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A Novel Way for Pilot Decontamination in Massive MIMO Multi-Cell Systems

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ABSTRACT. *The performance of massive Multi-input Multi-output (MIMO) system is limited by pilot contamination, due to the pilots with similar energy can be received by users at the same time, which brings the difficulty of determining the domain pilot. An effective way to solve this problem in Time Division Duplex (TDD) wireless system is using weighted graph for pilot allocation. However, this method is badly influenced by the number of pilots. In this paper, weighted graph is combined with Soft Pilot Reuse Scheme (SPRS) and cell classification. In order to deal with the influence of too much pilots, SPRS and cell classification will be presented. Program of cell classification will divide cells into two groups and prepare orthogonal pilots to make two groups of cells be orthogonal to each other. For whole users in one cell, they will be divided into edge users and center users by large-scale-fading factor. For center users, edge-weighted interference graph (EWIG) will measure their degrees of affection by pilot contamination and form the weighted graph. After that, the graph will be used as reference to assign pilot. As for edge users in the same category, they will use orthogonal pilots to reduce the pilot contamination. The simulation gives powerful results of the interference rejection and the achievable rate enhancement.*

KEYWORDS: *Pilot contamination, Massive MIMO, Cell classification, SPRS, WGC scheme*

1. Introduction

With the development of wireless communication technology, the accuracy and capacity of channel estimation are required to be higher. Massive multiple-input multiple-output (MIMO) is one of the key elements in today's emerging 5G technology [1]. With this technology, hundreds of antennas are grouped together in arrays at both transmitter and receiver side(for each user there is a signal antenna and there are hundreds of users in reality, which will multiplying the capacity of the wireless connection within the same frequency range, which further promotes the spectral efficiency [2][3]. More importantly, power efficiency is also improved by radiating the focused beam towards users.

Pilot signal is an integral part of uplink signal, which can be used to estimate channel. In the SISO (signal-input signal-output), channel state information (CSI) can be obtained by pilot [4]. However, in the massive MIMO system, traditional feedback CSI is no longer applied since the time needed to accomplish the feedback will longer than the coherence time. Therefore, in large-scale MIMO system, time division duplex system is usually used. In addition, in order to improve the performance of large-scale MIMO system, orthogonal signal is also introduced [5]. However, in reality, due to the limited resources of orthogonal signal, non-orthogonal pilot sequences are used to do the channel estimation. While each user in different cells are using same pilot signal, the BS would not able to recognize each user, this phenomenon is so-called pilot contamination [6].

In order to reduce the pilot contamination, several methods are proposed. The first way is to divide different cells in to different groups, then we use orthogonal pilot in different groups [7]. In this way, it can reduce the requirement of the number of orthogonal signal, while it can also reduce pilot contamination. The second way is to shift the frame structure of the signal, which will transmit both pilot and down-link data at non-overlapping time [5]. In this way, it could also reduce the pilot contamination. Other methods are also designed to reduce the pilot contamination, such as to estimate the angle of arrival (AOA) of each user, which ignore the influence of the use of non-orthogonal signal and only have to determine the AOA. There are several other methods can be used to reduce the pilot contamination, in reality, but in reality, each method has its own shortcomings, some methods cannot be applied. In this paper, one

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new method is proposed which have greater efficacy on pilot decontamination. First of all, we divide all cells into 2 groups, users' pilots in different group cells are orthogonal to each other. Therefore, as we assume all users' pilots in one single cell are orthogonal to each other, pilot contamination will only exist between the same group of cells. Secondly, we established an adjustable proportion coefficient to divide the cells into edge user group and center user group. We assign orthogonal pilots in all edge users. In the center user group, WGC-PD algorithm is used to allocate pilots which have the lowest PC to the center users who have the largest potential PC, so as to reduce the pilot pollution. The model is established and simulated by MATLAB. The influence of parameters such as edge partition on the performance of the model is studied by controlling variables, and the effect of the model on reducing pilot pollution is evaluated.

