A Novel User Grouping Technique for Improving the System Capacity of Massive MIMO

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Abstract: We report here a novel technique for improving the system sum-rate of a Massive MIMO system. We consider semi-orthogonality between the selected users and also fairness in selection. For a uniform distribution of N users with single transmit and receive antenna in a circular service area of the base station (BS) with M antennas, the users are divided into groups. The service area is divided into clusters using the K-means clustering algorithm, and further divided into the equal area by circular sheets. A fixed number of users Q are selected from each cluster which is divided into sheets using two schemes. In scheme A we select an unequal number of users from each sheet under each cluster of Q users, and in scheme B we consider an equal number of users. Considering highly scattering Rayleigh fading channel for small scale fading, and also large scale fading for different distances of users from the BS, we calculate the system sum-rate of the Massive MIMO system.

Keywords— User Grouping; Massive MIMO; fifth Generation; User Selection; Antenna Selection; Precoding.

I. Introduction

The exponential growth in mobile data and multimedia traffic imposes high-speed data requirements in the fifth-generation (5G) wireless networks. To outfit this demand, a new potential wireless technology needs to be in 5G wireless communication system. Massive multiple-input multiple-output (M-MIMO) is envisioned as a favourable technology for 5G cellular networks and beyond, due to its high potential for improving both spectral efficiency (SE) and energy efficiency (EE) [1]. The system typically consists of base stations (BS) with a large number of antennas, which helps in enhancing the throughput and also provides services to a large number of users. It is defined as an arrangement of multiuser MIMO system wherein a large number of antenna elements (hundreds or thousands) at BSs and a large number of antennas at terminals are deployed. The antennas connected to the BS simultaneously work for considerably fewer (tens or hundreds) terminals using similar time and frequency resources.

To enable simple and linear beam-forming as in paper [1], shows that channel state information (CSI) is a basic need in the M-MIMO system. Some limited factor of M-MIMO system is the coherence time of the channel when the CSI is perfect. In a practical scenario to acquire the perfect CSI is a very difficult task. In [2], joint spatial division and multiplexing (JSDM) for downlink multiuser MIMO system were studied. The JSDM scheme aims to cater the users by clustering them into some small groups, such that the users within a group will have almost identical channel covariance; however, the users across groups have nearly orthogonal covariance. A dynamic user clustering is proposed in [3], which does not need estimation of the covariance matrix results and thus decrease the feedback to the index of subspace on which users' channel is concentrated. To enhance the user sum-throughput as in paper [4], proposed an improved *K*-means user grouping scheme. To significantly simplify the user clustering process with frequency division duplex (FDD) technique M-MIMO system as in [5], proposed a new agglomerative user clustering scheme. In paper [6], for user grouping, the authors proposed three similarity measure techniques such as Fubini-study, weighted likelihood, and subspace projection method. Also, proposed two user clustering methods like *K*-modoids clustering and hierarchical clustering scheme.

As soon as the group is formed, the next significant issue is the user selection. The grouping impacts on user selection because only the users within the groups are chosen. User scheduling is a most important concern in the M-MIMO system since the BS antennas usually can't provide services simultaneously to the unlimited number of users, which might be for two causes. Firstly, as one RF chain can simply transmit one information stream simultaneously but in the M-MIMO system, there are certainly larger numbers of users to be served than the number of radio-frequency (RF) chains available at the BS. Secondly, the instantaneous channels among users are non-orthogonal to each other, which bring mutual interference among the users and resulting in decrease of system performance. Due to this, it is important to select a user from a group for scheduling to maximize the SE or user fairness. Based on the dynamic channel condition of the M-MIMO system with the second stage precoding in [4], it proposed a dynamic user scheduling technique that achieved huge system gain. A low complexity Gram-matrix based greedy user scheduling method is suggested jointly with the incremental inter-user-interference (IUI) minimization norm [7]. A cooperative user scheduling scheme is proposed in [8] based on the cooperation among users to obtain higher system capacity and to guarantee the efficient transmission of data, EE, and low feedback in the M-MIMO system.

