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MIMO Non-orthogonal Multiple Access Schemes

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Abstract-Based on non-orthogonal multiple access (NOMA) schemes applied on MIMO communication systems, it is going to design some new precoding and detection matrices for NOMA-MIMO systems. In order to achieve the adequate performance in new schemes, it assumes with user pairing method, which can make up of cluster groups in receivers, which can be considered. Also, zero-forcing algorithm, block diagonalization (BD) in particular, can used to analyze power allocation coefficient and transmission rate. Generally with basic system model, the paper discusses the fundamental principles, compares to conventional conditions, and analyzes problems with mathematics estimation. In addition, depending on computer simulation, the results can be concluded and extended for overall performance. And according to conclusion it can demonstrate systems shortage and future communication development.

I. Introduction

The conventional multiple access technique-orthogonal multiple access (OMA) schemes have been the dominant technology to employ the wireless systems. However, the conventional multiple access cannot satisfy high communication speed and load at the low data rate. Especially, 5th generation wireless systems require a faster and massive connections system to support transmission capacity and service billion of users. non-orthogonal multiple access (NOMA) can provide significant performance gains over OMA schemes, it has been recognized as a viable solution of achieve spectrally efficient multiple access [1]. Non-orthogonal multiple access can support more connections than other systems and improve allocation of system capacity and fairness. Basically, NOMA schemes consist of two parts: power-domain multiplexing and code-domain multiplexing [2].

The basic idea of NOMA for multiple access is to introduce power domain, which the previous generation of mobile networks have been relying only on the time/frequency/code domain. NOMA allocates a great amount of power to subcarriers with many users in weak conditions to facilitate a balance and trade-off between system throughput and users fairness. It means that NOMA scheme can meet the demanding 5G requirements of ultra-low latency and ultra-high connectivity [2],[10],[47-48],[50]. Besides that, the users who can perform much better and have good resource allocation will use the successive interference cancellation (SIC) policy [3],[9]. For example, they will decode the transmission information to the users who have relatively poorer resource distribution. Consequently they decode themselves' information by excluding other users.

In this paper, we aim to combine the schemes of multiuser applied in multiple-input multiple-output (MIMO) scheme with NOMA downlink communication systems [3]. As multiple techniques can achieve multi-stream beam-forming coding diversity, the use of MIMO techniques brings flexible dimension for performance improvements. On the other hand, based on zero-forcing (ZF) technique, low complexity linear precoding scheme can reduce inter-interference when channel transmission [8]. Clearly, block diagonalization (BD) is typical linear precoding technique with implemented in the downlink of multiuser MIMO systems [4],[13],[15],[17],[20]. This method can decompose a downlink MU-MIMO channel to multiple parallel independent single-user downlink subcarriers [5]. At transmitter, each user is pre-processed by modulation matrix. Hence, multiple users interference is set to zero in the system, there will be no interference between different users [8],[19].

In addition, considering a general MIMO-NOMA communication network scenario with multiple users to introduce basic schedule [12]. It is clear that the signal is transmitted with NOMA in multiple output [13], each channel can support two users at least. Secondly, we will define new system throughput compared to orthogonal multiple access (OMA) systems [14]. For example, demonstrating NOMA power allocation policies, the use of successive interference cancellation in some users with good conditions, and the relationship between NOMA and conventional information theoretic concepts illustrate the advantages of NOMA. Then, we combine MIMO and NOMA to cooperation [3],[12].

More specifically in this paper, we contribute on one downlink communication system within a single base station connecting with multiple subcarriers. In the downlink area, we propose receive users distributed in groups, which means a cluster is made up of two users in the systems. Generally, the number of transmit antennas is equivalent with the number of clusters. So with applied block diagonalization (BD) algorithm [8],[15],[20] in terms of power control or maximum outputs, it has to consider channels restriction where the total number of transmit antennas (n_T) is equal or greater than the corresponding number of receive antennas (n_R) through the operation process ($n_T \geq n_R$) [6]. Based on the above regulation, it demonstrates within each cluster we implement NOMA schemes, and in terms of eliminating inter-cluster interference we implement MIMO detection [11]. This proposal can prevent random beamforming to influence the quality of service (QoS) experienced by users negatively [2].

Depended on controllable interference by non-orthogonal resource allocation in receiver complexity, the NOMA's benefits can be described by improved spectral efficiency, massive connectivity and low transmission latency and signaling cost [7]. As a consequence, with NOMA-MIMO scheme implemented, the performance of conventional OMA-MIMO will be much lower than implemented NOMA schemes. Also, it can achieve multiple users communication with reasonable trade-off and without interference[39], [43].

Furthermore, based on the framework which we propose in this paper, it can illustrate MU-MIMO-NOMA schemes can realize better performance in network systems [20]. Then with involving zero-forcing precoding and some types of detection vectors, it assumes that the system can develop throughput rate and capacity efficiently according to simulation data analysis [17-19]. The fundamental purpose is to implement NOMA in LTE and 5G networks significantly. We review and discuss problems formulation, and we will summarize the potential challenges and make some promising future directions.

II. System Model

We are trying to establish a downlink communication schedule with NOMA model, where a base station installed with M antennas connects to receiver, and there are N antennas connected with each user correspondingly, particularly, M and N need to satisfy the condition as N > $\frac{M}{2}$. There is a disc (denoted by $\mathcal{D}$) where multiusers can be deployed. Basically, the radius of disc is r, and the center of $\mathcal{D}$ is base station [2],[13]. In order to decrease the load of system, it has proposed to pair two users for NOMA implementation [2]. Then the disc will also be divided into two sections $\mathcal{D}_1$ and $\mathcal{D}_2$, corresponding included m users and m' users which contributes into M pairs of users [13]. So these users are paired together randomly.

In this paper, based on previous analysis including SISO-NOMA schemes and MC-NOMA schemes [48], the author will demonstrate the two system models briefly. Then it is going to focus on MU-MIMO-NOMA systems. In the third complex scheme, there are M transmission antennas from a single base station connected to the downlink channels, correspondingly, there are N antennas that each user equipped, particularly $N > \frac{M}{2}$ in this paper.

