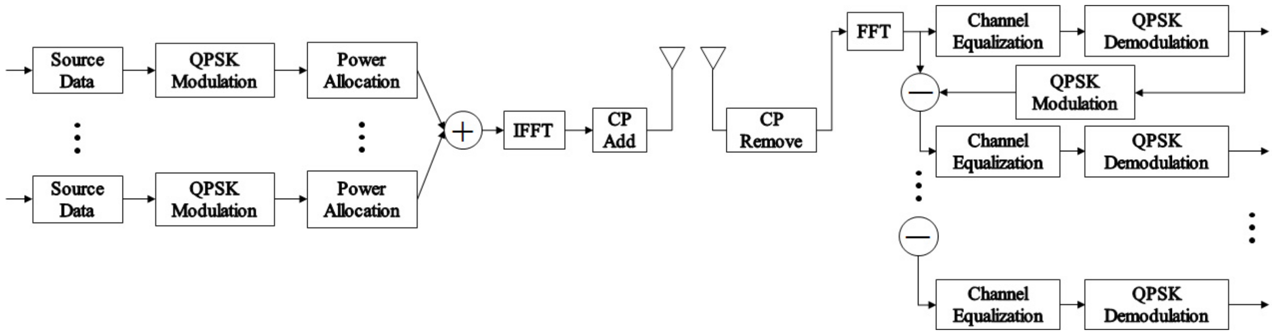

FIGURE 1. A basic NOMA system block diagram.

components to increase overall sum capacity. J.W.Kim suggested generalized space shift keying applied NOMA system to increase sum capacity and BER performance at the same time [14]. The spatial domain is assigned to cell-edge users for transmitting symbol information using the antenna index only without SIC. However, in [12], time synchronization is necessary to gain reasonable BER performance. Without time synchronization, TS-NOMA cannot avoid the timing error. In [13], the sub-optimal IGS coefficient that increases sum capacity can be achieved only after the system iteration which consumes time and power. In [14], BER and capacity performance are increased but additional transmit antennas are necessarily needed.

Therefore, this paper proposes a method which improves BER performance and compensates sum capacity with no additional relay unit, antenna, power and iterative sequence. Since the proposed method is applied upon the instantaneous user grouping method, the system can apply varying channel states. The power allocation complexity also decreases by maintaining the power level. Consequently, the proposed method mitigates the inter-user interference by using the user grouping scheme and raises the BER quality by using subcarrier diversity. It also compensates the capacity that is decreased by the diversity scheme with power adaptation.

User grouping is a scheme that groups multi user data by certain order in each subcarrier [15], [16]. It is used to reduce inter-user interference while accommodating multiple users in the proposed scheme. Receive diversity is a scheme that combines same data in different channel to achieve diversity gain. There are many combining methods of receive diversity in the literature [23]–[25]. The proposed scheme takes advantage of using one of the methods called maximal ratio combining (MRC) to achieve maximum channel gain. Power adaptation scheme is a scheme that adjusts the allocated power of the data [17], [18]. It aims to enhance sum capacity of the system in the proposed scheme.

Section 2 describes the system model of the basic power domain NOMA which doesn't use user grouping scheme. Section 3 describes the instantaneous user grouping scheme for the mitigation of the inter-user interference. Section 4 describes the proposed method that applies receive diversity with power adaptation. Section 5 shows simulation results and section 6 concludes the paper.

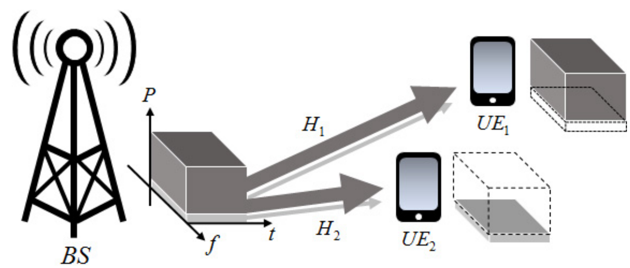

FIGURE 2. A basic NOMA system model.

II. POWER DOMAIN NOMA

Fig. 2 shows the downlink transmission of the basic power domain NOMA system model. *BS* and *UE* indicate a base station and a user entity respectively. P, f, and t in the third dimension graph indicate power, frequency, and time. H_1 and H_2 indicate a channel from *BS* to UE_1 and a channel from *BS* to UE_2 respectively.

