Beamspace NOMA Using User Clustering and Throughput Optimisation Algorithms for Massive MIMO

Haitham Al Fatli, Khairun Nidzam Ramli, and Elfarizanis Baharudin
Faculty of Electrical and Electronic Engineering, Universiti Tun Hussein Onn Malaysia, 86400 Parit Raja, Batu Pahat, Johor, Malaysia
Email: haithamalfatli@gmail.com, khairun@uthm.edu.my, elfa@uthm.edu.my

Abstract—Massive Multiple Input Multiple Output (MIMO) using millimetre wave transmissions received significant attention due to its significance of high data rate. However, achieving energy and spectrum efficient millimetre wave communications is challenging due to the dedicated Radio Frequency (RF) chain. Non-Orthogonal Multiple Access (NOMA) is used in beamspace MIMO (BS MIMO) significantly overcome such challenges. This paper proposes the enhanced approach of beamspace MIMO NOMA using a simple yet effective clustering solution with a C-NOMA throughput optimisation algorithm. This proposal involves the lightweight user clustering, lens antenna, and clustering-based iterative power allocation algorithm to enhance each cluster's spectral and energy efficiency performance. After cluster formation, the throughput optimisation function applies. Iterative power optimisation method is proposed to allocate power to each user in each cluster dynamically. Therefore, compared to recent clustering and NOMA methods, the proposed BS MIMO C-NOMA improves Energy Efficiency (EE) and Spectral Efficiency (SE) with minimum computational overhead. Results demonstrate that high EE and SE, respectively, as compared with the percentage of improvement of 26% and 37% in the existing BS MIMO NOMA and improvement of 16.47 % and 27.72 % in User Clustering based on Channel Gain (UCCG) MIMO NOMA among 50 and 100 users.

***Index Terms*—**SE, EE, mmWave, Beamspace MIMO, clustering, channel gain

I. INTRODUCTION

Despite the large transmission of data capacities, a small number of wavelengths have a license at the mmWave wireless communication system, which can obtain the special antenna in a similar physical location that links with huge MIMO to give a multiplexing increase and beamforming allocation [1]-[4].

This study has shown that the mmWave huge MIMO can increase the orders of magnitude in the limit of the framework [4]. Furthermore, it is hard to acknowledge mmWave with huge MIMO because of the high transceiver complexity and energy utilisation [3]. Therefore, every antenna array in MIMO frameworks needs one attached RF chain [5]. Along with these, utilising a large number of antennas in mmWave huge MIMO frameworks need to product a similarly large number of RF chains. Likewise, that lead to high energy consumption up to 70% of the total transceiver service utilisation [3]. Therefore, the equipment price and service utilization caused by many RF cables in mmWave huge MIMO frameworks lead to unreasonably expensive in practically speaking.

This paper can achieve results that enhance the EE, SE and scalability of complex frameworks without intra and inter beamspace interference to alleviate the issues of current methods. This paper proposes a novel mmWave based communication method that combines the connotation from NOMA beamspace MIMO with efficient user clustering to increase the SE and EE performances at minimum calculation efforts, which call beamspace MIMO-Clustering NOMA, i.e. (BS MIMO C-NOMA).

The results of EE, SE can compare to the newest method of UCCG-MIMO NOMA and our previous results in other ways. The EE and SE in C-NOMA are much higher than BS MIMO NOMA by the percentage of 26% and 4.2%, respectively. Additionally, 16.47% and 27.72% improvement compared to the clustering based on User Channel Gain (UCCG) MIMO NOMA among 50 and 100 users, respectively.

II. RELATED WORKS

In [6], the increase in the SE in NOMA demonstrate from framework usage by utilising a two-user case. The broader possibility associated with a number of users (*M*) has been arbitrarily explored in [7]. Regarding the rationality argument among single-antenna users, power division progression was examined in [8]. However, in [9], the single antenna-based solutions cannot be too scalable and have performed poorly for spatial domains. Thus, many methods were proposed using multiple antennas to further enhancing the NOMA. The author in [10] researched a multiple-input single-output (MISO) and NOMA situation with a proposed two-organise beamforming technique to help multiple users. The MIMO NOMA correspondence framework presented, the ergodic framework limits the MIMO NOMA frameworks upgraded utilising power allotment strategies in [11].

Manuscript received August 15, 2021; revised February 1, 2022.
This work was supported by the Universiti Tun Hussein Onn Malaysia and the UTHM Publisher's Office under Grant No. E15216.
Corresponding author email: haithamalfatli@gmail.com
doi:10.12720/jcm.17.6.463-471

In [12], the precoding design and symmetry network was proposed for a MIMO NOMA framework to avoid MIMO symmetrically multiple access. In [13], the downlink NOMA is helpful to correspondence frameworks, and the Base Station (Bs) works with two kinds of users, which describes as Relay Users (RU) and Far Users (FU). In [14], a new asset determination technique was proposed to enable NOMA to merge with MIMO. Initially, a method was used to lessen the versatile Proportional Fairness (PF) resource allocation schemes scheduling characteristics. Afterwards, they presented an iterative water-filling based on power flow to a Single-User MIMO (SU-MIMO) state.

[15] described the complexities outlined in the work criteria for uplink and downlink NOMA transmission. They proposed a picking plan for the users that have low-multifaceted nature. In [16], a linear beam modulation system has been proposed that all antennas can reduce the inter beam interference. In [17], MIMO NOMA was originally considered a Multi-User downlink (MU) aiming to increase overall rates through Integrated Assessment (IA) procedures.

In [18], Discrete-Sine Transform (DST) network precoding-based uplink NOMA conspired to decrease the Peak to Average Power Ratio (PAPR). In [19], the MISO framework in downlink with NOMA was proposed, where the users standardised single Beamforming (BF) vectors. In [20], the authors considered the implementation of two ambiguous input frames with non-orthogonal users.

In [21], the NOMA idea was presented to increase the bandwidth for the 5G downlink framework.