In the past few decades, there are many models that can be used to solve the problem of pilot contamination. Here we will discuss several schemes which have been proposed to suppress pilot pollution. Time shift pilot scheme from: By using different frame structures, adjacent cells can avoid transmitting pilot at the same time and reduce pilot contamination [5]. However, due to the fact that the downlink data transmission power is significantly higher than the uplink pilot power, the time-shift pilot scheme is vulnerable to the impact of the power and cannot produce accurate channel estimation.

The scheme of using large-scale fading information of channel to suppress pilot pollution: By using large-scale fading information to quantify the degree of interference between users, the pilot is allocated to the users who are easy to be interfered, and the pilot is multiplexed to the users who are less interfered[6].

Multi cell cooperation and coordination scheme: This scheme needs to exchange channel covariance information between base stations, but with the increase of the number of antennas, the amount of information needs to be exchanged also increases and becomes a considerable burden [11].

Angle of arrival(AOA) information is another way used to suppress pilot contamination.As long as the AOA of the user signal does not overlap each other, and the base station uses the minimum mean square error to estimate the channel, even if the same pilot sequence is used between users, it will almost not affect each other, but this method has the problem of high complexity because of using the minimum mean square error estimation [8].

Blind estimation method based on subspace division to reduce pilot contamination: Assuming that different user channels are orthogonal, this blind estimation method is easy to produce large errors, because when the number of base station antennas is close to infinity, the channel orthogonality is satisfied, but in practical applications, the number of base station antennas is limited [9].2 System Model

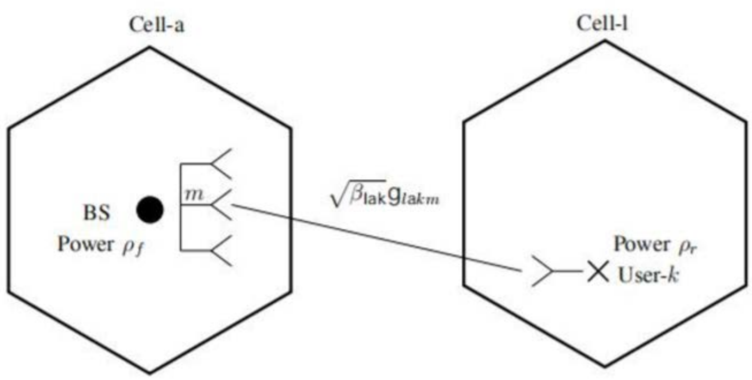

Fig.1 Linking Spanning between the K-th User in l-th Cell and the m-th Antenna in a-th Cell.

For system model, a L-cell system where each cell has a base station(BS) are put into the consideration. For each base station there are M antenna elements and there are K (K≤M) randomly located users in each cell. Next,we consider there are totally available S (S≤K) pilots Φ (1≤ i≤S) are used in one cell. At the same time, these pilots are orthogonal to each other and the we reuse the same pilot group Φ in other cells due to limited pilot resource. $(\Phi = [\Phi_1, \Phi_2, ..., \Phi_s]^T C^{S\times\Gamma}, \Phi\Phi^H = I_S)$. Furthermore, we randomly assigns pilot $\Phi_{p(l,k)}$ to user (l, k) and

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guarantees that different pilots will be assigned to different users within one cell. In this system model, the channel vector h_{lakm} denotes the link spanning from the kth user of the lth cell to the mth antenna in the ath cell, whose kth column $h_{lakm} = \left[h_{lak1}, h_{lak2}, ...h_{lakm}\right]^T$ represents the gains of the channels from user k in cell l to BS a, which can be formulated as [10]

$$h_{lakm} = \sqrt{\beta_{lak}} g_{lakm} \tag{1}$$

where β_{lak} is the large-scale fading coefficients which relate to both path loss and shadow fading. g_{lakm} denotes the small-scale fading coefficient. Thus, the channel between all antennas in cell a and all the K users in the cell 1 can be represented by a matrix as