Antenna selection scheme is employed in the M-MIMO system in order to achieve higher sum-rate with low transmission power. Due to a large number of antennas equipped at BS; the computational complexity and hardware cost make the M-MIMO system more challenging. To provide a balance between the benefits, complexity, and cost of the M-MIMO system, the suitable antenna selection (AS) scheme might be an effective solution that certainly decreases the burden at BSs. In the

M-MIMO system, in order to increase the EE based on the norm of the channel matrix and CSI, the authors proposed an AS scheme in [9]. In [10], authors proposed a low complexity AS algorithm based on the *K*-means clustering technique to maximize the system performance. Two-hybrid AS schemes were proposed in [11] to successfully reduce the computational complexity with the small cost of capacity performance loss.

In this paper, we used ZF and MMSE linear precoding schemes for signal processing. In these two precoding schemes, the weighted vectors are chosen to avoid interferences among the users and usually, these are power inefficient as the weight vectors are not matched to user channels. But, when the number of users N is significantly large, it provides a huge system sum-rate. This happens because of multiuser diversity [12]. Recently many works are undergoing on M-MIMO for user grouping, user selection, and antenna selection but there are no such works that are jointly presented. The block diagram of joint user grouping, user selection, antenna selection, and precoding scheme is shown in Fig.3. The major contributions of this paper summarized as follows:

i. Using simple *K*-means clustering, a large number of users are separated into four clusters around the BS.
ii. Each cluster is further divided into three zones of equal area group (g) by circular sheets.
iii. From each group best users are selected based on the semi-orthogonality measure with two schemes.
iv. Antennas are selected based on maximum channel gain.
v. ZF and MMSE linear precoding schemes are used to reduce group user's interference.

The rest of this paper is ordered as follows. Section-II, present the system model. We report the linear precoding in section-III. User grouping is described in section-IV; user selection and antenna selection are explained in detail in section-V and VI respectively. The simulation results and discussion are described in section-VII and section-VIII concluded this paper.

Notations: In the paper, unless otherwise specified, bold lower case, bold upper case, and upper case are used to represent vectors, matrices, and sets, respectively. Correspondingly $\mathcal{CN}(0, \sigma^2)$ represents the complex Gaussian distribution with zero mean and unit variance. $(\cdot)^H$ is the Hermitian of the matrix, $(\cdot)^T$ is transposed, $(\cdot)^\dagger$ is the Moore Penrose Pseudo-inverse, $tr(\cdot)$ is the trace of a matrix.

II.System Model

We consider a downlink M-MIMO time division duplex (TDD) based system. For sent and received data, every user has a single antenna. This system at BS consists of a huge number of antennas that simultaneously serve a large number of users. The proposed system models are shown in Fig.1 and Fig.2, where the figures denoted an area that is expected to be a weak signaling area. We assume the weak areas [13], since inside this area generally the signal quantity is extremely weak besides the presence of users are also rarer. We consider the radius of this weak area as $r_w=100m$. Excluding this area, N users uniformly distributed with the maximum cell area radius as $r=1000m$. The N users are separated into the $G=4$ cluster using a simple *K*-means clustering algorithm and each cluster contains L number of users such that $N=GL$. Each cluster is further divided into three zones of equal area group (g) by circular sheets so that number of users in any cluster and three zones contain an approximately equal number of users. We have selected $S=24/36/48$ users from all clusters and groups, and eventually the equal number of antennas are scheduled for transmission and reception of information from M antennas. The channel between the user and BS is considered to be of Rayleigh fading with zero mean and σ^2 variance i.e. $\mathcal{CN}(0,\sigma^2)$. Both LSF and SSF are considered for the channel.