A. SISO-NOMA Transmission Schedule

Simply, in system downlink framework we illustrate basic NOMA concept and implement the case with single transmit antenna and single receive antenna [12],[21]. In other words, it is a single input single output (SISO) system [13-14],[48],[52]. Then without loss of generality, we can define the signal observation is:

$$y_i = h_i x + w_i, \qquad (1)$$

where h_i represents the channel coefficient between user-i and base station [21-23], w_i is additive white Gaussian noise (AWGN) [24], and the power spectral density of w_i is $N_{0,i}$. The following Fig.1 shows the downlink NOMA with SIC in terms of two users.

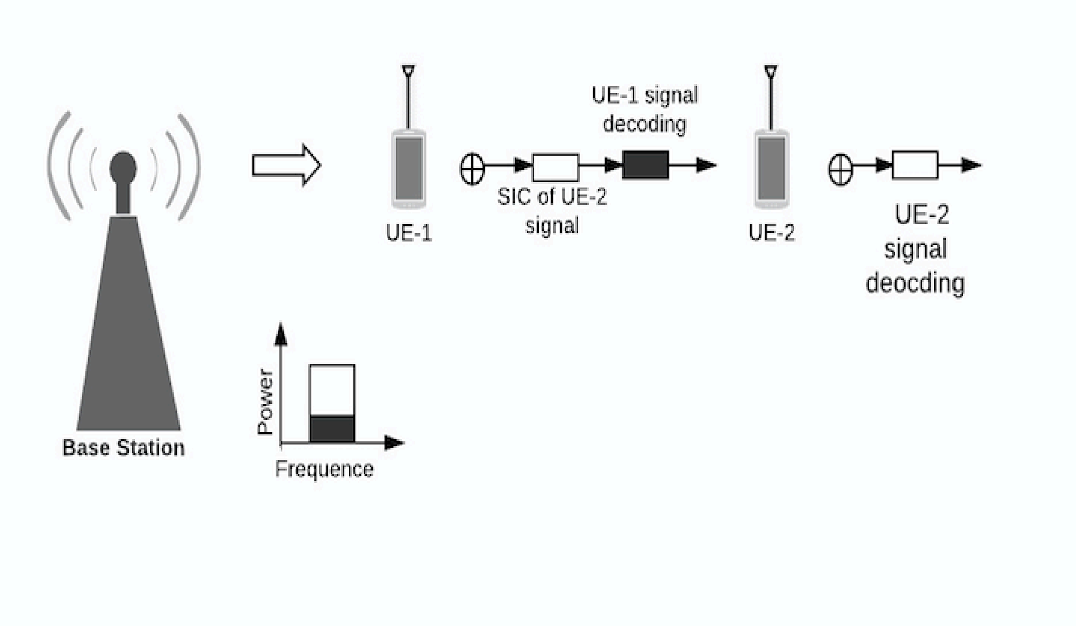

Figure.1 Downlink NOMA with applied SIC in SISO scheme.

B. Combination of NOMA and MIMO

As Fig.2 shown, random beamforming is used for form of combination of downlink NOMA with MIMO [49]. In this diagram, the base station transmitter creates multiple beams to MC (multicarrier)-MIMO, and each user is within each beam. Relatively, stronger users in receiver produce SIC which is used for intra-beam user demultiplexing to decode signal [26],[49].

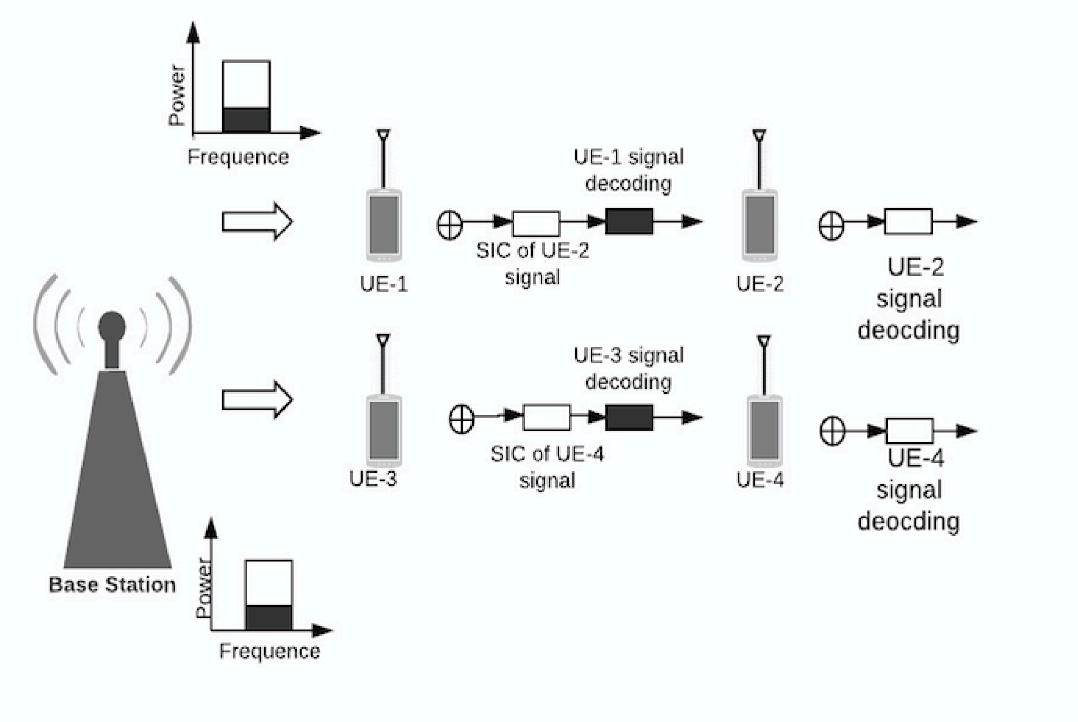

Figure.2. Downlink MIMO-NOMA applied SIC scheme

There are multiple users who are treated with kinds of services level in terms of power distribution in NOMA systems with power domain allocation because of multiple access. Specifically, for a given subcarrier, in the better downlink channel resource allocation a user can decode and remove the co-channel interference (CCI) from other user who has a relatively poorer downlink channel condition by using SIC [9],[13-14],[16],[32],[36],[45],[51]. We assume that two users m and n are multiplexed on subcarrier i. Then the system throughput on subcarrier i can be illustrated as:

$$U_{m,n}^{i}\left(p_m^i p_n^i s_{m,n}^i\right) = s_{m,n}^i \left[w_m \log_2\left(1+\frac{H_m^i p_m^i}{H_m^i p_n^i+1}\right) + w_n \log_2(1+H_n^i p_n^i)\right], \qquad (2)$$

where $H_m^i = \frac{\rho_m |h_m^i|^2}{\sigma_{z_m}^2}$, $H_m^i \leq H_n^i$, and $0 \leq w_m \leq 1$ [37].