BS superimposes all user data and allocates power. Power allocation is done by measuring channel states of each user entity. It is assumed that channel H_2 has better condition than channel H_1 according to their distances between BS and UEs. Therefore, *BS* allocates stronger power to the data of UE_1 than to the data of UE_2. Power allocation of the NOMA scheme is different from the usual case that user of good channel state gets stronger power and user of bad channel state gets weaker power [19], [20]. Since power domain NOMA distinguishes user entities by transmit power, each user of the system undergoes inter-user interference. Therefore, if the user with bad channel state gets weaker power than the others, the performance of the user with bad channel state becomes very poor.

It is assumed that the BS of the system model allocates power according to the channel sates of the subcarriers. Therefore, power distribution of the power domain NOMA system is done by using the channel state information (CSI) [21]. Power distribution is expressed as follows,

$$P_i = \frac{P_t}{|H_i|^2 \sum_{l=1}^{m} \frac{1}{|H_l|^2}}, \tag{1}$$

where P_i, P_t, H_i, and m indicate the individual allocated power, the total power, the channel state between *BS* and UE_i, and the number of total UEs respectively. It is assumed that the total power P_t is constrained in the transmitter. With the allocated power P_i, total transmit data X_t can be written as follows,

$$X_t = \sum_{i=1}^{m} P_i X_i, \tag{2}$$

where X_i indicates the UE_i's required data. User entity which has H_i channel state from the BS requires the data X_i. BS than obtains channel information from the feedback channel and allocates power P_i to the X_i according to (1). BS accumulates all data to form X_t and broadcasts it to every user entities. Therefore, the received signal Y_i at the UE_i is expressed as follows,

$$Y_i = X_t H_i + N_i, \tag{3}$$

where N_i indicates the thermal noise at the receiver. User entities of the receiver side should perform SIC calculation to extract their own data from the received data Y_i. In the system model of the Fig. 2, UE_2 performs SIC and UE_1 does not perform SIC. Since the allocated power of UE_1's data is large enough to consider the data of UE_2 as noise, UE_1 directly demodulates Y_1.

However, basic power domain NOMA which is also shown in [22], has major problem that the distributed power for each user decreases as the number of user entity increases and leads to poor BER performance since the total transmit power Pt is a fixed value. Therefore, the power domain NOMA without user grouping scheme is inappropriate to support multi users. This paper therefore proposes method to improve BER performance and compensate sum capacity by utilizing the structure of the conventional instantaneous user grouping which mitigates the inter-user interference and error propagation. In the next sections, since three users are the minimum number to show the meaningful results of the user grouping scheme, NOMA system with three users is considered. However, since the proposed method can be extended to m-users, the system model and simulation results considering m-users are shown in the simulation part.

III. INSTANTANEOUS USER GROUPING

Basic power domain NOMA is inappropriate to accommodate multi users due to inter-user interference. Therefore, this paper utilizes user grouping scheme which groups the data of user entities by applying instantaneous channel states over the whole bandwidth to mitigate inter-user interference and improve BER performance. Since the instantaneous user grouping scheme considers a varying channel among subcarriers, it can be used in scenario where a lot of random noise signals with different frequencies exist.

Fig. 3 shows the superimposed data partitioned into several subcarriers where s_k refers to the $k-th$ subcarrier of the aggregated data. Three user data are multiplexed and grouped into two power levels P_1 and P_2 in each subcarrier. Since there are only two power levels in the user grouping NOMA, the SIC calculation for every single subcarrier is reduced compared to the basic power domain NOMA which accommodates more than three users. Channel gains between the BS and the users can be defined as follows,

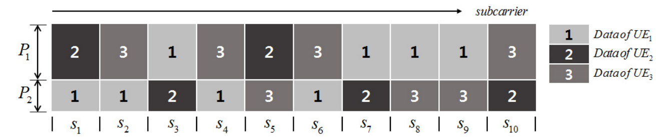

FIGURE 3. Efficient user grouping with 3 user entities.

$$\begin{aligned} H_1 &= (h_{1,1}, h_{1,2}, \ldots, h_{1,U}) \\ H_2 &= (h_{2,1}, h_{2,2}, \ldots, h_{2,U}) \\ H_3 &= (h_{3,1}, h_{3,2}, \ldots, h_{3,U}), \end{aligned} \tag{4}$$

where U indicates the number of total subcarriers. H_1, H_2, and H_3 represent channel gains between BS and each user which has U subcarriers. Therefore, $h_{1,1}$ represents the first subcarrier of H_1 which indicates channel between BS and UE_1. The process to group three user data requires channel sorting by using the subcarriers of the channels as follows,

$$h_{max,k} = max(|h_{1,k}|^2, \ldots, |h_{i,k}|^2)\ (k = 1, \ldots, U), \tag{5}$$

$$h_{min,k} = min(|h_{1,k}|^2, \ldots, |h_{i,k}|^2)\ (k = 1, \ldots, U), \tag{6}$$