$$H_{la} = G_{la} \times D_{la}^{0.5} \tag{2}$$

Where we decrease the dimension of small-scale fading coefficient from g_{lakm} to G_{la}, which is a $M \times K$ matrix representing the small-scale fading coefficient between M antennas in the ath cell and K users in the lth cell, and D_{la} is a $K \times K$ diagonal matrix whose diagonal elements are $\left[D_{la}\right]_i = \left[\beta_{la1}, \beta_{la2}, ...\beta_{lak}\right]$. [12] Then the equations that prove the existence of uplink pilot contamination can be deduced in the following section.

1.1 Uplink Pilot Contamination

At the beginning of every coherence interval, we assume all users in each cells transmit pilot symbols at the same time, and each BS estimates the channels of its corresponding users. Thus, the data BS received in the ath cell's mth antenna can be formulated as

$$Y_{am}^u = \sum_{l=1}^{L}\sum_{k=1}^{K}\sqrt{\rho_r \gamma} h_{lakm} \Psi_{lk} + W_{am}^u \tag{3}$$

or

$$Y_{am}^u = \sum_{l=1}^{L}\sum_{k=1}^{K}\sqrt{p_u} h_{lakm} \Psi_{lk} + W_{am}^u \tag{4}$$

Where ρ_r is users' average transmit power and γ is the length of training sequences.The product of $\rho_r \gamma$ represents the uplink pilot power and we denote it as p_u. Ψ_{lk} denotes the symbol transmitted from the kth user in the lth cell and $\Psi_l = \left[\Psi_{l1}, \Psi_{l2}, ...\Psi_{lK}\right]^T$. W_{am} denotes the additive white Gaussian noise (AWGN) , where $W_{ai} = \left[W_{a1}, W_{a2}, ...W_{aM}\right]^T$ and W_a is an $M \times \gamma$ noise matrix. H_{la} denotes the set of channel between all the K users in the cell l and all antennas in cell a. Thus, we can decrease the dimension of pilot sequences' matrix received at the BS of the ath cell to:

$$Y_a^u = \sum_{l=1}^{L}\sqrt{p_u} H_{la} \Psi_l + W_a^u \tag{5}$$

By separating the received pilots of the users in the target cell and pilots in the neighboring cells, (5) can be rewritten as

$$Y_a^u = \sum_{l=1}^{L}\sqrt{p_u} \Psi_a H_{aa} + \sum_{l=1, l \neq a}^{L}\sqrt{p_u} H_{la} \Psi_l + W_a^u \tag{6}$$

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in which the firrst part is the pilots transmitted in one single cells which is the desired received pilots, and the second part is the pilots transmitted from neighboring cells. As we assume that same pilot group is reused in other cells due to the limited pilot resource, this will cause the pilot contamination.

In this paper, we use SINR as an evaluation index for the pilot decontamination degree. Thus, the up link SINR of $u_{k,l}$ can be formulated by [6]:

$$SINR = \frac{\left\| h_{(l,k),j}^{H} \right\|^4}{\sum_{(l^{'},k^{'})\in\Omega_{(j,k)}} \left\| h_{(l,k),l}^{H} \right\|^4 + \frac{\sigma_{(l,k)}^2}{\delta^2}} \approx \frac{\beta_{(l,k),l}^2}{\sum_{(l^{'},k^{'})\in\Omega_{(j,k)}} \beta_{(l^{'},k^{'}),l}^2} whenM \to \infty \tag{7}$$

where $\sum_{(l^{'},k^{'})\in\Omega_{(j,k)}}$ denotes users in cells other than cell l using the same pilot as user(l,k), $\sigma_{(l,k)}^2$ denotes the uncorrelated noise and interference that can be substantially reduced by increasing the number of BS antennas $M.\delta^2$ is the transmitted power. Therefore, when the number of antennas tends to be infinity, uncorrelated noise and interference can be considered zero and the SINR equation can be converted into a function related the large scale fading coefficient. Hence the related average achievable rate R of uplink $u_{k,l}$, is formulated as[12]:

$$R = (1-\mu_0)E\left\{\log_2(1+SINR)\right\} \tag{8}$$

Where μ_0 is the fraction of spectral efficiency loss allocated to channel estimation.[15] It is clear that the average uplink achievable rate is limited by the PC in SINR. Therefore, our method using the uplink achievable rate and the SINR as measuring index during the simulation.