C. MIMO-NOMA Transmission Schedule

The base station is equipped with M antennas that communicate multiuser connected with N antennas each. The users are grouped into M clusters, and each cluster consists of two users [2],[13],[30-34],[53]. Both users and base station have CSI. Generally, the system model can be described as the following Fig.3.

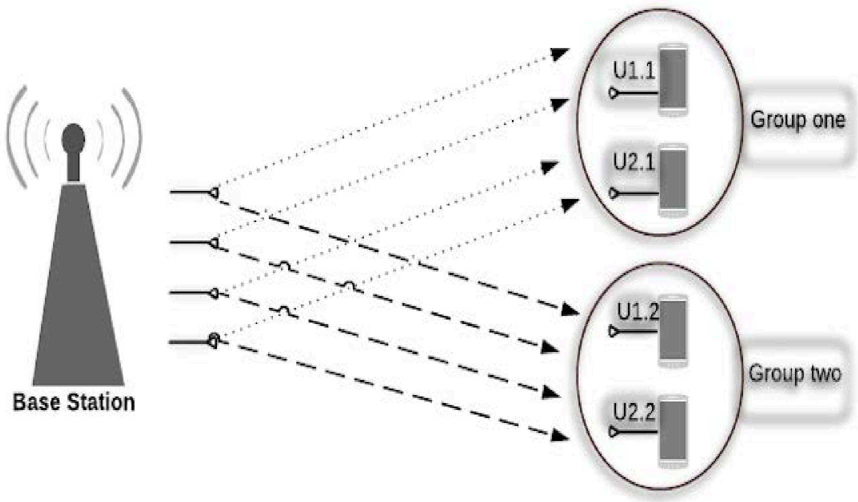

Figure.3 Downlink multiuser MIMO-NOMA scheme

Therefore, the signals are described as:

$$x=Ps, \tag{3}$$

The M × 1 transmitted information vector from base station can be illustrated as:

$$s = \begin{bmatrix} \alpha_1 s_1 + \alpha_{1'} s_{1'} \\ \vdots \\ \alpha_M s_M + \alpha_{M'} s_{M'} \end{bmatrix}, \tag{4}$$

where s_m is signal intended for user m, α_m is the power allocation coefficient [45], and $\alpha_m + \alpha_{m'}$ = 1 [13]. The formulation $H_m = \frac{G_m}{\sqrt{L(d_m)}}$ represents channel matrix between base station and user-m. G_m is an N x M matrix, which denotes

Rayleigh fading channel gains. d_m means the distance between base station and user-m [2]. Also,

$$L(d_m)\begin{cases} d_m^{\alpha}, if\ d_m > r_0 \\ r_0^{\alpha}, otherwise \end{cases}, \tag{5}$$

where α represents the path loss exponent. r_0 denotes small distance to avoid singularity. The user m observation formula is:

$$y_m = \frac{G_m}{\sqrt{L(d_m)}} Ps + w_{I_m} + n_m, \tag{6}$$

where P is precoding matrix in M x M, w_{I_m} means the user received total co-channel interference, n_m represents the noise vector [13],[35].

Then we bring a channel detection vector v_m into the observation, the new expression formula become as:

$$\begin{aligned} v_m^H y_m &= v_m^H \frac{G_m}{\sqrt{L(d_m)}} Ps + v_m^H\left(w_{I_m} + n_m\right) \qquad (7) \\ &= v_m^H \frac{G_m}{\sqrt{L(d_m)}} P_m(\alpha_m s_m + \alpha_{m'} s_{m'}) + \textstyle\sum_{i\neq m} v_m^H \frac{G_m}{\sqrt{L(d_m)}} p_i(\alpha_i s_i + \alpha_{i'} s_{i'}) + \\ &\quad v_m^H\left(w_{I_m} + n_m\right), \end{aligned}$$

where P_m means the m-th column of P.

Based on the construction of transmission formulation, it has to remove inter-interference in each group. Thus, the following regulation needs to be satisfied:

$$\begin{bmatrix} v_m^H G_m \\ v_{m'}^H G_{m'} \end{bmatrix} p_i = 0_{2\times 1}, \forall_i \neq m, \tag{8}$$

where $0_{m\times n}$ represents the m x n all zero matrix.

In order to improve system throughput, it is going to apply interference alignment in the system. Regarding to the detection vector, it has to meet the constraint as:

$$v_m^H G_m = v_{m'}^H G_{m'}, \tag{9}$$

or

$$\begin{bmatrix} G_m^H & -G_{m'}^H \end{bmatrix} \begin{bmatrix} v_m \\ v_{m'} \end{bmatrix} = 0_{M\times 1}, \tag{10}$$

U_m is a 2N x (2N-M) matrix, $[G_m^H \quad -G_{m'}^H]$ is right singular vectors of U_m corresponding to the zero singular values. We can regulate as:

$$\begin{bmatrix} v_m \\ v_{m'} \end{bmatrix} = U_m x_m, \tag{11}$$

where x_m is a (2N – M) x 1 vector, and $|x|^2 = 2$. On the other hand, the detection vector (11) has to satisfy the following condition.

$$[G_m^H \quad -G_{m'}^H] U_m x_m = 0_{M\times 1}, \tag{12}$$

Based on the design in (9), the signal alignment can protect the channels of a cluster into the same direction. Then we define $g_m = G_m^H v_m$ as channel vector in same pair [13]. Consequently, the following new definition can meet the existing of non-zero vector p_i.

$$[g_1 \quad \cdots \quad g_{i-1} \quad g_{i+1} \quad \dots \quad g_M]^H p_i = 0_{(M-1)\times 1}, \tag{13}$$

where $[g_1 \quad \cdots \quad g_{i-1} \quad g_{i+1} \quad \dots \quad g_M]^H$ is an (M-1)×M matrix.