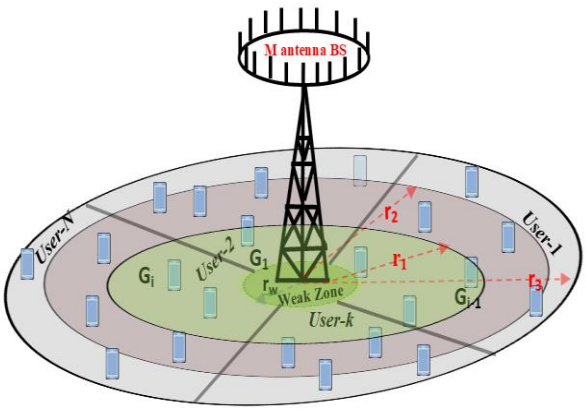

Fig-1: Block diagram of Group base Massive MIMO System

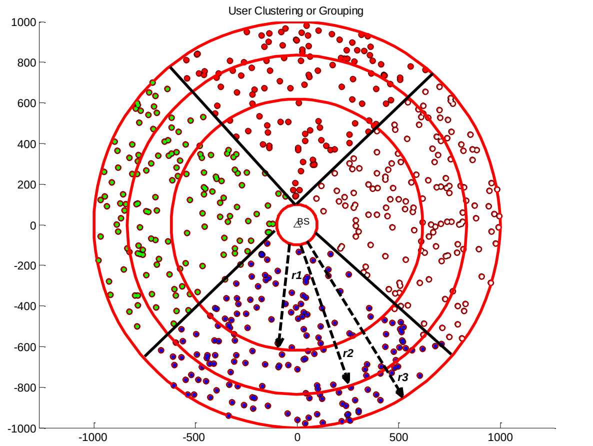

Fig-2: User Clustering and Group base Massive MIMO Systems

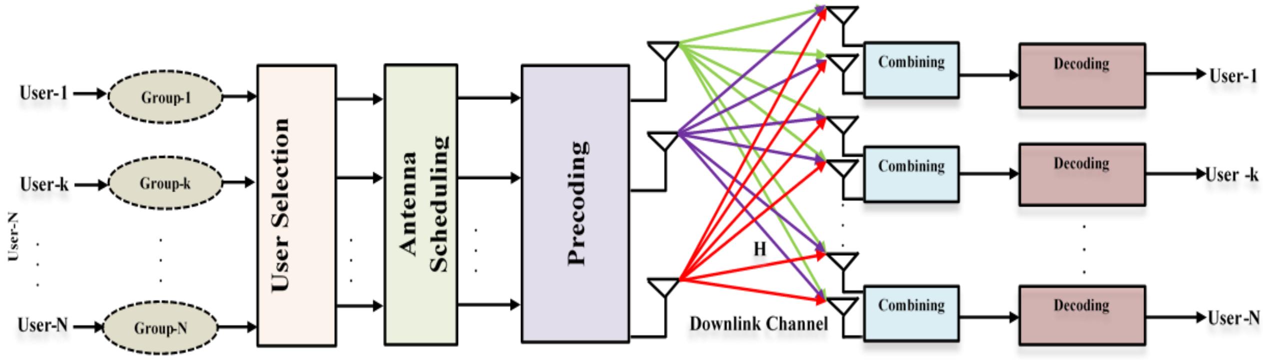

Fig.3.Block Diagram of Massive MIMO System with the user group, user scheduling, antenna selection, and Precoding

The receive signal matrix $\boldsymbol{r}$ of $N\times 1$ is given by the below equation.

$$\mathbf{r} = \sqrt{\rho_{dl}}\boldsymbol{G}\mathbf{x} + \mathbf{n} \cdots\cdots\cdots (1)$$

where ρ_{dl} is the downlink transmit SNR and $\mathbf{x} \in \mathbb{C}^{M\times N}$ is the transmit data-bearing matrix and $E\{||\mathbf{x}||^2\}=1$ is the power constraint, where $\mathbf{x}=\mathbf{Ws}$. Where $\boldsymbol{W}$ is the precoding weighted matrix with constraint power $E\{(\boldsymbol{WW})^H\}=1$.and $\mathbf{s}=[\mathbf{s_1}, \mathbf{s_2}, \ldots, \mathbf{s_N}]^{\mathbf{T}}$ is the symbol to be transmitted. The complex channel matrix is defined as bellow

$$\boldsymbol{G} = \sqrt{\boldsymbol{D}}\boldsymbol{H} \cdots\cdots\cdots (2)$$

where, $\boldsymbol{H} \in \mathbb{C}^{M\times N}$are the fast fading channel coefficients of N users and M BS antennas. All the elements $\boldsymbol{H}$ are independent and identical distribution (i.i.d) random variable with zero means and unit variance i.e. $\mathcal{CN}(0,1)$. The diagonal matrix can be represented as below equation