where $h_{i,k}$ indicates the $k-th$ subcarrier of H_i. $h_{max,k}$ and $h_{min,k}$ represent maximum and minimum channel gain for each $k-th$ subcarrier among three channels. BS gets each channel gain from the users through feedback channel and performs channel sorting by calculating best and worst channel gain such as (5) and (6). The channel sorting process should be done over the whole subcarriers. After this procedure, BS calculates power according to (1). Calculating allocation power is essential to group three user data. Weak power P_2 is allocated to the data of the user i which its subcarrier $h_{i,k}$ has the best channel state. Similarly, strong power P_1 is allocated to the data of the user i which its subcarrier $h_{i,k}$ has the worst channel state. Finally, BS aggregates all user data as in Fig. 3 and broadcasts the aggregated data. With this user grouping, superimposed data reflect the state of the individual subcarrier channels, and BS can group more than two users into two power levels. Therefore, inter-user interference is mitigated by this user grouping scheme.

Fig. 4 shows the user grouping transmission from BS to three user entities. BS transmits the aggregated data to all three users simultaneously. In Fig. 4, weak power is allocated to the data of UE_1. Only one SIC calculation is performed to extract the data of UE_1. Since Fig. 4 represents the situation of the subcarrier s_1 and s_2 in Fig. 3, in the view of s_3 in Fig. 3, UE_2 should perform single SIC calculation to extract the data. Therefore, with the user grouping, all user data can be allocated by the weak or strong power over the whole subcarriers. Accordingly, unlike conventional NOMA, user entities of user grouping NOMA system should know the position of their subcarriers.

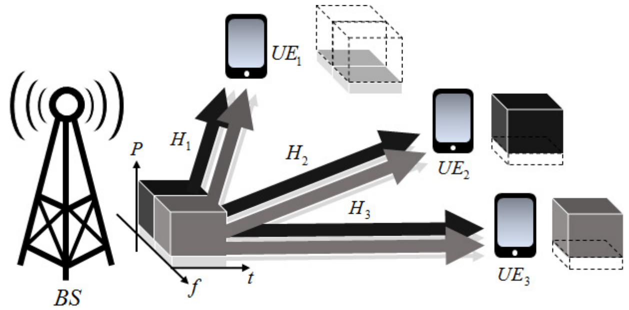

FIGURE 4. User grouping system with 3 user entities.

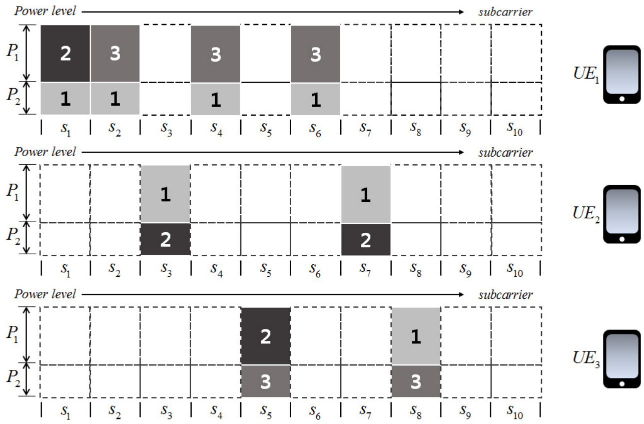

FIGURE 5. Subcarrier allocation of the aggregated data.

It is assumed that user entities obtain the information which subcarrier s_k carries UE_i's data as the data with strong or weak power through the feedback channel from the BS. The information is based on (5) and (6) from the BS. With this information, each user entity finds its data in the subcarriers. Therefore, for individual subcarrier, all three user entities get the superimposed data as follows,

$$Y_{i,k} = \sqrt{P_1}x_{i,k} + \sqrt{P_2}x_{j,k}\ (i, j = 1, 2, 3), \tag{7}$$

where $Y_{i,k}$, $x_{i,k}$, and $x_{j,k}$ indicate the $k-th$ subcarrier of the aggregated data at the UE_i, the UE_i's data in the $k-th$ subcarrier and the UE_j's data in the $k-th$ subcarrier respectively. (7) shows the user grouping property that the demodulation process for a certain user data should be sequentially different among the whole subcarriers. In the view of UE_1, UE_1 directly demodulates its data from the subcarriers where strong power is allocated to UE_1. On the contrary, UE_1 performs SIC calculation to extract its data from the subcarriers where weak power is allocated to UE_1. Finally UE_1 gets its whole data after this demodulation process.

With the instantaneous user grouping scheme, three user entity NOMA system avoids the inter-user interference caused by multi users in the same channel and the error propagation caused by the accumulation of the demodulation error.