Based on zero forcing precoding method, the matrix at base station can be expressed as:

$$P = G^{-H}D, \tag{14}$$

where $G \triangleq [g_1 \quad \cdots \quad g_M]^H$, and D is a diagonal matrix at the base station.

So depended on (9) and (14), the user's signal observation will become as:

$$\begin{aligned} v_m^H y_m &= \frac{g_m^H}{\sqrt{L(d_m)}} P_m(\alpha_m s_m + \alpha_{m'} s_{m'}) + \sum_{i\neq m} \frac{g_m^H}{\sqrt{L(d_m)}} p_i(\alpha_i s_i + \alpha_{i'} s_{i'}) + v_m^H\big(w_{I_m} + n_m\big) \\ &= \frac{\alpha_m s_m + \alpha_{m'} s_{m'}}{\sqrt{(L(d_m))(G^{-1}G^{-H})_{m,m}}} + v_m^H\big(w_{I_m} + n_m\big) \end{aligned} \tag{15}$$

Generally, we regulate $y_m = v_m^H y_m$, $h_m = \frac{1}{\sqrt{(L(d_m))(G^{-1}G^{-H})_{m,m}}}$, $w_{Im} = v_m^H w_{I_m}$, $n_m = v_m^H n_m$. Depended on zero-forcing precoding and detection matrix, MU-MIMO-NOMA channels are decomposed into M clusters single antenna NOMA subcarrier with signal alignment. In each cluster or group, the signal model of two users can be defined as:

$$y_m = h_m(\alpha_m s_m + \alpha_{m'} s_{m'}) + w_{I_m} + n_m, \tag{16}$$

$$y_{m'} = h_{m'}(\alpha_m s_m + \alpha_{m'} s_{m'}) + w_{I_{m'}} + n_{m'}, \tag{17}$$

where $h_m = \frac{1}{\sqrt{(L(d_m))(G^{-1}G^{-H})_{m,m}}}$, $h_{m'} = \frac{1}{\sqrt{(L(d_{m'}))(G^{-1}G^{-H})_{m,m}}}$. It is clear that both users in same pair will share same small scale fading gain in different distances [13].

III. Performance Analysis

In this section, we consider to analyze downlink communication system performance based on the above three schemes. Basically, we design equal power allocation strategies [45] into each system.

A. SISO-NOMA System

Firstly, in SISO-NOMA downlink users receiver with implemented successive interference cancellation decodes [52] in the sequence of reducing channel gain normalized by noise and cell interference power, $|h_i|^2/N_{0,i}$ (channel gain) [21]. Then we assume that one of users can decode others' signals. In this case, it is assumed that $|h_1|^2/N_{0,1} < |h_2|^2/N_{0,2}$ [12], which means that user-1 does not perform interference cancellation due to its first order position in the process sequence [21]. Clearly, user-1 treats user-2's signal as noise, and user-2 performs SIC, which means user-2 decode user-1's signal first then decode its own signal [25]. Because the transmit signal has total power P, then $x = x_1 + x_2$. Finally, we can calculate the throughput of user-1 and user-2 in successful transmission, which can be represented as:

$$R_1 = \log_2\left(1 + \frac{P_1|h_1|^2}{P_2|h_1|^2 + N_{0,1}}\right), \tag{18}$$

$$R_2 = \log_2\left(1 + \frac{P_2|h_2|^2}{N_{0,2}}\right), \tag{19}$$

On the other hand, with bandwidth of $\alpha \in (0,1)$ (Hz), in OMA scheme, it can be represented as:

$$R_1 = \alpha \log_2(1 + \frac{P_1|h_1|^2}{\alpha N_{0,1}}), \tag{20}$$

$$R_2 = (1-\alpha)\log_2\left(1 + \frac{P_2|h_2|^2}{(1-\alpha)N_{0,2}}\right), \tag{21}$$

So in this case, we propose $\alpha = 0.5$, equal power allocation for $P_1 = P_2 = 1/2P = 5W$. According to calculation, the system performance in NOMA is better than OMA system. Specifically, the sum of throughput rate is improved by 19% [16],[21],[23].

B. Simple MIMO-NOMA System

In simple MIMO-NOMA system, we first define the system in low SNR (SNR $\ll$ 1) condition and only two users in each subcarrier, without lost of generality, we assume as:

$$H_m^i \leq H_n^i, \tag{22}$$

$$0 \leq w \leq 1, \tag{23}$$

Within four constraints considered, including a. $\sum_{m=1}^{k}\sum_{n=1}^{k} S_{m,n}^i \leq 1$, b. $S_{m,n}^i \in \{0,1\}$,

c. $P_m^i \geq 0, \forall_i, m$, d. $\sum_n \sum_m \sum_i \left(P_m^i + P_n^i\right) S_{m,n}^i \leq P_{max}$. When there is $p_m = p_n$, after SIC applied [37], the original throughput formulation becomes:

$$w_m \log_2\left(1 + \frac{H_m^i p_m^i}{H_m^i p_n^i + 1}\right) + w_n \log_2(1 + H_n^i p_n^i)] \tag{24}$$

$$= w_m \log_2\left(\frac{H_m^i p_n^i + 1 + H_m^i p_m^i}{H_m^i p_n^i + 1}\right) + w_n \log_2(1 + H_n^i p_n^i)]$$

$$= w_m \log_2\left(2H_m^i p_m^i + 1\right) - w_m \log_2\left(H_m^i p_n^i + 1\right) + w_n \log_2(1 + H_n^i p_n^i)$$

$$\approx H_m^i p_m^i \log_2 e - w_m H_m^i p_m^i \log_2 e + w_n H_n^i p_m^i \log_2 e$$

$$= 1.44 w_m H_m^i p_m^i + w_n H_n^i p_m^i$$

$$= 1.44 p_m^i (w_m H_m^i + w_n H_n^i) \tag{25}$$

Then based on channel gain or weight or both channel gain and system weight [23], it can conclude that depended on total system power P, user-m for p_1 should greater than user-n for p_2.