$$[\boldsymbol{D}]_{kk} = \beta_k \cdots\cdots\cdots (3)$$

The β_k is calculated by equation (4)

$$\beta_k = \frac{r_f}{\left(\frac{r_k}{r_w}\right)^a} \cdots\cdots\cdots (4)$$

where r_f is the shadow fading variable with standard deviation σ_{shadow} is the log-normal random variable, r_w is the radius of the weak area and r_k is the distance between the BS antenna to user and path loss exponent is 'a'.

In our analysis, considered ρ_{dl} is the downlink transmit SNR and the long-term power constraint is written in the equation below

$$\rho_{dl} \geq E[tr(\mathbf{xx^H})] \cdots\cdots\cdots (5)$$

The power controlling factor Υ is calculating by equation (6)

$$\Upsilon = \sqrt{\frac{\rho_{dl}}{tr(\boldsymbol{GG}^H)^{-1}}} \cdots\cdots\cdots (6)$$

For equal power distribution among the users in our proposed model, we use a water-filling power allocation scheme. Suppose two users $\boldsymbol{U_1}$ and $\boldsymbol{U_2}$ are said to be a semi-orthogonal to each other if the angle between them is $\phi=90^0$ or $cos\phi=0$ i.e. ($\boldsymbol{U_1} \perp_\phi \boldsymbol{U_2}$) and must follow below equation (7) [14].

$$\phi \geq \frac{|\boldsymbol{U_1}^{\boldsymbol{H}}\boldsymbol{U_2}|}{||\boldsymbol{U_1}||||\boldsymbol{U_2}||} \cdots\cdots\cdots (7)$$

The value of ϕ is always positive [12] and in this paper, assumed the $\phi=0.1$. Using equation (2), (3), and (4), we may rewrite equation (1) as below.

$$\mathbf{r} = \sqrt{\rho_{dl}\beta}\boldsymbol{HWs} + \mathbf{n} \cdots\cdots\cdots (8)$$

The k^{th} receive signal matrix is represented in the equation below.

$$\mathbf{r}_k = \underbrace{\sqrt{\rho_{dl}\beta_k}\boldsymbol{H}_k\boldsymbol{W}_k\boldsymbol{s}_k}_{\text{desired signal}} + \underbrace{\sqrt{\rho_{dl}\beta_k}\sum_{j\neq k}\boldsymbol{H}_k\boldsymbol{W}_j\boldsymbol{s}_j}_{Interference} + \underbrace{\mathbf{n}_k}_{\text{AWGN}} \cdots\cdots\cdots (9)$$

In equation (9) $\boldsymbol{H_k}$ and $\boldsymbol{W_k}$ are the k^{th} rows and column matrix of $\boldsymbol{H}$ and $\boldsymbol{W}$ respectively. The $\mathbf{n_k}$ is the k^{th} column matrix of $\boldsymbol{n}$. In our analysis, consider the system has perfect CSI i.e. $\boldsymbol{n_k}$=1. Hence, the signal to interference plus noise ratio (SINR) of k^{th} users of the system is written as below-

$$SINR_{\boldsymbol{k}} = \frac{\rho_{dl}\beta_k|\boldsymbol{H}_k\boldsymbol{W}_k|^2}{\rho_{dl}\beta_k\sum_{j\neq k}\left|\boldsymbol{H}_k\boldsymbol{W}_j\right|^2 + 1} \cdots\cdots\cdots (10)$$

The average spectral efficiency is calculated as

$$\boldsymbol{R_k} = \sum_{n=1}^{N} log_2(1 + SINR_{\boldsymbol{k}})$$

$$\boldsymbol{R_k} = \sum_{n=1}^{N} log_2\left(1 + \frac{\rho_{dl}\beta_k|\boldsymbol{H}_k\boldsymbol{W}_k|^2}{\rho_{dl}\beta_k\sum_{j\neq k}\left|\boldsymbol{H}_k\boldsymbol{W}_j\right|^2 + 1}\right) \cdots\cdots\cdots (11)$$

III.Linear precoding

We consider two linear precoding schemes that are used for the analysis of SE of the M-MIMO system. Precoding is a method in which by multiplying the precoding matrixes with user data capable to suppress the interference of the system that is produced due to the signals of other users [14]. From equation (8), the precoding scheme is shown in Fig.4.