IV. PROPOSED METHOD

A. SUBCARRIER RECEIVE DIVERSITY

User grouping scheme enables each subcarrier to apply channel state instantaneously. With the structure of user grouping, receiver diversity can be applied by assuming that there are the same data in the weak power position. For example, it is assumed that the data, which are allocated with P_2 within subcarrier s_1 and s_2 in Fig. 3, are the same. This paper applies maximal ratio combining (MRC) which is one of many diversity methods [23]–[25]. With the MRC, the signal to noise ratio (SNR) of the NOMA system is maximized for subcarriers using the structure of the user grouping while giving up certain amount of capacity since the same data are assumed in subcarrier pairs.

Each user gets the whole aggregated data which BS broadcastes to the users. During the demodulation process, subcarrier diversity scheme is applied to maximize the performance of the user data which are allocated with P_2. Subcarriers which have the data of UE_i allocated with P_2 are shown in Fig. 5. By the basic principle of the power domain NOMA, user entities directly demodulate the data in subcarriers which are allocated with P_1. For the data which are allocated with P_2, user entities perform subcarrier diversity using the structure formed by instantaneous user grouping.

For the data of UE_1, P_2 is allocated in subcarriers s_1, s_2, s_4, and s_6 in Fig. 3. Among the subcarriers, there are subcarrier pairs which have the same data in the position of weak power while having different data in the position of strong power. Since individual subcarriers can be regarded as individual channels, s_1, s_2 pair and s_4, s_6 pair can be calculated with subcarrier diversity using MRC [25] in Fig. 5. All user entities can perform MRC with the pairs of subcarriers which have the same data allocated with weak power P_2 and different data allocated with strong power P_1. Overall processes of the MRC are as follows,

$$\begin{aligned} Y_{1,1} &= \sqrt{P_1}x_2h_{1,1} + \sqrt{P_2}x_1h_{1,1} + n_{1,1} \\ Y_{1,2} &= \sqrt{P_1}x_3h_{1,2} + \sqrt{P_2}x_1h_{1,2} + n_{1,2}, \end{aligned} \tag{8}$$

where $n_{i,k}$ indicates noise of the UE_1's $k-th$ subcarrier. For the understanding ease, this paper calculates MRC procedure focused in the view of subcarrier s_1 and s_2 of UE_1. Therefore, this paper expresses the index of s_1 and s_2 of UE_1 as subscript $(1, 1)$ and $(1, 2)$ in the equation (8). However, this paper generalizes subscript $(1, 1)$ into a and $(1, 2)$ into b since s_1 and s_2 are not the only subcarriers which use MRC. Received data Y_a and Y_b have UE_1's data in common with P_2. To extract UE_1's data, UE_1 should perform SIC in the received signal Y_a to demodulate the data which are allocated with P_1 as follows,

$$\begin{aligned} \frac{Y_a}{\sqrt{P_1}h_a} &= x_2 + (\frac{\sqrt{P_2}}{\sqrt{P_1}}x_1 + \frac{n_a}{\sqrt{P_1}h_a}) \\ \frac{Y_b}{\sqrt{P_1}h_b} &= x_3 + (\frac{\sqrt{P_2}}{\sqrt{P_1}}x_1 + \frac{n_b}{\sqrt{P_1}h_b}). \end{aligned} \tag{9}$$

To extract UE_1's data which are allocated with P_2, UE_1 demodulates the data which are allocated with P_1 and subtracts it from the received data as follows,

$$Y_a - \sqrt{P_1}\tilde{x_2}\tilde{h_a} = \sqrt{P_2}x_1 h_a + \tilde{n_a}$$
$$Y_b - \sqrt{P_1}\tilde{x_3}\tilde{h_b} = \sqrt{P_2}x_1 h_b + \tilde{n_b}. \tag{10}$$

It is assumed that channel estimation and user data demodulation process are perfect. Therefore, tilde sign in (10) can be removed. If $Y_a - \sqrt{P_1}\tilde{x_2}\tilde{h_a}$ and $Y_b - \sqrt{P_1}\tilde{x_3}\tilde{h_b}$ are represented as Y'_a and Y'_b, the following equations can be obtained,

$$h_a^* Y'_a = \alpha_1^2\sqrt{P_2}x_1 + h_a^* n_a$$
$$h_b^* Y'_b = \alpha_2^2\sqrt{P_2}x_1 + h_b^* n_b, \tag{11}$$