$$R_1 = \log_2\left(1 + \frac{P_1 |h_1|^2}{P_2 |h_1|^2 + N_{0,1}}\right) = \log_2\left(1 + P\frac{|h_1|^2}{N_0}\right) - \log_2(1 + \frac{1}{4} P \frac{|h_1|^2}{N_0}), \tag{26}$$

$$R_2 = \log_2\left(1 + \frac{P_2 |h_2|^2}{N_{0,2}}\right) = \log_2(1 + \frac{1}{4}\frac{5|h_1|^2}{N_0} P), \tag{27}$$

Therefore, compared to MU-OMA (20) and (21) with equal power allocation and same bandwidth, the NOMA scheme in terms of throughput (26) and (27) can perform much better at same total system power over complete calculation [23],[32],[37].

C. Multiuser MIMO-NOMA schemes

Then in the advanced multiuser communication system, the author continues to analyze the performance. According to system schemes, power allocation policy should also be considered. Firstly, we define that base station transmit signal with equal power allocation into each group. In the multiuser MIMO-NOMA communication systems, it defines that transmit antennas carry equivalent power through channels to each group [23].

We recommend that the total transmission power is 10dB. There are two groups or two user pairs in downlink system. So each cluster can receive 5dB energy. Then inside each group, in order to eliminate inter- pair interference, the condition $\begin{bmatrix} v_m^H G_m \\ v_{m'}^H G_{m'} \end{bmatrix} p_i = 0_{2\times 1}$ should be satisfied, in this case m = 1 or m = 2. There is 8 x 2 matrix. Specifically, G_m denotes an 2 x 2 matrix, U_m denotes an 4 x 2 matrix, also we define $|x_m|$ = 2. Thus, according to the formulas (11) and (12), we can acquire the value of detection vector, where v_m is a 2 x 2 matrix depended on system matrix. As a result, based on detection vector v_m, we can calculation each pairs' scalar observations.

In addition, $[g_1 \quad \dots \quad g_{i-1} \quad g_{i+1} \quad \dots \quad g_2]^H$becomes an 1 x 2 matrix. We define $G \triangleq [g_1 \quad g_2]^H$, then precoding matrix will become (14). Consequently, at BS the transmission power will be:

$$tr\{PP^H\}\rho = tr\{G^{-H}DD^HG^{-1}\}\rho = M\rho, \tag{28}$$

where ρ is the transmit SNR. Therefore, in this case general definition (16) and (17) will rewritten as:

$$y_1 = h_1(\alpha_1 s_1 + \alpha_{1'} s_{1'}) + w_{I_1} + n_1, \tag{29}$$

$$y_{1'} = h_{1'}(\alpha_1 s_1 + \alpha_{1'} s_{1'}) + w_{I_{1'}} + n_{1'}, \tag{30}$$

and

$$y_2 = h_2(\alpha_2 s_2 + \alpha_{2'} s_{2'}) + w_{I_2} + n_2, \tag{31}$$

$$y_{2'} = h_{2'}(\alpha_2 s_2 + \alpha_{2'} s_{2'}) + w_{I_{2'}} + n_{2'}, \tag{32}$$

where user-1 and user-2 in same pair are came from two sections D_1 and D_2 respectively [13], which means that $d_1 < d_2$. Thus, it is clear that inside each pair users are arranged unambiguously.

D. Downlink System performance

In terms of system performance, we can define the signal-to-interference-plus-noise ratio (SINR). Based on previous system model, we denote one of groups of system performance [23],[54]. For example:

$$SINR_{m'} = \frac{\rho|h_{m'}|^2\alpha_{m'}^2}{\rho|h_{m'}|^2\alpha_{m'}^2+|v_{m'}|^2+|v_{m'}^H 1_N|^2 I_{m'}}, \tag{33}$$

where $I_{m'} = \sum_{j\in\Psi_I}\frac{\rho_I}{L(d_{I_{j,m'}})}, d_m < d_{m'}, \alpha_m \le \alpha_{m'}$.

Correspondingly, other user in same pair will carry out successive interference cancellation (SIC) through removing the information to pairing user in same group with SINR, which $SINR_{m,m'} = \frac{\rho|h_m|^2\alpha_{m'}^2}{\rho|h_m|^2\alpha_m^2+|v_m|^2+|v_m^H 1_N|^2 I_{m'}}$. After that, this user will start to decode its own information with SINR.

$$SINR_m = \frac{\rho|h_m|^2\alpha_m^2}{|v_m|^2+|v_m^H 1_N|^2 I_m}. \tag{34}$$

where α_m is power allocation coefficient, v_m is system detection vector, h_m is channel fading gain, ρ is the transmit signal-to-noise ratio (SNR), and when $\rho_I = 0$, it will become SNR. Therefore, based on system model analysis, we can calculate the outcomes of SINR and compare the values within each pair. We start to generate H_m matrix. Due to $H_m = \frac{G_m}{\sqrt{L(d_m)}}$, we recommend the distance between base station and receiver is at specified distance ($d_m < d_{m'}$). As a result, depending on (11), we can calculate (33) and (34) to obtain system throughput. Generally, we assume in a single pair where $d_m < d_{m'}$, and $\alpha_m \le \alpha_{m'}$ and user-m can implement SIC on user-m', so user-m may have better system capacity and operation ability, and it can provide better performance.

IV. Simulation Results

A. Multicarrier MIMO-NOMA Performance

Firstly, we implement simulation with matlab in simple MIMO-NOMA schemes. Based on the outcomes, we can investigate the users' performance in each subcarrier in NOMA-MIMO scheme. Basically, in this system we formulate ten subcarriers and ten downlink users, then we select two users in each subcarrier randomly [37]. We also set the frequency of carrier to 2MHz, bandwidth to 200kHz, channel gain to 10dB, cell size to 500m and reference distance to 50m respectively. Furthermore, we suppose P_{max} as the maximum transmission power of the base station totally, and path loss realization and channel realization are set to 100 and 1000 respectively. We calculate the noise power as:

$$P_{noise} = 1.38*1e - 23*290*200*10^3, \qquad (21)$$

Thus, we can obtain the each subcarrier's throughput rate in the plotting figure-4 below. Basically, the x-axis denotes P_{max} with the unit of dBm, the y-axis denotes averaged system data rate with the unit of bit/s/channel use. And according to noise power formula, the noise power is equal to 8.0040e-15W [38].