M-MIMO system equipped with M BS antennas and N users both having a single antenna used for transmission and reception of information data. In this system, ZF and MMSE precoding is used for suppression of IUI for $M \geq N$.

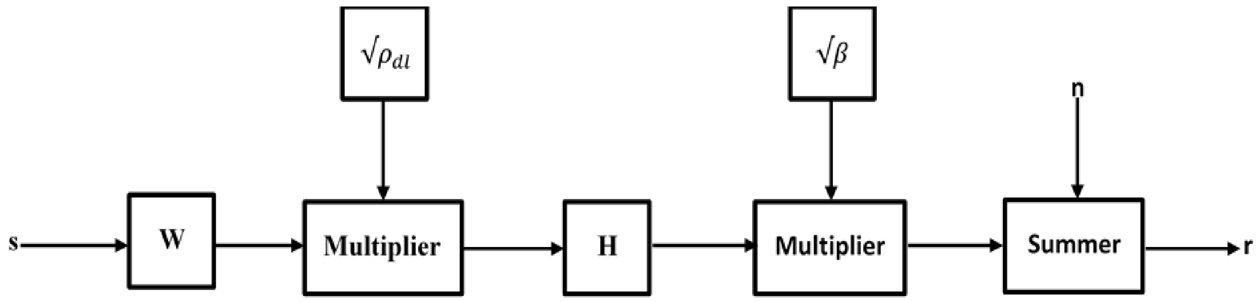

Fig.4. Block diagram of Precoding Scheme

i. Zero-Forcing (ZF) Precoding

ZF precoding is a linear precoding scheme. This precoding scheme is designed in such a way so that it completely mitigates the IUI of each user. Let, k^{th} user precoding weighted matrix is $\boldsymbol{W}_k$. This precoding scheme eliminate the interference to zero, such that

$$\boldsymbol{H}_k\boldsymbol{W}_j = 0 \quad \text{for j} \neq k \cdots\cdots\cdots (12)$$

Hence, equation (9) may be rewritten as

$$\mathrm{r_k} = \underbrace{\sqrt{\rho_{dl}\beta_k}\boldsymbol{H}_k\boldsymbol{W}_k\boldsymbol{s}_k}_{\text{desired signal}} + \underbrace{\mathbf{n}_k}_{\text{AWGN}} \cdots\cdots\cdots (13)$$

where the Moore-Penrose pseudo-inverse of ZF precoding scheme which is given below-

$$\boldsymbol{W}_{ZF} = \boldsymbol{H}^{\dagger} = \boldsymbol{H}^H(\boldsymbol{H}\boldsymbol{H}^H)^{-1} \cdots\cdots\cdots (14)$$

As mentioned above in this paper use the water-filling power allocation algorithm over the users. Hence, the achievable SE of the M-MIMO system is obtained from equation (13) after the application of the ZF precoding scheme is given as

$$\boldsymbol{R}_{ZF,k} = \sum_{n=1}^{N} log_2\left(1 + \rho_{dl}\beta_k\left|\boldsymbol{H}_k\boldsymbol{W}_{ZF,k}\right|^2\right) \cdots\cdots\cdots (15)$$

ii. Minimum Mean Square Error (MMSE) Precoding

The MMSE is another type of linear precoding scheme that cannot eliminate interference rather it can offer a good trade-off between the noise improvement and suppression of interference. The MMSE estimator follows an estimation method through which it can reduce the mean square error. The post-detection SINR maximization the MMSE precoding weighted matrix is given by

$$\boldsymbol{W}_{MMSE} = \boldsymbol{H}^H\left(\boldsymbol{H}\boldsymbol{H}^H + \frac{\sigma^2\boldsymbol{I}}{\rho_{dl}}\right)^{-1} \cdots\cdots\cdots (16)$$