where h_a^* and h_b^* indicate the conjugate of the channel group a, and the conjugate of the channel group b. Since the channel h_a and h_b are represented as $\alpha_1 e^{j\theta}$ and $\alpha_2 e^{j\theta}$ with the weight factor α in [25], $h_a^* h_a$ and $h_b^* h_b$ can be represented as α_1^2 and α_2^2 on the right hand side of (11). Since the data of UE_1 are the only data left in (11), MRC calculation proceeds as follows,

$$h_a^* Y'_a + h_b^* Y'_b = \sqrt{P_2}(\alpha_1^2 + \alpha_2^2)x_1 + h_a^* n_a + h_b^* n_b, \tag{12}$$

$$\frac{h_a^* Y'_a + h_b^* Y'_b}{\sqrt{P_2}(\alpha_1^2 + \alpha_2^2)} = x_1 + (\frac{h_a^* n_a + h_b^* n_b}{\sqrt{P_2}(\alpha_1^2 + \alpha_2^2)}). \tag{13}$$

Data of UE_1 can be demodulated with (13). The denominator of the noise term becomes larger than the case of original SIC calculation for basic power domain NOMA. Therefore, the noise term is minimized and the SNR is increased by the subcarrier diversity method.

However, there are remaining issues of this proposed scheme. First, since subcarriers have to form pairs to perform MRC, the subcarrier which doesn't have its pair cannot perform MRC when the number of subcarriers is odd. The subcarrier that does not have its pair should perform SIC calculation as same as the basic power domain NOMA. Second, the BER performance gain of the MRC changes by the number of the subcarrier pairs. Therefore, the closest user tends to have the best performance enhancement by the MRC while the furthest user tends to have the worst performance enhancement. However, by using MRC combined with instantaneous user grouping, proposed NOMA system is able to avoid the error propagation caused by SIC calculation and maximize the diversity gain of the subcarriers.

B. SUBCARRIER POWER ADAPTATION

In the basic power domain NOMA system, the BER performance of UE_i's data decreases when the allocated power decreases. However, BER performance of the user data which are allocated with weak power P_2 in the proposed method can be increased by using MRC. Therefore, this paper proposes power adaptation scheme which increases the strong power P_1 and decreases P_2 to compensate capacity which is decreased by the MRC. Capacity of each subcarrier of the proposed system model in Fig. 4 can be expressed according to the Shannon's theorem as follows,

$$C_{sum} = \frac{1}{2}\Delta f log_2(1 + \frac{P_2(|h_{i,k}|^2 + |h_{i,k'}|^2)}{P_N}) + \Delta f log_2(1 + \frac{P_1|h_{j,k''}|^2}{P_2|h_{j,k''}|^2 + P_N}), \tag{14}$$

where k and k' indicate subcarrier indexes which use MRC as a pair in the condition of $k \neq k'$. k'' indicate subcarrier index which doesn't use MRC. C_{sum} and Δf indicate the sum capacity of a single subcarrier, and bandwidth of a single subcarrier. P_N, i, and j indicate noise power, UE index which uses MRC, and UE index which doesn't use MRC. The first term of the equation is a capacity of the user i in a subcarrier k which uses MRC. Since it is assumed that there are the same data in a subcarrier pair which uses MRC, the first term has to be divided into two. The second term of the equation is a capacity of the user j in a subcarrier k'' which doesn't use MRC.

Since power adaptation method aims to increase the strong power P_1 and to decrease the weak power P_2, the sum capacity in equation (14) increases when the power adaptation mehod is applied. Power adaptation method is done by the transmitter. The transmitter increases P_1 to P'_1 and decreases P_2 to P'_2 of the subcarriers which use MRC as follows,

$$R = \frac{(\alpha_1^2 + \alpha_2^2)}{\alpha_1^2}, \tag{15}$$

$$P'_1 = \frac{\sqrt{P_1}R}{\sqrt{P_2} + \sqrt{P_1}R}, \tag{16}$$

$$P'_2 = \frac{\sqrt{P_2}}{\sqrt{P_2} + \sqrt{P_1}R}, \tag{17}$$

where R, P'_1, and P'_2 indicate the ratio of channel gain increment, adjusted strong power and the adjusted weak power.

Fig. 6 shows the aggregated data applied by adaptive power allocation. The subcarriers s_9 and s_{10}, have the same power allocation as in Fig. 3. However, transmitter adjusts the allocated power for the subcarriers which use MRC. Transmitter decreases the weak power of the data which use MRC in the subcarriers s_1 to s_8. It can be seen that the UE_3's data of s_5 and s_9 have different error rate by the difference of allocated power. Since the error rate of the UE_3's data in s_5 is more tolerable than that of s_9 because of the MRC, power difference of the strong and weak power can be adjusted to improve the error rate and sum capacity of the user data in the strong power P'_1 position. Consequently, subcarrier receive diversity with power adaptation method enhances BER performance and compensates the sum capacity which is downgraded by the receiver diversity.