In [22], the author presented the analysis performance of MIMO NOMA users in a single group. In [23], the authors proposed selecting antennas using MIMO to estimate the channel capacity. In [24], the authors suggested the importance of using a lens antenna array for massive MIMO communications.

The researcher in [25] used the latest approach to reduce the RF chain challenges by means of lens antenna arrays with iterative power allocation algorithms. The authors offer RF chain decrease techniques to increase the energy and SE. In [26], a very recent clustering-based multi-user MIMO-NOMA downlink transmission system was proposed. They presented the solution in three subqueries: clustering, which formed as a mixed-integer linear programming (MILP) difficulty, beamforming, and supremacy allowance.

In [27], another two strategies for the user clustering with the dynamic power allocation algorithm was proposed for MIMO-NOMA. In [28], the most recent approach to tackle the challenges of RF chain reduction was reported by using the benefits of lens antenna array with iterative power allocation algorithms. The authors presented the RF chain reduction technique to enhance the energy and spectrum efficiency.

III. System Model

A. Beamspace MIMO C-NOMA

Based on the literature and reference in our previous study of the proposed BS MIMO C-NOMA, we studied the EE and SE challenges addressed using the beamspace MIMO NOMA, which can utilise lens antenna array to appreciably reduce the required numbers of RF chains in the cell by using massive MIMO services.

However, beamspace MIMO-NOMA method cannot improve the scalable and capacity causing the possibility of high complexity. Therefore, this paper proposes BS MIMO C-NOMA, which uses a user clustering algorithm with throughput optimisation to enhance scalability and reduce the complexity. However, we also compare the result to the UCCG MIMO NOMA. Fig. 1 shows the system model of the proposed BS MIMO C-NOMA.

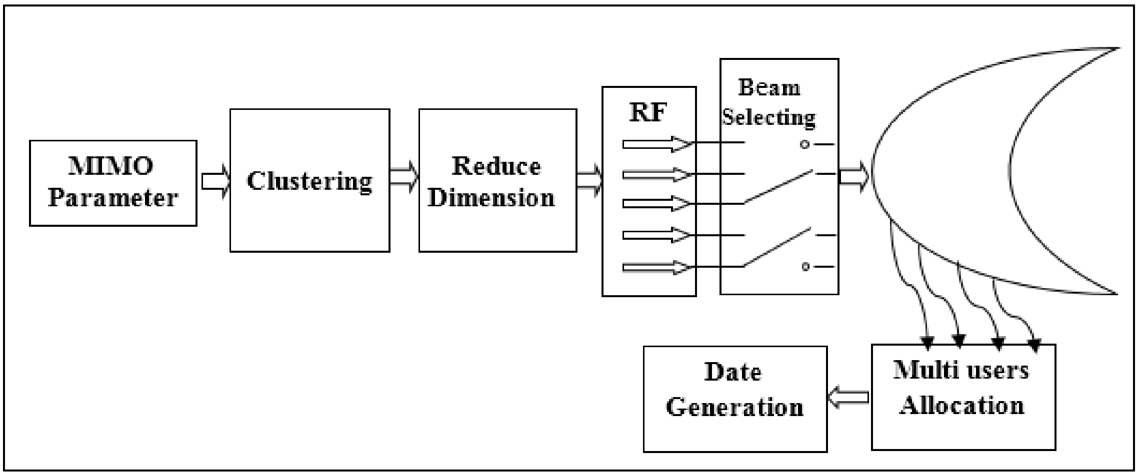

Fig. 1. System model beamspace MIMO C-NOMA

The lens antenna is responsible for selecting one beam for multiple users. After channel assignment, all multiple users can send their data to the receivers. Therefore, the objective of this task is maximising the throughput of that most critical user connecting among all the number of users (K) with dynamically sorting of users into several clusters. It means any returned user allocation can enhance the BS MIMO C-NOMA within all clusters. Thus, the power allocation coefficients are optimised according to the immediate channel positions in a particular cluster.

After grouping the users in a different cluster, we formulate throughput optimisation using an exhausted search approach across the groups.

B. User Clustering

In this work, we propose the simple of users clustering solution without having any inter-cluster interference problem. The unlimited number of users are separated into the total number of clusters *C* to form a cluster with various number of the users by using the cross-fading channel design which consists of Rayleigh fading channel matrix $G_{c,k}$ and path loss components $L_{c,k}$. Let's consider that the Bs cover a varying number of users $k,$ and $k \in \{1,2,3,..K\}$ in cluster c, and $c \in \{1,2,3,..,C\}, H_{c,k} = G_{c,k}/L_{c,k,}\ G_{c,k}\ C^{N\times C}$ denoting the Rayleigh fading channel matrix and $L_{c,k}$.

The path loss beamforming arrays is performed under two conditions: Firstly, the inter-cluster interference is removed by using Zero-Forcing (ZF) precoding at Bs. Secondly, the signal alignment is accompanied among the users in one cluster.

$$V_{c,1}^H, G_{c,1} = V_{c,2}^H\ G_{c,2} \tag{1}$$

Therefore, the receiving beam vector is represented as $V_{c,k}^H$ and all the users in the cluster shared the transmit beam vector. Hence, the Bs transmitted signal is represented as:

$$x = Ps \tag{2}$$

The total power $P = P_1, P_2 \dots P_C$ where $P_c \in C^{C\times 1}$ denotes the cluster transmit beam vector. The information-bearing vector (s) can be represented as:

$$s = \begin{bmatrix} a_{1,1}\ s_{1,1} + a_{1,2}\ s_{1,2} \\ \vdots \\ a_{C,1}\ s_{C,1} + a_{C,2}\ s_{C,2} \end{bmatrix} \tag{3}$$

Therefore, to improve the scalability of NOMA, we use the above clustering approach with the NOMA model to create a C-NOMA. The user cluster algorithm can be shown in Fig. 2.