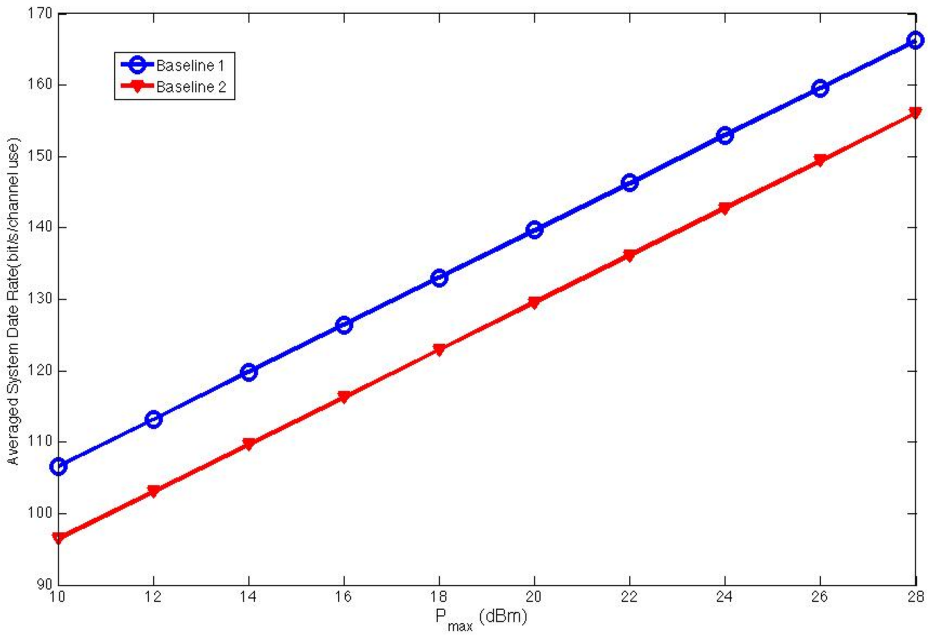

Figure-4 MU-NOMA and MU-OMA throughput rate versus the maximum transmit powers.

Fig.4 shows the ten subcarriers' users throughput rate distribution. We select two users randomly in ten subcarriers with equal power allocation. Basically, in the above figure, the baseline 1 represents NOMA scheme, and baseline 2 denotes OMA scheme. As we can observe, the averaged system data rate increases gradually with maximum transmit power in both baselines. The reason is that users can be allocated additional transmit power by settling the problem formulation according to four constraints in NOMA scheme significantly. Moreover, figure-4 shows the MU-OMA performance in terms of averaged system data rate. In fact, in MU-OMA scheme, the resource allocation algorithm is same as MU-NOMA scheme except interference

[22],[28-32],[37].

For comparison, the baseline 2 figures are under the baseline 1 during this period. In particular, the gap between two baselines in terms of throughput rate maintains around 10bit/s/channel use over ten P_{max} level. Also, in NOMA the data rate reach to 166.2414bit/s/channel use, but in OMA, the data rate rises to 156.0871bit/s/channel use in 28dBm respectively [38]. So the averaged system performance can improve about 6% with NOMA application, and totally the sum system throughput data rate is 185.0447bit/s/channel use in NOMA, 178.2061bit/s/channel use in OMA [10],[37], which is improved by 4%.

Thus, in simple MIMO-NOMA system, we can observe NOMA can complete competitive level of performance with a small number downlink channels and users. Assuming the proposed huge NOMA system design with optimal power and selection allocation can be implemented, it can achieve a higher system throughput performance.

B. Multiuser MIMO-NOMA Performance

In this communication system, it mainly focuses on multiple users MIMO-NOMA scheme in 2x2 model [40]. Clearly, it means there are two transmitted antennas form base station and two group user pairs, particularly two users in each pair. Basically, we select one group pair to analyze its system performance. In order to estimate system throughput, we formulate the following system parameters. We set the reference distance is 50m for user-m’ and 30m for user-m. Secondly, we also set the frequency of carrier to 2MHz, bandwidth to 200kHz, channel gain to 10dB, cell size to 500m. Due to equal power allocation, each user will be allocation 2.5 dB channel gain at first. And path loss realization and channel realization are both set 1 respectively. In addition, in this small scale fading scheme [51], we do not consider $d_{I_{j,m}}$ (the distance from user-m to j-th interference source) in the interference model. The reason is that the path loss would have more dominant impacts than the former. Clearly, if $\rho_I = 0$, it means this model do not exist interference, which means it will become SNR [13]. Therefore, during the calculation, we can omit the I_m and $I_{m'}$.

Then based on formulas (5), (9), (10), (11), (33) and (34), we could estimate the one of group user pairs of system performance. The following fig-5 can demonstrate the users' throughput rate distribution [13],[23],[54].