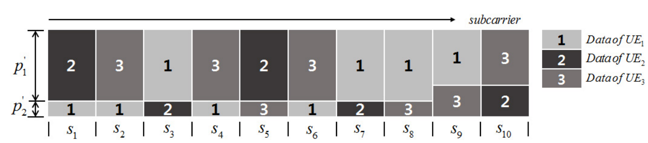

FIGURE 6. Adaptive power allocation.

V. SIMULATION RESULTS

In this section, simulation results are shown.

Table. 1 shows simulation parameters in this paper. Simulations are done by transmitting orthogonal frequency division multiplexing (OFDM) symbol with 128 subcarriers. The size of guard interval is 32. It is assumed that the number of transmit and receiver antenna is one. Binary phase shift keying (BPSK) is used for modulation and Rayleigh fading channel is assumed with 7 paths. In the simulation, the distance rate of the users is set to be 1.2. For example, if there are three users in the system, the distances between the BS and the users are 1, 1.2, and 1.44.

TABLE 1. The simulation parameters.

Parameter	Value
FFT size	128
Guard interval size	32
Number of antennas	Tx=1, Rx=1
Modulation	BPSK
Channel model	Rayleigh channel (Path=7)
Distance rate of the users	1.2

With the simulation parameters, Fig. 7 shows the BER performance of the NOMA schemes. The term UG and PA indicate user grouping and power adaptation. Black dotted line indicates the BER performance of the basic power domain NOMA. Black solid line indicates the BER performance of the user grouping applied NOMA. Blue line refers to the BER performance of the user grouping NOMA with MRC. Finally, red line indicates the BER performance of the proposed NOMA system which the power adaptation scheme is added. The black dotted line refers to the average BER performance of two user scenario while the solid lines refer to the average BER performance of three user scenario. Therefore, it can be seen that the inter-user interference is successfully mitigated by adjusting user grouping scheme.

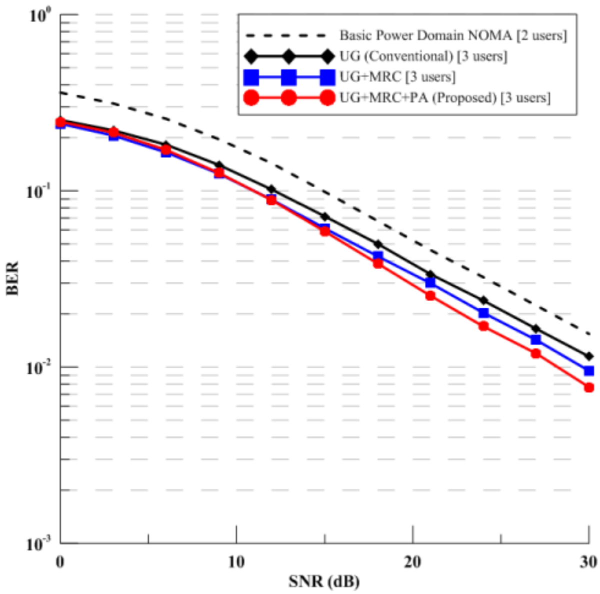

FIGURE 7. The BER performance of NOMA schemes.

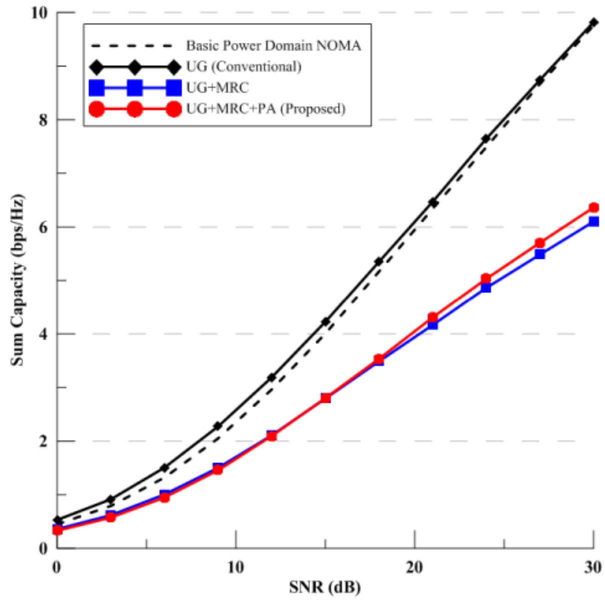

FIGURE 8. The sum capacity of NOMA schemes (3 user scenario).