2. Research Design

Before we investigate three methods we used in our scheme, we have to know that in reality, although pilot contamination can be reduced by the use of orthogonal pilots, the number of pilots is limited. Thus, the main idea of our scheme is to reduce the use of pilots, meanwhile, reduce pilot contamination.

2.1 Cell Classification

Firstly, we use cellular classification to divide different cells in a system into different groups as mentioned in[7], users' pilots are orthogonal to each other between different cell groups and reuse the same pilot resources among the same cell group. In figure 2, we only considered the centered cell l and its 6 adjacent cells. We can know that if each cell uses the same pilot, the up-link pilot of the intermediate cell and the surrounding six cells will interfere with each other, resulting in PC. Therefore, in the cellular networks, if each grid adopts orthogonal pilot signal, pilot contamination will be avoided. Then we can divide cells into 2 groups: the grayed one and the white one like it shown in the figure. For the center cell l, the cells that will reuse the same pilot and the pilot contamination would be reduced to 2 adjacent cells which are $cell_{l-1}$ and $cell_{l+1}$. If we want all users' pilots in the centered 7 cells to be orthogonal to each other, we have to use K L which is 7K orthogonal pilots. By classifying 2 groups of cells can we decrease the using number of orthogonal pilots resource from 7K to 2K. However, the pilot contamination still exists in this case among $cell_l$, $cell_{l-1}$ and $cell_{l+1}$. To reduce the PC, we divide users into center users and edge users by introducing Soft Pilot Reuse Scheme (SPRS). A simple case of cell classification is shown in figure 2, where each color(gray and white) denotes a group. Since the strength of PC is related to the coefficient $\omega_{(a,k)a}^2$ which is the large-scale fading coefficient, while $\omega_{(a,k)a}^2$ will be smaller with the distance become farther, thus, PC caused by users out of the dot line in the figure can be ignored.

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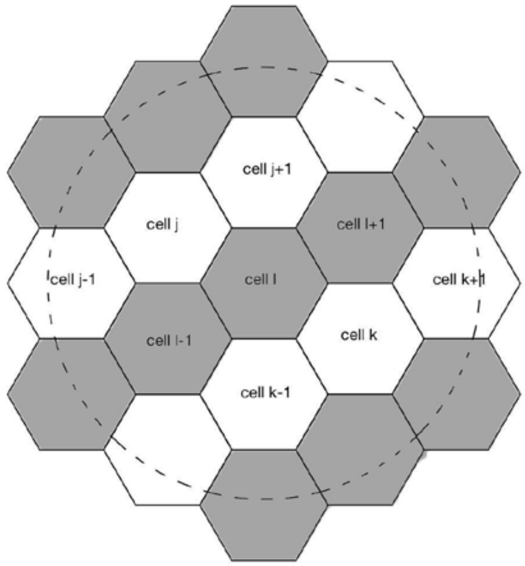