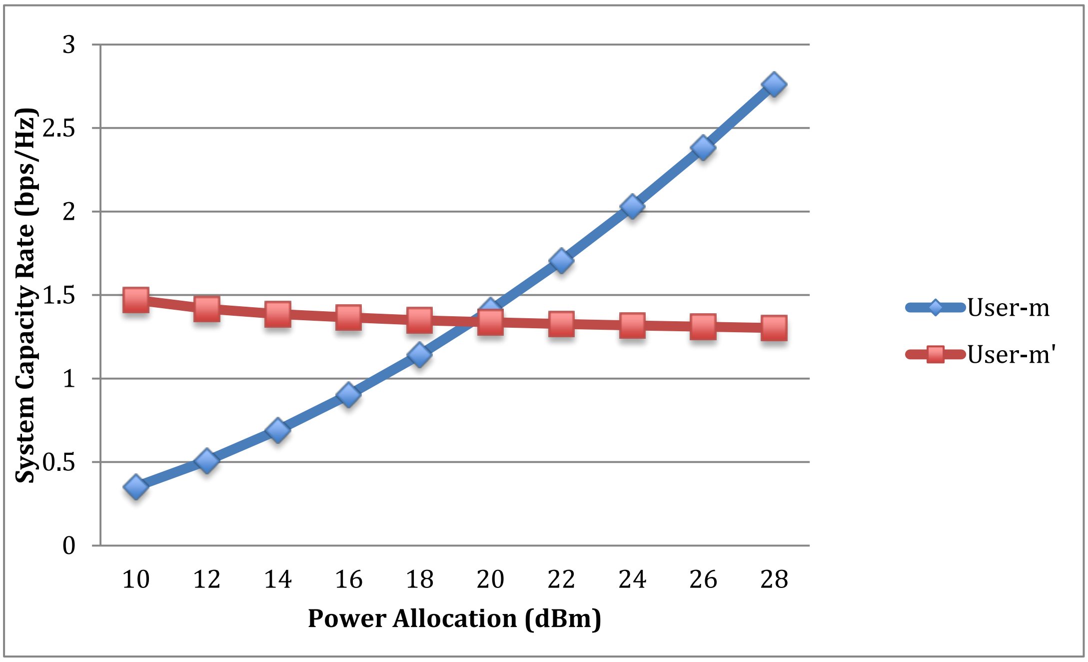

Figure.5 The Illustration of Performance of Two Users in Same Pair in MU-MIMO-NOMA System.

Based on the above figure, we figure that the x-axis denotes the power allocation from 10dBm to 28dBm with divided to ten parts in every 2dBm. And the y-axis denotes the system capacity rate in the unit of bps/Hz. The two lines illustrate the two users' data rate in same pair based on different power allocation simultaneously. However, it can be seen that the system capacity rate of user-m' keeps relatively stable, although the rate is higher than user-m on previous power allocation site. Correspondingly, the capacity rate of user-m has been increasing gradually, although user-m implement successive interference cancellation (SIC) to user-m' and remove its message with SINR. Thus, the user who implement SIC will have better capacity when the system allocate enough power [13],[42-43].

In addition, the following fig.6 demonstrates cumulative sum system capacity rate during this simulation.

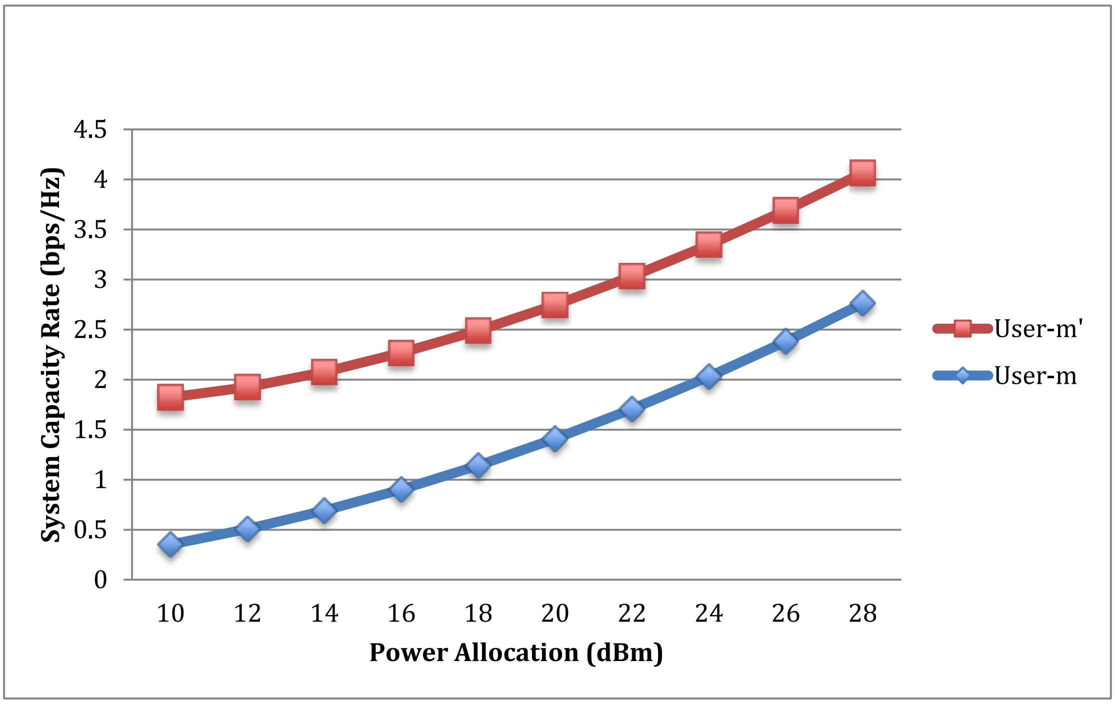

Figure.6 MU-NOMA System Performance versus the maximum transmit powers in One Random User Pair

The x-axis also denotes the power allocation from 10dBm to 28dBm with divided to ten parts in every 2dBm, and the y-axis denotes the system capacity rate in the unit of bps/Hz. It is clear that the system total capacity rate is rising along with the increasing of power. So the system total outage can achieve optimization in each pair group. Overall, according to these two graphs, without considering extra additional noise which influences the system, multiple users MIMO-NOMA communication system with suitable pairing applied detection vector and SIC techniques in reasonable power allocation can improve system performance without interference.

V. Conclusion

A. Summary

In this project, we firstly study NOMA technology scheme applied from SISO to MIMO within systematic and mathematical approach [27]. Based on power allocation and channel gain and weight priority, we provide some possible methods to speculate and verify whether NOMA technology can improve system performance compared to OMA. Specifically, after constructing system model, we demonstrate instantaneous weighted throughput and propose the problem formulation for resource allocation algorithm design [35]. According to resource allocation algorithm and system design, assuming applied NOMA schemes in MIMO systems can achieve close-to-optimal performance significantly [28-29],[33]. According to the simulation results, we can unveil that the applied MC-NOMA scheme can reach higher system performance than conventional MU-OMA. Particularly, it is increased by around 4% in terms of sum system throughput data rate. So applied NOMA scheme can enhance system performance significantly. Basically, in a large number of downlink users equipped optimal subcarriers can show much more evident improvement [44]. In addition, reasonable and efficient resource allocation optimization can improve the results as well.