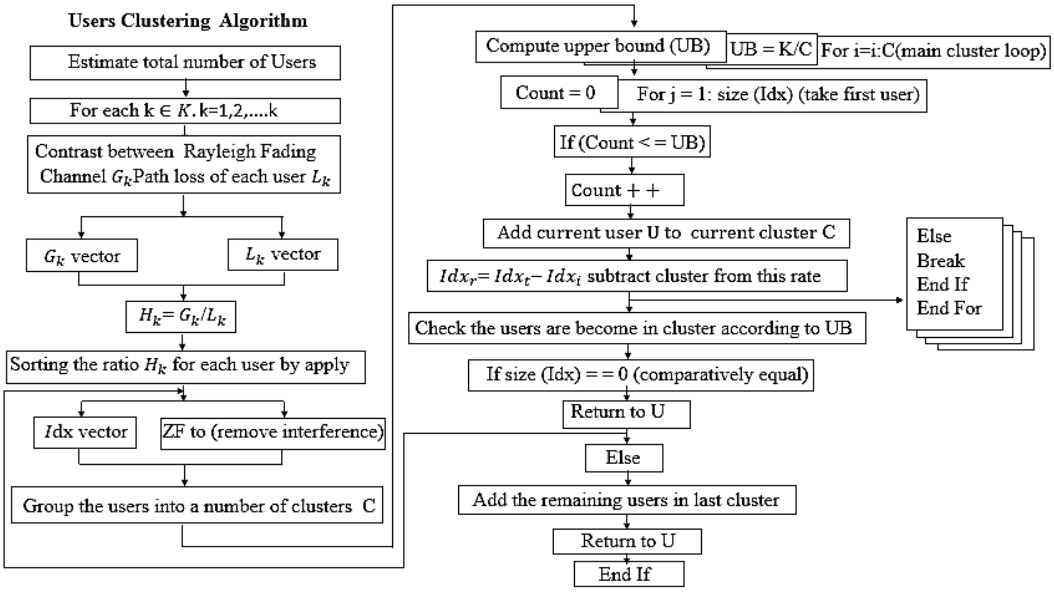

Fig. 2. Flowchart of user clustering algorithm

From equation (3), the $s_{c,k}$ and $a_{c,k}$ denotes the signal and power allocation coefficient respectively of the user *k* in cluster *c*. It is satisfied when $a_{c,1}^2 + a_{c,2}^2 = 1, \forall c$. For the sake of clarifying the clustering of the receiver side for the user, (c,k) is the normalised beamforming vector when $V_{c,k}$ is applied, which leads to the received signal $y_{c,k}$ represented as:

$$V_{c,k}^H y_{c,k} = a_{c,1} V_{c,1}^H H_{c,1} P_c s_{c,1} + a_{c,2} V_{c,2}^H H_{c,2} P_c s_{c,2} + \sum_{i\neq c} C \sum_{l=1} 2\ a_{i,l} V_{c,l}^H H_{c,l} P_i s_{i,l} + P_i s_{i,l} + v_{c,k}^H n_{c,k,} \tag{4}$$

where the Additive White Gaussian Noise (AWGN) is represented to remove the inter-cluster interference in the $n_{c,k}$ beam of the k^{th} user in the n^{th} beam of c^{th} cluster at iteration *t* to the input vector $h_{m,n,c}$ by using the ZF precoding method. The obtained signal reformulates as:

$$V_1^H yk = a_1 V_1^H H_1 P s_1 + a_2 v_2^H H_2 P s_2 + V_k^H n_k \tag{5}$$

C. Optimisation Throughput Cluster

The cluster forms into different number of user groups before the power allocation approach is lead to throughput performance degradation. Therefore, the clustering is performed by sorting the ratio of H_k which expresses the ratio between the Rayleigh fade channel matrix $G_{c,k}$ and path loss component $L_{c,k}$. Thus, each user uses the *Idx* vector in MATLAB code without considering the power allocation dynamics. Therefore, an aggregation optimisation approach is necessary on clustering to perform an appropriate dynamic distribution of energy and improve the throughput of the proposed C-NOMA framework.

D. Iterative Power Allocation

After sorting the users in various number of clusters with the aim of throughput optimisation and SE-EE, we propose the iterative power allocation scheme to provide the required power for each cluster without extra power as same as the traditional power method. Iterative power allocation method is designed to allocate the power for the k^{th} user at the n^{th} beam in the cluster c^{th}. This algorithm starts with the input of a set number of K users. We assume the number of users is 32, the specified number of the clusters is four and N is the beams, which form as $h_{k,n,c}$ lens array matrix. The input for this algorithm consists of: (See Fig. 3).

- Number of users is k = 1, 2, ... K
- Number of beams is n = 1, 2, ... N
- Number of clusters is c = 1, 2, ... C

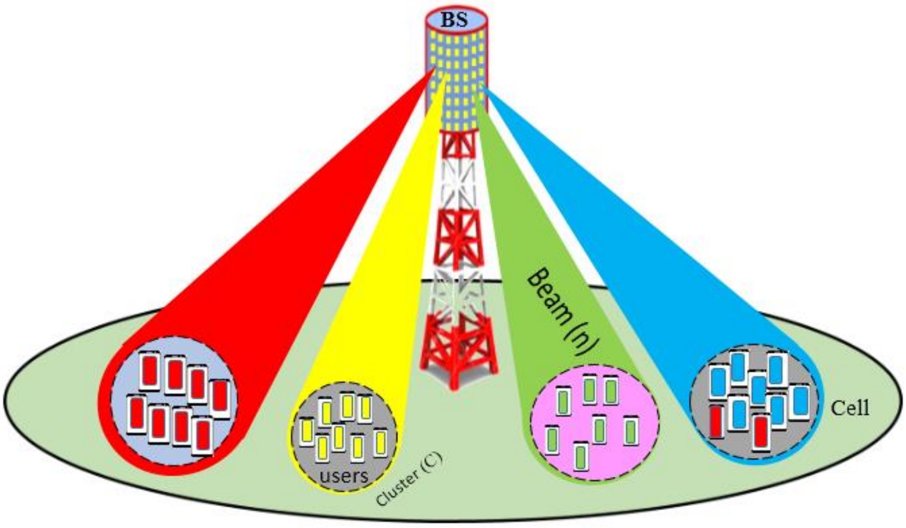

Fig. 3. Iterative power allocation provides for each cluster

The beamspace channel vector after beam selection is $h_{k,n,c}$ between the Bs and the k^{th} user at the n^{th} beam in the c^{th} cluster. w_n is the uniform precoding vector for the users in the n^{th} beam. Therefore, the receiver signal vector $y = [y, y_2 \dots, y_k]^T$ can be represented as:

$$y = H^H W P s + n \tag{6}$$

where the transmitted signal vector for all the K users is $S = [S_1, S_2, \dots, S_k]^T$ of $K \times 1$ and the transmitted power for the users is $P = \left[\sqrt{P_1}, \sqrt{P_2}, \dots \sqrt{P_k}\right]$ to fulfill $\sum_{k=1}^{k} P_k \leq P$ where P is the maximum transmitted power at the Bs. Also, $W = [w_1, w_2 \dots, w_k]$ is presented as precoding matrix in size $N \times K$, where the $\|w_k\|_2 = 1$ to k = 1, 2, 3,... K users, n is the noise vector, and the complex normal distribution CN (0, $\sigma^2 I_k$) at last $H = [h_1, h_2 \dots, h_k]$ in size $N \times K$ is presented as the spatial channel vector between the Bs and the k^{th} user. Therefore, in the beamspace channel matrix h_n, any column of h_n compares to one beam, and all n lines relates to the n beams with spatial bearings independently. Along this line, the number of components in each space of the ray channel vector $h_{k,n}$ is a lot little than n; to be specific, the beamspace channel framework has a scanty nature. The incorrect architecture can be misused in configuration measurements, reducing the BS MIMO systems performance with beam identification without obvious implementation errors. In particular, as indicated by the scanty beamspace channel network, just a small number of beams can be chosen to serve K users. After reducing the dimension, we perform the proposed iterative power allocation algorithm to allocate the required power for each cluster, as shown in the flowchart in Fig. 4. The power allocation problem can be formulated as:

$$\max_{P_{k,n,c}} \sum_{n=1}^{N_{RF}} \sum_{k=1}^{|S_n|} R_{k,n,c} \tag{7}$$

$$\begin{aligned} \text{S.t} \quad & C_1 : P_{k,n,c} \geq 0 \; \forall n, k \\ & C_2 : \sum_{n=1}^{N_{RF}} \sum_{k=1}^{|S_n|} P_{k,n,c} \leq P \\ & C_3 : R_{k,n,c} \geq R_{min}, \forall n, k \end{aligned}$$

The goal of the clustering algorithm is related to optimisation which means the optimal channel equalisation coefficient has to be estimated. Therefore, at first, the optimal channel equalisation coefficient $\left\{ch_{k,n,c}^{(t)}\right\}$ is estimated for the k^{th} user in the n^{th} beam of c^{th} cluster at iteration (t) to the input vector $h_{m,n,c}$. This function aims to minimise the channel estimation error at all users within the same cluster in the beam. We can obtain the optimal solution of the optimal channel equalisation coefficient in the tenth iteration. The channel equalisation coefficient equation is given by:

$$\left\{ch_{k,n,c}^{(t)}\right\} = \left(\sqrt{P_{k,n,c}^{(t-1)}} h_{k,n,c}^H W_n\right) \left(p_{k,n,c}^{(t-1)} \| h_{k,n,c}^H \|_2^2 + \varepsilon_{k,n}^{(t-1)}\right)^{-1} \tag{8}$$

Then, according to (6), the SINR at the k^{th} user in the n^{th} beam of c^{th} cluster can be presented as:

$$\gamma_{k,n,c} = \frac{\|h^H_{kc,n,}\, w_n\|_2^2\, p_{k,n,c}}{\varepsilon_{k,n.c}} \tag{9}$$

where

$$\varepsilon_{k,n}^{(t-1)} = ||h^H_{k,n,c}W_n||_2^2 \sum_{i=1}^{k-1} p_{i,n}^{(t-1)} + \sum_{j\neq n} ||h^H_{k,n}W_j||_2^2 \sum_{i=1}^{|S_j|} p_{i,j}^{(t-1)} + \sigma^2 \tag{10}$$