MRC is applied to enhance the BER performance by using the structure of user grouping scheme. Therefore, blue line has better BER performance than the solid black line. Additionally, to compensate the sum capacity, this paper adjusted power adaptation method by increasing the strong power and decreasing the weak power. Therefore, the overall BER performance further increases in Fig. 7.

Fig. 8 shows the sum capacity of the NOMA schemes in three user scenario. The black dotted line refers to the sum capacity of the basic power domain NOMA. The black solid line refers to the sum capacity of the NOMA with user grouping. The user grouping NOMA has slightly better capacity than the basic power domain NOMA since the user grouping mitigates the inter-user interference. The blue line refers to the user grouping applied in the NOMA with MRC. By adjusting subcarrier diversity scheme, the sum capacity of the NOMA system decreases since there are identical data in subcarrier pairs which use MRC. It can be seen in the first term of (14) that the capacity is divided into two. Therefore, the sum capacity of NOMA system which uses MRC downgrades. However, BS of the proposed scheme compensates sum capacity by adjusting power as the red line in Fig. 8. The BS decreases the allocated power of the user data which use MRC, while increasing the allocated power of the data which doesn't use MRC to increase sum capacity.

Fig. 9 shows the required feedback information bits per subcarrier of the NOMA schemes. *BS* needs to inform the *UE*s of the presence of their data in subcarriers. *BS* also needs to inform the *UE*s whether they need to perform MRC or not. Therefore, it can be thought that the proposed scheme requires more information bits to deliver to *UE*s than the basic NOMA scheme. However, Fig. 9 shows that the basic NOMA without user grouping needs more information bits than the proposed NOMA when the number of user entity m

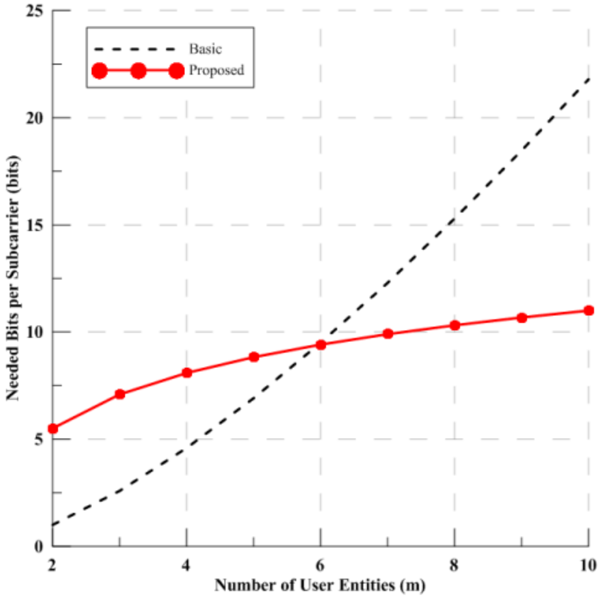

FIGURE 9. Required bits per subcarrier.

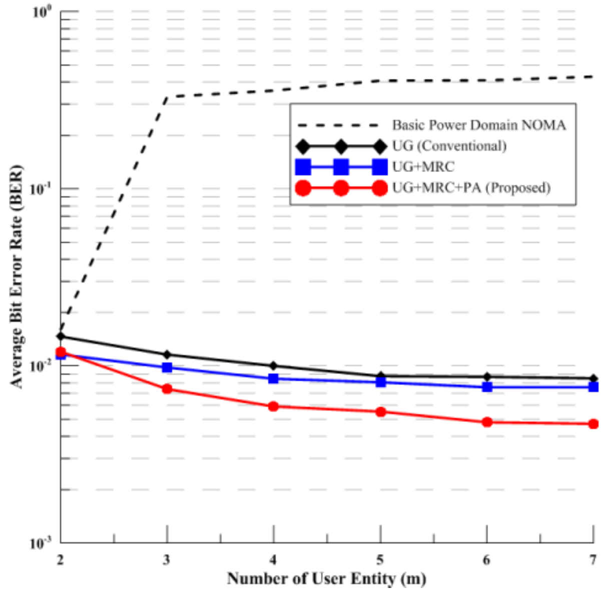

FIGURE 10. The BER performance of NOMA schemes.