where σ^2 is the variance of noise power. We assume the channel has a perfect CSI and its value assumed $\sigma^2=1$ and $\boldsymbol{I}$ am the identity matrix. The k^{th} achievable SE of M-MIMO system is obtained from equation (11) after the application of the MMSE precoding scheme which is given below-

$$\boldsymbol{R}_{MMSE,k} = \sum_{n=1}^{N} log_2\left(1 + \frac{\rho_{dl}\beta_k\left|\boldsymbol{H}_k\boldsymbol{W}_{MMSE,k}\right|^2}{\rho_{dl}\beta_k\sum_{j\neq k}\left|\boldsymbol{H}_k\boldsymbol{W}_{MMSE,j}\right|^2 + 1}\right) \cdots\cdots (17)$$

$$\boldsymbol{R}_{MMSE,k} = \sum_{n=1}^{N} log_2\left(1 + \frac{\left|\boldsymbol{H}_k\boldsymbol{W}_{MMSE,k}\right|^2}{\sum_{j\neq k}\left|\boldsymbol{H}_k\boldsymbol{W}_{MMSE,j}\right|^2 + \frac{1}{\rho_{dl}\beta_k}}\right) \cdots\cdots (18)$$

IV. User Grouping

In this paper, N numbers of users are divided into G cluster using a simple K-means clustering method. These clusters separated the users into four different parts surrounding the BS as shown in Fig.1 and Fig.2. Each cluster is further divided into three zones of equal area group (g) by circular sheets so that approximately equal numbers of users consists in each group. Each cluster consists of the L number of users and $N=GL$. When large numbers of users are separated into groups, the channel matrix size of each group is becoming very small; hence, the computational complexity of the algorithm is reduced. The steps of K-means users clustering and grouping algorithm is presented in below-

Initialization:

1. The number of clusters, $G=4$.
2. Randomly choose G number of centroids on the cell around the BS and then randomly selecting users for each centroid.

Repeat

3. Re-assign each user to the cluster to which the user is to the closest cluster, based on the mean value of the users in the cluster.
4. Keep iterating until there no change to the users.

End

5. G numbers of clusters are formed around the BS.
6. Further, Each cluster is divided into three zones of equal area group (g) by circular sheets. The radius of each sheet are-$r_1=r/\sqrt{3}$ $r_2=(\sqrt{2}\ r)/\sqrt{3}$, and $r_3=r$.
7. Total $g=12$ number of groups are formed.
8. Hence nearly the same number of users is contained in each group in the cell.

V. User Selection

In this paper, we consider the semi-orthogonal user selection (SUS) algorithm for the system SE performance analysis in the M-MIMO system. From N users, S users are selected from G clusters and g groups with two different combinations using the SUS algorithm. The steps of this algorithm are described below.

Semi-orthogonal User Selection Algorithm

1. Total no of antenna=M; Total no of User N;
2. Iteration$i \leftarrow 1$;
3. $\Delta \leftarrow \{1,2,\ldots\ldots,N\}$is the set of all users
4. $S_S \leftarrow \phi$ is the set of selected users from all clusters and groups.
5. $S_1 = \text{argmax}_{k\in\Delta}\left\|\boldsymbol{H}_{S,A}\right\|_F^2$ the first set of user-select
6. $S_S \leftarrow S_S \cup S_1$;
7. while $i < S$
8. For each k in Δ do
9. $\frac{|\boldsymbol{H}_k^H\boldsymbol{H}_{k-1}|}{\|\boldsymbol{H}_k\|\|\boldsymbol{H}_{k-1}\|} \leq \phi$ for orthogonality test between the users.
10. end
11. $\Omega_S = \text{argmax}_{k\in\Delta}\left\|\boldsymbol{H}_{k,A}\right\|^2$

12. Update $S_S \leftarrow S_S \cup \Omega_S$; $\Delta \leftarrow \Delta \backslash S_S$
13. $\boldsymbol{H}_S = \boldsymbol{H}_{S,A}$ Set of Channel vector of the selected user
14. $i = i + 1$
15. end
16. Repeat the process from step *8* to *16* till *S* users are selected from all clusters and groups.
17. $\boldsymbol{S}_{SUS} = \boldsymbol{S}_s$