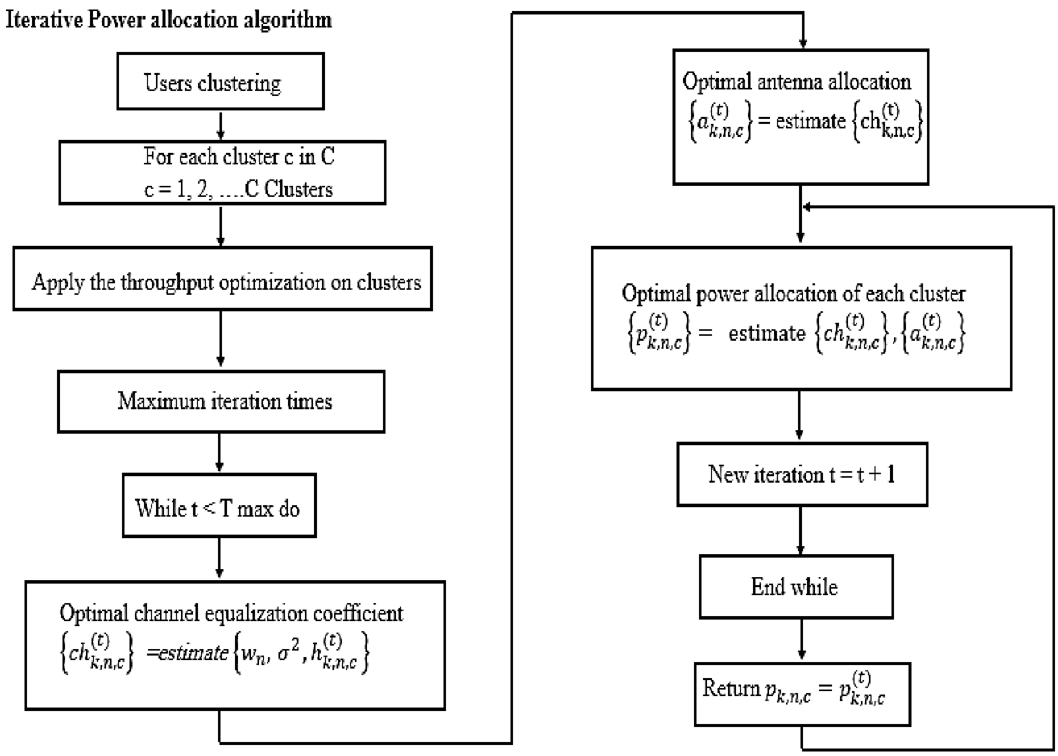

Fig. 4. Flowchart of the proposed iterative power allocation algorithm

Therefore, the achievable sum rate of the BS MIMO C-NOMA system is:

$$R_{k,n,c} = \sum_{n=1}^{N_{RF}} \sum_{k=1}^{|S_n|} R_{k,n,c} \tag{11}$$

Then we have:

$$\left(1+\gamma_{k,n,c}\right)^{-1} = 1 - \left\|h^H_{kc,n,}\, w_n\right\|_2^2 p_{k,n,c}$$

$$\left(\left\|h^H_{kc,n,}\, w_n\right\|_2^2 p_{k,n,c} + \varepsilon_{k,n.c}\right)^{-1} \tag{12}$$

where the number of beams $n = 1,2,3,..,N_{RF}$ and the number of the set signal of the users is presented by $k = 1,2,3,..,|S_n|$.

The expression (12) corresponds to the MMSE in the t^{th} iteration, which can be expressed as:

$$e^{0(t)}_{k,n,c} = 1 - \left\|h^H_{k,n,c}W_n\right\|_2^2 p^{(t-1)}_{k,n}$$

$$\left(h^H_{k,n}W_n||\, h^H_{k,n}||_2^2 + p^{(t-1)}_{k,n} + \varepsilon^{(t-1)}_{k,n}\right)^{-1} \tag{13}$$

After calculation of the optimal channel equalisation coefficient, we further calculate the optimal solution for the k^{th} user in the n^{th} beam of the c^{th} cluster at the iteration (t) in vector $\{a^{(t)}_{k,n,c}\}$ using the calculation output of $\{ch^{(t)}_{k,n,c}\}$. Therefore, the vector $\{a^{(t)}_{k,n,c}\}$ is the optimal antenna allocation for k^{th} user in the n^{th} beam of c^{th} cluster at the iteration (t) by using the optimal estimation channel equalisation step. The optimal solution of $\{a^{(t)}_{k,n,c}\}$ in the t^{th} iteration can be obtained by:

$$\{a^{(t)}_{k,n,c}\} = \frac{1}{e^{0(k)}_{k,n,c}} \tag{14}$$

Then, the power allocation for the k^{th} user in the n^{th} beam of the c^{th} cluster at the iteration t^{th} is performed in vector $p^{(t)}_{k,n,c}$ using the calculation output of $\{ch^{(t)}_{k,n,c}\}$ and $\{a^{(t)}_{k,n,c}\}$ as:

$$p^{(t)}_{k,n,c} = \left(\frac{a^{(t)}_{k,n,c}\, Re\left(ch^{(t)}_{k,n,c} h^H_{k,n,c} w_n\right)}{T}\right)^2 \tag{15}$$

IV. Simulation Results

According to the results in our previous studies of the proposed BS MIMO C-NOMA, we designed the communication models with a varying number of MIMO users and SNR values in MATLAB. In this paper, the performances of various method are measured for SE and EE mainly. The results are evaluated and the performance of the proposed BS MIMO C-NOMA method is compared with the other methods:

- Fully digital MIMO (FD-MIMO): In this method, each antenna is connected to only one dedicated RF chain.
- Beamspace MIMO (BS MIMO): In this method, each beam consists of only one user.
- Beamspace MIMO NOMA (BS MIMO NOMA): In this method the BS NOMA uses the lens antenna and iterative power allocation.
- UCCG MIMO NOMA: The recent user clustering based on the MIMO NOMA technique in which user grouping is performed using channel gain and hence it is called User Clustering based on Channel Gain (UCCG).
- Beamspace MIMO C-NOMA (BS C-NOMA): The proposed model is user clustering with a throughput optimisation-based of the iterative power allocation method.

The number of clusters is set to four for the proposed BS MIMO C-NOMA for experimental analysis purposes. Therefore, the SE and EE are computed as described below.

SE Analysis (δ): SE is determined as achievable sum rate of the k^{th} user in n^{th} beam of c^{th} clusters where the achievable sum rate is presented as:

$$R_{sum} = \delta = \sum_{n=1}^{N_{RF}} \sum_{k=1}^{|S_n|} R_{k,n,c} \tag{16}$$

where, N_{RF} is the complete number of transmit antennas (i.e. 256 in this work) with $|S_n|$ has detected the signal of k^{th} user. The $R_{k,n,c}$ is the achievable sum rate of the k^{th} user at the n^{th} beam. Therefore, $R_{k,n,c}$ can be calculated according to [28].

EE Analysis (Φ): EE is calculated as the ratio of achievable sum rate of the total power consumption, i.e. SE of the total power consumption $(P, P_{RF}, P_{SW}, P_{BB})$ such as:

$$\Phi = \frac{\delta}{P + N_{RF}.P_{RF} + N_{RF}.P_{SW} + P_{BB}} \ (bps\ /Hz/W) \tag{17}$$

where P is the maximum transmitted power, P_{RF} refers to the power consumes by any RF, P_{SW} represents the switching power consumption, and P_{BB} refers to the baseband power consumption in the conversion from Analog-to-Digital Converter (ADC) and Digital-to-Analog Converter (DAC). Therefore, to experiment and analysis, many values of such variables are presented in Table I.