In the second part of this paper, we proposed framework about a signal alignment into MIMO-NOMA downlink transmission communication system [44],[46]. After analyzing the system model, there may have limited transmit antennas, which cannot meet to transmit information to each receivers through corresponding transmit antennas. So we can make group with user pairs to tackle with limited channel state information at the transmitter (CSIT) [8] in large region communication environment. And more importantly, guaranteed successful pair distribution could remove inter-pair interference by applied detection vector through zero-forcing precoding [8],[15] to ensure the maximum throughput probability possibly. In order to implement this scheme, we formulate some measurements to achieve the proposal. Finally, according to the calculation of figure, it can be summarized that the communication system model that we construct can satisfy the main purpose in simple 2x2 MIMO-NOMA downlink schemes with equal power allocation [53].

Positively, although there are some challenges existing. For example, to exploit the most efficient and optimal system scheme will need vast calculation and study. Also in terms of more complicated communication system, how to allocate power, how to implement transmission distribution and how to remove interference to achieve maximum throughput probability need to continue to explore [41],[44]. On the other hand, developing new technology allows quite amount of expenditure. We can address resource allocation algorithm and optimize system design with advanced research, meanwhile, we can control the costs at a tolerable level [44]. Overall, it is believed that NOMA mechanism may achieve optimization wireless communication system, and it will paly an important role in future 5G networks [50]. Combining MIMO and NOMA schemes efficiently and practically, it can improve telecommunication field significantly.

B. Future Plan

During the project part A and part B, I finished the section of NOMA concept and proposed algorithm based on some problem formulation to improve the systems performance compared to OMA scheme. According to the results, it can prove that MU-NOMA systems perform better in terms of weighted system throughput over OMA scheme. Furthermore, in the following project part B, based on the previous study, we continue to analyze MIMO-NOMA scheme in terms of multiuser situation. In addition to establish system model and calculate the simulation results, we can estimate this communication system can improve throughput rate. However, we only focus on simple distribution case and allocate equal power to each users. Thus, in the future, it should be going to study more complicated communication framework and produce more precise outcomes. All in all based on one year study and research, I had realize some basic principles regarding to current techniques in terms of information transmission and should continue to explore more advanced communication technology.

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Appendix

Title: Multiple users in MIMO systems with applied Non-orthogonal Multiple Access Schemes

Topic number: N/A

Student Name: Feng Jia **Student ID:** z5004552

A. **Problem statement**

Compared to OMA scheme, NOMA scheme can realize SIC during information transmission process to improve system performance. In addition to multiple users communication, there is not enough transmitted equipment to support mass information transmission. Thus it needs to consider make groups for users into pairs. Then there may exist inter-pair interference, it also has to remove the interference to ensure better system throughput. Overall, new system scheme and new algorithms should be provided to address current problem.

B. **Objective**

Based on MIMO scheme, review OMA technique, provide more flexible NOMA technology to analyze multicarrier and multiuser framework in communication system. It aims to verify NOMA scheme has better system output than OMA scheme and illustrate MIMO-NOMA with multiuser can achieve maximum system throughput with less transmit antennas than receiver and eliminate inter-pair interference (zero-forcing) within transmission system.

C. **My solution**

Multicarrier MIMO-NOMA scheme
Multiuser MIMO-NOMA scheme
Proposed equal power allocation
Implemented successive interference cancellation
Applied detection vector to remove inter-pair interference
Simulation estimation analysis based on matlab and mathematics calculation

D. **Contributions** (at most one per line, most important first)

Demonstrate some system models in terms of framework and system performance.
Strong user provides SIC to weak user in same subcarrier to achieve better system performance.
Mathematics arguments on contrast with OMA and NOMA throughput probability.
Matlab simulation to compare user data rate in OMA and NOMA scheme.
Mathematics calculation to illustrate system throughput rate in multiuser MIMO-NOMA system.
Reference noted.

E. **Suggestions for future work**

Involve simulation on m x n matrix system model to compare outcomes.
Focus on more complicated communication system to apply these proposals.
Explore more advanced technology (compare to zero-forcing, MMSE, etc.) to achieve maximum system throughput.

While I may have benefited from discussion with other people, I certify that this report is entirely my own work, except where appropriately documented acknowledgements are included.

Signature: __________Feng Jia________________________ Date: 25/10/2016

Pointers

List relevant page numbers in the column on the left. Be precise and selective: Don't list all pages of your report!

3	Problem Statement
5,6	Objective

Theory (up to 5 most relevant ideas)

4-6	General background
7-10	Several systems overview
12	Zero-forcing
10-13,15-16	Multiple users transmission model

Method of solution (up to 5 most relevant points)

10,16	MIMO-NOMA
12	Zero-forcing
15	SIC
14-15,21-22	Mathematics calculation
19	Matlab simulation

Contributions (most important first)

17,21-22	Mathematics calculation to illustrate system throughput rate in multiuser MIMO-NOMA system.
18-19	Matlab simulation to compare user data rate in OMA and NOMA scheme.
15,18	Mathematics arguments on contrast with OMA and NOMA throughput probability.
15	Strong user provides SIC to weak user in same subcarrier to achieve better system performance.
9,10,16	Demonstrate some system models in terms of framework and system performance.
26-33	Reference noted.

My work

9-13	System block diagrams/algorithms/equations solved
13-14,16,17,18	Description of assessment criteria used
14,15,20	Description of procedure (e.g. for experiments)

Results

14,15,17	Succinct presentation of results
18,20	Analysis
19,21-22	Significance of results

Conclusion

24-25	Statement of whether the outcomes met the objectives
26	Suggestions for future research

Literature: (up to 5 most important references)

10-13,16-17	[13]Ding, Z., Schober, R., & Poor, H. (2016).
6,7,10	[2]Dai, L., Wang, B., Yuan, Y., Han, S., Chih-Lin, I., & Wang, Z. (2015)
10,15,18	[37]Sun, Y., Ng, D.W.K., Ding, Z. and Schober, R. (2016)
5,8,14	[12]Choi, J. (2016)
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