VI. Antenna Selection

Antenna selection is performing after the user scheduling scheme. In this paper, the *S* number of antennas are selected from *M* antennas at the BS for transmission of data. In our antenna selection algorithm, at every step, from *S* selected users a particular user is considered. The channel is assumed as a reciprocal and maximum channel gain-based antenna selection algorithm is considered to select a set of *S* antennas from *M* antennas which corresponds to the strongest orthogonal channel from the user to the BS to schedule with selected users set. The data in regards to the index of the selected antenna is then sent to the BS. Lastly, the BS update the set of available transmits antennas to the next user in order. Thus, the selected users are allocated with the set of transmit antennas.

Antenna Selection Algorithm on maximum channel gain based:

1. For each user inS_{SUS}, $\boldsymbol{H}_S = \boldsymbol{H}_{S,A}$Set of Channel vector of the selected user
2. No of BS antenna M; Iteration$j \leftarrow 1$;
3. $A \leftarrow \{1, \ldots m, \ldots, M\}$is the set of all Antennas at BS.
4. $\boldsymbol{S}_{S,S} \leftarrow \phi$ is the set of the selected antenna at BS.
5. while $j \leq A$
6. $\boldsymbol{S}_A = \mathrm{argmax}_{i \in A} \left\|\boldsymbol{H}_{S,i}\right\|_F^2$
7. Update $\boldsymbol{S}_{S,S} \leftarrow \boldsymbol{S}_{S,S} \cup \boldsymbol{S}_A$; $\boldsymbol{A} \leftarrow \boldsymbol{A} \backslash \boldsymbol{S}_{S,S}$;
8. $\boldsymbol{H}_{S,S} = \boldsymbol{H}_{S,i}$ Set of Channel vector of selected user and antenna
9. $j \leftarrow j + 1$
10. end
11. Repeat the process from step *6* to *10* till *S* users are selected.
12. $\boldsymbol{S}_{S,S} = \boldsymbol{S}_{SUS-AS}$

VII. RESULTS AND DISCUSSION

In this section, we study the performance of an M-MIMO system by simulation in MATLAB. We consider the user grouping as explained above; users are semi-orthogonal amongst each other in the individual group and also semi-orthogonal among all groups. We assume the following parameters shown in table-1. As said above, we consider ZF and MMSE precoding with Rayleigh fading channel, and the system with variation in SNR values, the total number of BS antennas *M*, and the *Scheme A* and *Scheme B* with the same number of total users *S*. The corresponding numbers of S BS antennas are selected based on maximum SNR for a given selected user as explained in the algorithm. The circular service area is divided into equal circular zones so that each zone contains the approximately same number of users. The computation complexity of our considered SUS algorithm is also very small compared to the other exiting SUS algorithms. The computational complexity comparison table of our considered SUS algorithms with other exiting SUS algorithms is shown in table-2.

Table1: Values of Parameters use during Simulation

Parameters name	values
Total no of Users (*N*)	*600*
Total no of clusters (*G*)	*4*
Total no of zones under a cluster	*3*
Total no of groups (*g*)	*12*
Total Selected number of users from all clusters and groups (*S*)	*24/36/48*
No of users select from each cluster (*Q*)	*6/9/12*
Users in different zones in *Scheme A*	*(3,2,1)/(4,3,2)/(5,4,3)*
Users in different zones in *Scheme B*	*(2,2,2)/(3,3,3)/(4,4,4)*
The radius of the weak area is (r_w)	*100m*
The radius of the circular service area (*r*)	*1000m*
AWGN ($\boldsymbol{n_k}$)	*1*
Shadow fading variable with standard deviation is (r_f= σ_{shadow})	*8 dB*
Path loss exponent (*a*)	*3.8*
ϕ	*0.1*

Table-2: Complexity Comparison of SUS algorithms

Reference	Complexity
Reference [15]	$\approx O(N^3)$
Reference [16]	$\approx O\left(\frac{K}{3}\hat{R}^4 N^3\right)$
Proposed SUS Algorithm	$\approx \frac{1}{Gg}\{O(M^2N)\}$

As we simulate the system assuming 1 Hertz is the bandwidth of each user, the system sum-rate equals the spectral efficiency of the system. For the simulation of a practical Massive MIMO system, the algorithm is run for large times, and the average value of the Spectral efficiency is obtained. In Fig. 5 we show the results for *S=24*, *36*, and *48* and of *Scheme A* and *Scheme B*, where we varied the received SNR of the users, and considering ZF and MMSE precoding. The trend of SE of all the schemes is the same. We observe that *Scheme A* performs better than *Scheme B*.