A. Analysis by Varying Numbers of Users

Design parameters for a varying number of users in two states are shown in Table I., such as A (10: 10: 50) and B (10: 5: 100). Therefore, both states are used to estimate the SE and EE individually to perform user scalability.

TABLE I: DESIGN PARAMETERS FOR A VARYING NUMBER OF USERS

Parameters	Value
SNR Level	10
Number of Iterations	50
N_{RF}	256
P	32 mW
P_{RF}	300 mW
P_{SW}	5 mW
P_{BB}	200 mW
Number of Users	A: 10:5:50 B: 10:10:100
Lambda	½
Number of Paths per User	3

Figs 5 and 6 show the SE performance for cases A=50 users and B=100 users, respectively.

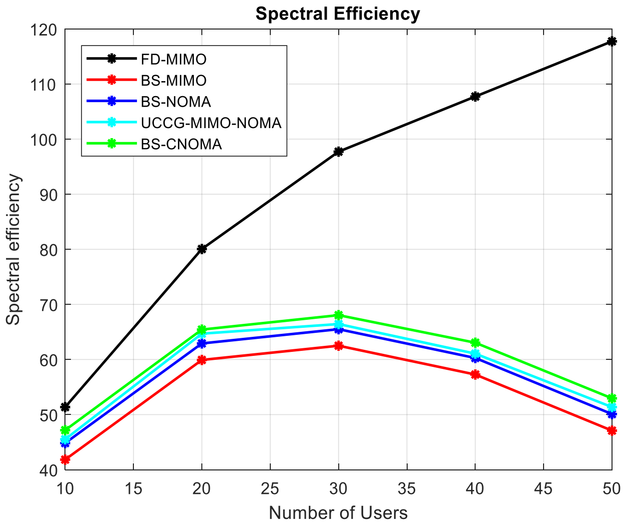

Fig. 5. SE analysis with maximum users of 50

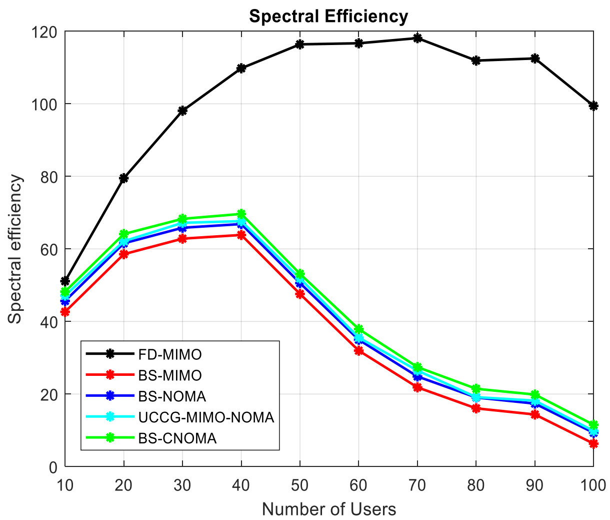

Fig. 6. SE analysis with maximum users of 100

TABLE II: SE AVERAGE RESULTS WITH A MAXIMUM OF 50-100 USERS

Methods	Maximum 50 Users	Maximum 100 Users
FD-MIMO	93.83	101.61
BS MIMO	55.62	36.91
BS NOMA	58.62	39.91
UCCG MIMO NOMA	61.89	41.31
BS C-NOMA	63.42	43.12

As seen in both cases of A (10:5:50) and B (10:10:100) in Fig. 5 and Fig. 6, the SE results show that the FD-MIMO technique provides higher SE than other BS MIMO techniques. Table II justifies the average SE results of both cases. The proposed solution of BS C-NOMA shows the improved SE results compared to the recent clustering-based NOMA technique, i.e. UCCG-MIMO-NOMA solution in both cases of 50-100 users.

B. EE Analysis Varying Numbers of Users

The EE versus the varying number of users is demonstrated in Fig. 7 when using the maximum number of 50 users and Fig. 8 when using the maximum number of 100 users. According to Table III, the results of FD-MIMO show that EE performance is very weak in both cases 50-100 users if compared to all BS methods because it requires a dedicated RF chain.