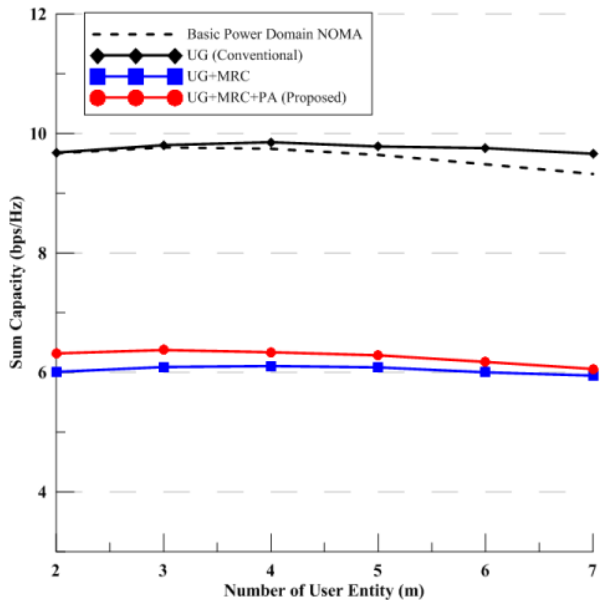

FIGURE 11. The sum capacity of NOMA schemes.

exceeds six. The number of required feedback bits of the basic NOMA is calculated as $klog2(m!)$. Since a single subcarrier is occupied by m users, there are $m!$ possible combinations. k is multiplexed for the number of subcarriers. Therefore, the number of required bits of basic power domain NOMA is calculated as follows,

$$E_{basic} = klog2(m!), \tag{18}$$

where E_{basic} indicates the number of required bits of basic power domain NOMA. However, the proposed method requires more diverse information such as the possible combination of the user occupation, the number of subcarriers which use MRC, and the presence of the UEs data in subcarriers. Therefore, the number of required bits of proposed NOMA is calculated as follows,

$$E_{proposed} = klog2({}_mP_2) + \frac{k}{2}log2(k) + k, \tag{19}$$

where $E_{proposed}$ indicates required bits of the proposed NOMA with user grouping. The possible combination of the user position can be calculated as ${}_mP_2$ in a single subcarrier since there are only two levels of power distribution in the proposed NOMA system. BS also needs to inform the exact location of the subcarrier index which uses MRC. Since there are two pairs of subcarriers which use MRC, UE only needs to search for $k/2$ times and it is shown as the second term of (19). Additionally, UE needs to search all k subcarriers whether its data is presence in the weak power position or not and it is shown as the third term of (19). By the (18) and (19), it can be seen in Fig. 9 that the number of required bits of the basic NOMA exceeds the proposed NOMA when the number of UEs in the system is over six. Therefore, it is more practical to use the proposed NOMA scheme than the basic NOMA in the system where there are more than six UEs.

Fig. 10 shows the BER performance of the NOMA schemes with m-users. The user grouping scheme successfully mitigates the inter-user interference by constraining the power level into two. Therefore, the average BER performance of NOMA system with the user grouping outperforms the basic power domain NOMA. In order to increase the BER performance by using the user grouping scheme, MRC is applied to further increase the BER performance in the proposed scheme and the simulation result is shown in the blue line of Fig. 10. However, since the sum capacity of the user grouping NOMA with MRC is decreased, the power adaptation is proposed to compensate the loss of sum capacity. Consequently, if the power adaptation is applied, the BER performance of the proposed method is increased than the user grouping NOMA with MRC.

Fig. 11 shows the sum capacity of the NOMA schemes with *m*-users. It is shown that the conventional NOMA scheme with user grouping has the largest sum capacity. Since each user in the conventional scheme should consider every other users as interference, the sum capacity decreases as the number of user increases. However, because the user data of the user grouping NOMA system with MRC are same in subcarrier pairs, sum capacity is decreased while BER performance is increased. Therefore, power adaptation is proposed to increase the sum capacity.

VI. CONCLUSION

Massive user capacity is required to increase the data traffic in 5G communication. NOMA is one of the key technologies to efficiently improve the user capacity. However, since the users are distinguished with power difference in the NOMA system, basic power domain NOMA has serious BER performance degradation. To improve the BER performance, this paper proposes subcarrier diversity over conventional instantaneous user grouping scheme which mitigates the effect of inter-user interference and error propagation. Power adaptation is also proposed to compensate the sum capacity loss which is occurred by the subcarrier diversity and further improve the BER performance. However, since the method to improve the BER performance decreases sum capacity, the proposed scheme needs improvement to balance the BER performance and the sum capacity. Therefore, proposing an optimization framework to find the optimal or sub-optimal point of BER and sum capacity trade-off is left for future work. The method to find the optimal point of BER and sum capacity trade-off in random channel state by using machine learning is also left for future work. A well trained artificial model is expected to decrease the computational complexity of the proposed NOMA system.

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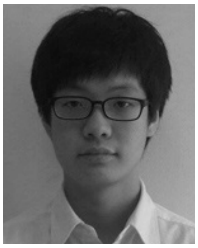

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