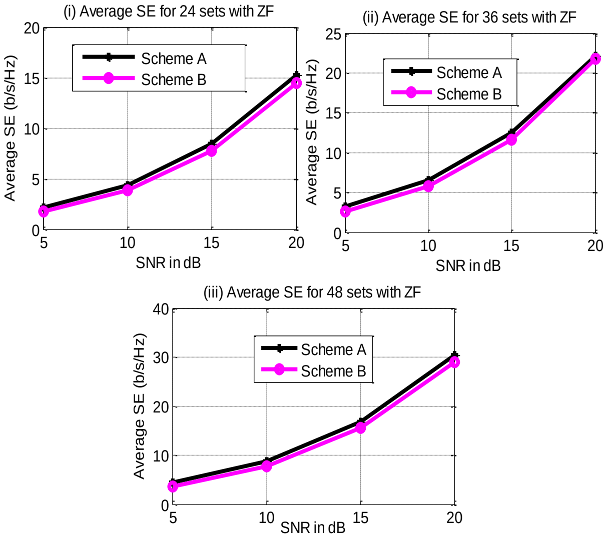

Fig.5: Average SE versus a range of SNR with ZF precoding and *Scheme A* and *Scheme B* with $M=64$, $N=600$, $r=1000m$, and $r_w=100m$ for users and antenna sets (i) *24*, (ii) *36*, and (iii) *48*.

We repeat the above experiment with MMSE precoding, and the results are in Fig. 6. The trends of the sum-rate of all the schemes are the same. We observe that *Scheme A* performs better than *Scheme B*.

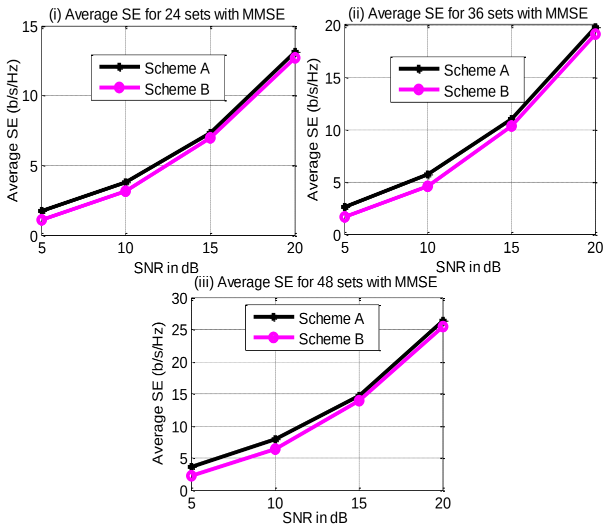

Fig.6: Average SE versus a range of SNR with MMSE precoding and *Scheme A* and *Scheme B* with $M=64$, $N=600$, $r=1000m$, and $r_w=100m$ for users and antenna sets (i) *24*, (ii) *36*, and (iii) *48*.

Conclusion

A novel user scheduling technique is proposed for use in Massive MIMO. The technique is based on grouping the users under the circular service area of the BS. The grouping is carried by first clustering the total users into four clusters using *K*-means clustering. Each cluster is further divided into three zones of equal area group so that number of users in any cluster and three zones contain an approximately equal number of users. Users are selected based on semi orthogonality measure and ZF and MMSE precoding are applied to obtain the total average sum-rate of the Massive-MIMO system. The average sum-rate is explored by varying the number of BS antennas, and the received SNR of each user. Two schemes are proposed and the performance of the scheme where an unequal number of users are chosen from each zone from a total of each group is higher.

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