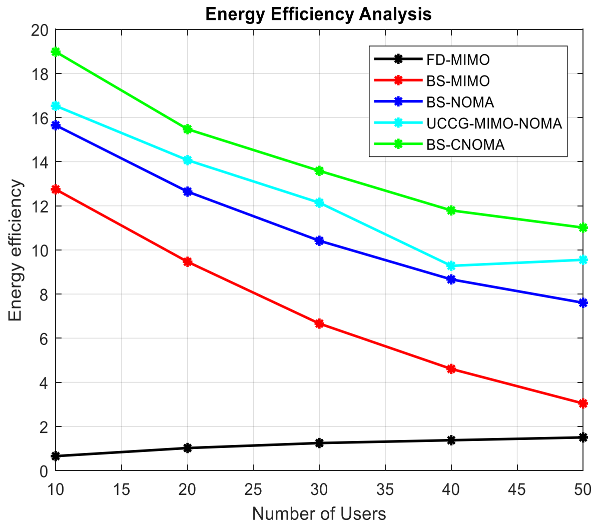

Fig. 7. EE analysis with maximum users of 50

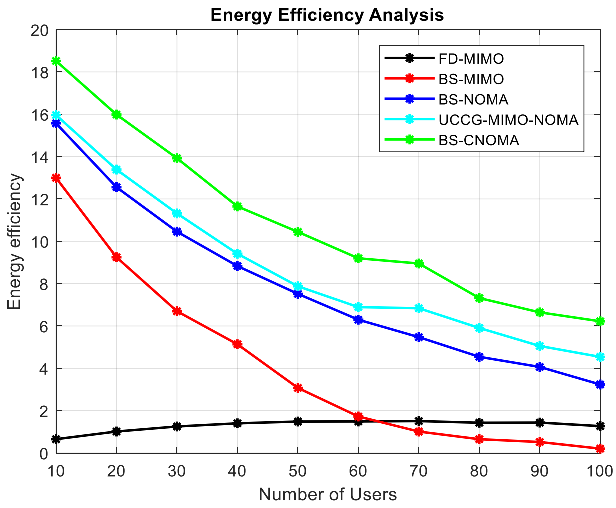

Fig. 8. EE analysis with maximum users of 100

The results of EE clearly show that the proposed BS C-NOMA greatly reduces energy consumption for any case of A=50 users or B=100 users, because clustering helps to redistribute the power over and over again, according to user groups. Clustering the users with similar properties help to reduce the efforts of allocating the power for the users in one group. Hence, the EE improves significantly compared to BS MIMO, BS NOMA methods and UCCG MIMO NOMA. The results of SE and EE show that the proposed BS C-NOMA is more effective than other methods. By using a higher number of users in each beam leads to more power consumption. However, the proposed solution gives consistent results for EE, because the results of the BS MIMO method show that after 60 users, the EE performance will be deteriorating. Therefore, we can provide in Table III a big drop in EE performance in the other methods when compared to the maximum number of 100 users, and maximum number of 50 users.

TABLE III: EE AVERAGE RESULTS WITH A MAXIMUM OF 50-100 USERS

Methods	Maximum 50 Users	Maximum 100 Users
FD MIMO	1.1727	1.29
BS MIMO	7.249	4.08
BS NOMA	10.879	7.85
UCCG MIMO NOMA	11.78	9.78
BS C-NOMA	13.72	10.82

V. CONCLUSION

To improve the user capacity with spectral and EE performances, we introduced the BS MIMO to C-NOMA approach in this paper which consists of the user clustering, lens antenna, and iterative clustering based of power allocations. Furthermore, this paper addressed the EE-SE relationship for a single cell downlink BS MIMO C-NOMA system. In addition, we compare our proposed method with BS MIMO NOMA system and UCCG MIMO NOMA. The simulation results confirm the EE behaviour of C-NOMA and its superiority against NOMA and support the validity of the proposed approaches and their effectiveness compared to the optimal one. Further combining BS MIMO with C-NOMA is expected to enhance the overall achievable capacity. The simulation results show that high EE achieved an improvement rate of 26% compared to the existing BS MIMO NOMA and 16.47 % compared to UCCG MIMO NOMA among 50 and 100 users, respectively. Finally, we recommend in the future studies to develop the use of lens antenna and implement clustering techniques by using different methods such as K-means clustering, hierarchical clustering, fuzzy clustering, and spectral clustering.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

Author 1 conducted the research, analyzed the data and wrote the paper. Author 2 and 3 reviewed and corrected the paper. All authors approved the final version of the paper.

ACKNOWLEDGEMENT

Communication of this research is made possible through monetary assistance by Universiti Tun Hussein Onn Malaysia and the UTHM Publisher's Office via Publication Fund E15216.

REFERENCES

[1] P. Thakur, G. Singh, and S. N. Satasia, "Spectrum sharing in cognitive radio communication system using power constraints," *Perspectives in Science,* vol. 8, pp. 651-653, Sep 2016.

[2] J. H. Brady and A. M. Sayeed, "Differential beamspace MIMO for high-dimensional multiuser communication," in *Proc. IEEE Global Conference on Signal and Information Processing (Global SIP)*, Dec. 2015, vol. 10, pp. 310-314.

[3] X. Gao, L. Dai, Z. Chen, Z. Wang, and Z. Zhang, "Near-optimal beam selection for beamspace mmWave massive MIMO systems," *IEEE Communications Letters*, vol. 4, pp. 1054-1057, Mar 2016.

[4] A. H. Nalband, M. Sarvagya, and M. R. Ahmed, "Optimal hybrid precoding for millimetre wave massive MIMO systems," *Procedia Computer Science*, vol. 171, pp. 810-819, Jan 2020.

[5] X. Gao, F. Tufvesson, O. Edfors, and F. Rusek, "Measured propagation characteristics for very-large MIMO at 2.6 GHz," in *Proc. Conference Record of the Forty Sixth Asilomar Conference on Signals, Systems and Computers (ASILOMAR) IEEE,* Nov. 2012, pp. 295-299.

[6] X. Chen, A. Benjebboui, Y. Lan, A. Li, and H. Jiang, "Evaluations of downlink non-orthogonal multiple access (NOMA) combined with SUMMO," in *Proc. IEEE Annual International Symposium on Personal, Indoor, and Mobile Radio Communication (PIMRC*), Sep. 2014, pp. 1887-1891.

[7] A. Anwar, B. C. Seet, M. A. Hasan, and X. J. Li, "A survey on application of non-orthogonal multiple access to different wireless networks," *Electronics*, vol. 8, p. 1355, Nov. 2019.

[8] M. Aldababsa, M. Toka, S. Gökçeli, G. K. Kurt, and O. Kucur, "A tutorial on non-orthogonal multiple access for 5G and beyond," *Wireless Communications and Mobile Computing,* Jun 2018.

[9] P. D. Diamantoulakis, K. N. Pappi, Z. Ding, and G. K. Karagiannidis, "Optimal design of non-orthogonal multiple access with wireless power transfer," in *Proc. IEEE International Conference on Communications (ICC),* May 2016, pp. 1-6.

[10] D. Vargas and Y. J. Kim, "Two-layered superposition of broadcast/multicast and unicast signals in multiuser OFDMA systems," *IEEE Transactions on Wireless Communications*, vol. 19, pp. 979-994, Nov. 2019.

[11] J. Li, X. Li, A. Wang, and N. Ye, "Performance analysis for downlink MIMO-NOMA in millimeter wave cellular network with D2D communications," *Wireless Communications and Mobile Computing*, Jun 2019.

[12] S. Tang, Z. Ma, M. Xiao, and L. Hao, "Hybrid transceiver design for beamspace MIMO-NOMA in code-domain for mmWave communication using lens antenna array," *IEEE Journal on Selected Areas in Communications*, vol. 38, pp. 2118-2127, Jun. 2020.

[13] P. T. Hiep and T. M. Hoang, "Non-orthogonal multiple access and beamforming for relay network with RF energy harvesting," *ICT Express*, vol. 6, pp. 11-15, Mar 2020.

[14] S. R. Islam, M. Zeng, O. A. Dobre, and K. S. Kwak. "Resource allocation for downlink NOMA systems: Key techniques and open issues," *IEEE Wireless Communications*, vol. 2, pp. 40-47, Apr. 2018.

[15] X. Sun, L. Yu, and Y. Yang, "Jointly optimising user clustering, power management, and wireless channel allocation for NOMA-based Internet of Things," *Digital Communications and Networks*, vol. 2, pp. 40-47, Feb. 2021.

[16] S. Liu and C. Zhang, "Non-orthogonal multiple access in a downlink multiuser beamforming system with limited CSI feedback," *EURASIP Journal on Wireless Communications and Networking*, vol. 1, pp. 1-11, Dec. 2016.

[17] Z. Q. Al-Abbasi, D. K. So, and J. Tang, "Resource allocation for MU-MIMO non-orthogonal multiple access (NOMA) system with interference alignment," in *Proc. IEEE International Conference on Communications (ICC)*, vol. 2. May 2017, pp. 1-6.

[18] A. Khan and S. Y. Shin, "Linear precoding techniques for OFDM-based NOMA over frequency-selective fading channels," *IETE Journal of Research*, vol. 63, pp. 536-551. Jul 2017.

[19] H. M. Al-Obiedollah, K. Cumanan, J. Thiyagalingam, A. G. Burr, Z. Ding, and O. A. Dobre, "Energy efficient beamforming design for MISO non-orthogonal multiple access systems," *IEEE Transactions on Communications*, vol. 67, pp. 4117-413, Feb. 2019.

[20] D. Dinh-Thuan, N. T. Luan, and M. L. Byung, "Transmit antenna selection schemes for NOMA with randomly moving interferers interference-limited environment," *Electronics*, vol. 9, Jan. 2020.

[21] A. Marcano and H. L. Christiansen, "Performance of non-orthogonal multiple access (NOMA) in mmWave wireless communications for 5G networks," in *Proc. International Conference on Computing, Networking and Communications (ICNC)*, Jan 2017, pp. 969-974.

[22] M. Rihan, L. Huang, and P. Zhang. "Joint interference alignment and power allocation for NOMA-based multiuser MIMO systems," *EURASIP Journal on Wireless Communications and Networking,* vol. 1, pp. 1-3, Dec. 2018.

[23] P. Uthansakul, N. Promsuwanna, and M. Uthansakul. "Performance of antenna selection in MIMO system using channel reciprocity with measured data," *International Journal of Antennas and Propagation*, Apr. 2011.

[24] Y. Cho, G. Suk, B. Kim, D. Kim, and C. Chae, "RF lens-embedded antenna array for mmWave MIMO: Design and performance," *IEEE Communications Magazine*, vol. 7, pp. 1-3, Jul. 2018.

[25] M. Zeng, A. Yadav, O. A. Dobre, G. I. Tsiropoulos, and H. V. Poor, "Capacity comparison between MIMO-NOMA and MIMO-OMA with multiple users in a cluster," *IEEE Journal on Selected Areas in Communications*, vol. 35, pp. 2413-2424. Jul. 2017.

[26] S. Sanayei and A. Nosratinia, "Capacity of MIMO channels with antenna selection," *IEEE Transactions on Information Theory*, vol. 53, pp. 4356-4362, Nov. 2007.

[27] Y. Zeng and R. Zhang. "Millimeter wave MIMO with lens antenna array: A new path division multiplexing paradigm," *IEEE Transactions on Communications*, vol. 64, pp. 1557-1571, Feb. 2016.

[28] W. Bichai, D. Linglong, W. Zhaocheng, G. Ning, and Z. Shidong, "Spectrum and energy efficient beamspace MIMO-NOMA for millimeter-wave communications using lens antenna array," *IEEE Journal on Selected Areas in Communications*, vol. 10, pp. 2370-2382, Jul. 2017.

Haitham Al Fatli was born in Baghdad, Iraq, in 1964. He received the B.S. degree from the University of Science and Technology in Baghdad, and the M.S. degree from the University of Pune, India, in 2017, both in electrical engineering. He is currently pursuing the Ph.D. degree with the Faculty of Electrical and Electronic Engineering, Universiti Tun Hussein Onn Malaysia, Johor, Malaysia. His research interests include spectral estimation, array signal processing, and information theory.

Khairun Nidzam Ramli was born in Batu Pahat, Johor, Malaysia in 1974. He received his B.Eng. degree in electronic engineering from the University of Manchester Institute of Science and Technology, Manchester, United Kingdom, in 1997, his M.Eng. degree in communication and computer engineering from the Universiti Kebangsaan Malaysia, Selangor, Malaysia, in 2004, and his Ph.D. for research in electromagnetic analysis from the University of Bradford, United Kingdom, in 2011. Since 2011, he has been associated with the Faculty of Electrical and Electronic Engineering, Universiti Tun Hussein Onn Malaysia, Johor, Malaysia, where he is an associate professor. His main research interests are wireless technologies, antennas, electromagnetics, and engineering computing.

Elfarizanis Baharudin was born in in Petaling Jaya, Selangor, Malaysia in 1977. She received her B.Eng. degree in electrical engineering from the MARA University of Technology, Selangor, Malaysia in 2001, her M.Eng. degree in communication and computer engineering from the Universiti Kebangsaan Malaysia, Selangor, Malaysia, in 2006, and her Ph.D. for research in wireless communication engineering from the Universiti Putra Malaysia, Selangor, Malaysia in 2021. Since 2016, she has been associated with the Faculty of Electrical and Electronic Engineering, Universiti Tun Hussein Onn Malaysia, Johor, Malaysia. Her main research interests are electromagnetic material characterizations, antennas and microwave devices.