Fig.2 Cell Classification

2.2 User Classification by Soft Pilot Reuse Scheme (Sprs)

Although cell classification can attribute to the work of decontamination, strong PC still exists between users especially between two adjacent cells like cell l and cell l+1 or cell l-1 which is shown in the figure 3. To reduce PC between these users, a kind of pilot reuse scheme called SPRS is proposed, in which the users are separated into two categories: cell centered users and cell edged users. When we talk about PC, it is always related to a parameter ! which is the large-scale fading coefficient. For users, $\omega^2_{(a,k)a}$ can be different to each user in the same cell depend on there locations, and larger $\omega^2_{(a,k)a}$ means the user may have bigger potential to have sever PC with users from other cells, thus, we can divide users in the same cell into two groups and assign different kinds of pilots to them to reduce PC. To be specific, edge users which will have higher PC will be assigned with orthogonal pilots with other adjacent edged cells while the centered users, which have smaller PC, will use the same pilot resource in each cells. We can use equation written in[13] to determine whether they are center users or edge users:

$$\omega^2_{(a,k)a} \overset{?}{\leq} \rho_a \tag{9}$$

We consider a threshold ρ_a to determine the boundary of centered and edged users, which can be written as[13]:

$$\rho_a = \frac{\theta}{K}\sum_{k=1}^{K}\omega^2_{(a,k)a} \tag{10}$$

we can judge the users by the square of large scale coefficient $\omega^2_{(a,k)a}$, when it is smaller or equal to the threshold ρ_a ,it is the user from edge region, else if it is larger than the threshold, it is the user from center. While θ is adjustable according to the real situation,

$$\rho_a = \frac{1}{K}\sum_{k=1}^{K}\omega^2_{(a,k)a} = \frac{K+1}{2}\times\omega^2_{(a,k)a} \tag{11}$$

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All the users will be regarded as centered users if there exists at least one users($K \geq 1$) and the proposed SPR scheme becomes equivalent to the conventional scheme where all the cells are using the same pilot. when the parameter θ is set to 0, all the users will be regarded as edge users and a optimal situation is formed where

all users in all cells use orthogonal pilot sequences.

A figure of this method is shown in figure 3.

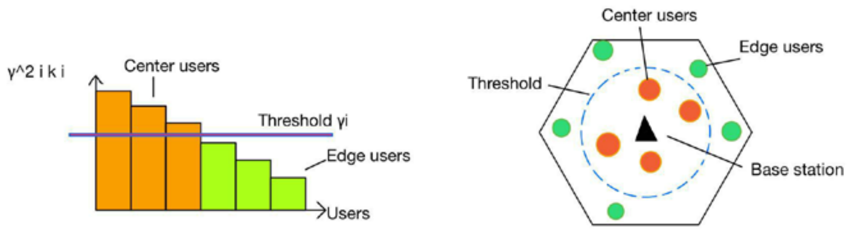

Fig.3 Threshold Boundary for User Division

Thus, the total number of the orthogonal pilot sequence required can be written as [13]:

$$K_{all} = K_{ct} + K_{eg} \tag{12}$$

and the number of k_{eg} is

$$K_{eg} = \sum_{l=1}^{L} K_C \tag{13}$$

where K_C denotes edge users in each cells.

$$\phi_{all} = \left[\phi_{ct}^T \times \phi_{eg}^T \right]^T \tag{14}$$

ct and eg represent user from center and edge respectively. Since matrix ϕ_{eg} can be separated into L rows partitions and corresponds to $K_{i,e}$ edge users, the orthogonality of pilots of edged users in each cells are guaranteed, and the pilot contamination will be reduced.

2.3 Weighted-Graph-Color Scheme

Since the pilot contamination from edged users can be eliminate by SPRS and cell classi cation, to improve the performance of the MIMO system further, the goal is to eliminate interference caused by the users from other users from the center of other cells.

Firstly, we will introduce a concept called pilot contamination strength(PCS) which can be used to measure the severity of PC between users. After that, we can introduce a graph called edge-weighted interference graph which can be used to present the relationship of PCS between users from different cells in a massive MIMO system. Since the PCS between two users < l,k > and < l', k' > with the same pilot are closely related to the ratios $\frac{\omega^2_{<l',k'>,l}}{\omega^2_{<l,k>,l}}$ and $\frac{\omega^2_{<l,k>,l'}}{\omega^2_{<l',k'>,l'}}$. we define $\tau_{<l,k>,<l',k'>}$ as PCS which is the pilot contamination intensity, and τ can be calculated as it written in[1]:

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$$\tau_{<l,k>,<l',k'>} = \frac{\omega^2_{<l',k'>,l}}{\omega^2_{<l,k>,l}} + \frac{\omega^2_{<l,k>,l'}}{\omega^2_{<l',k'>,l'}} \quad (15)$$

It is clear that larger τ indicates that larger PCS between two users. After measure PCS between every users, we can construct an indirect weighted graph and it can be written as G=(U,P), where $U =< l,k >: 1 \le l \le L, 1 \le k \le K$, it denotes all users in the MIMO system, and $E = \varsigma_{<j,k><j',k'>j'}$: which denotes PCS be-tween users. After all, we can get a graph G=(U,P) which called EWIG. A simple case of EWIG is shown in figure 5, where the spot denotes users in cells and the color of them shows which kind of pilot they are using, users with same color means they are using the same pilot. The line between users denotes PC between them, and the number shows the severity of PC, it is clear that PC between users from the same cell is negligible while the PC between users who is using same pilot in different cells is severe.

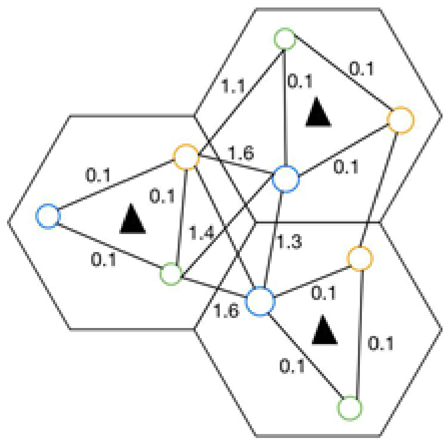

Fig.4 Formulation of Ewig

With the help of EWIG, it is simple to obtain the relationship of PC between each users in the massive MIMO system, and it is clear that users who have bigger $\tau_{<l,k>,<l',k'>}$ will cause more serious when they are assigned with same pilots. Since the PCS can be different which depends on the location of users, we can allocate same pilots to users whose PCS is negligible to save pilots from limited resources. For users who have larger potential to cause severe PC, we will assign orthogonal pilots to them to reduce PC. In WGC-PD scheme, PCS caused by center users in the system will be mitigated under the condition that the pilot resource is limited. In WGC-PD scheme, two users may be assigned with orthogonal pilots if the PCS of them $\tau_{<l,k>,<l',k'>}$ is severe, users who have smaller PCS $\tau_{<l,k>,<l',k'>}$ will be assigned with same pilots due to limited pilot resources. To be specific, the proposed algorithm of WGC-PD is provided below.

1) Initialization: In this part, we will select two center users from different cells with largest $\tau_{<l,k>,<l',k'>}$ in EWIG which means they have the biggest potential to cause severe PC in step 1.These two users can be written as $< l_1, k_1 >$ and $< l_2, k_2 >$. In step 2, these two users will be assigned with two orthogonal pilots φ_1 , φ_2 , respectively, then they will be added in to set ω , set ω contains users that have been assigned with pilots.

2)User selection: In this phase, a parameter $\delta_{<l.k>}$ will introduced to estimate the PCS between user $< l,k >$ and users from other cells in set ω . In step 6, the user $< l_0, k_0 >$ out of set ! which have the largest PCS with users in set ω will be selected.

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3)Pilot assignment: In step 8, set λ will be constructed which contains available pilot resources. The parameter ηT introduced in step 9 denotes the potential PCS between user $< l_0, k_0 >$ and users in set ω by assuming that they are using same pilots T. In the next step, pilot which have smallest potential PCS ηT will be selected to assigned with user $< l_0, k_0 >$. In step 11, the user$< l_0, k_0 >$ will be added into set ω. After this, we will continue this loop until all users are assigned with their corresponding pilots.

Algorithm 1 Proposed WGC-PD Scheme

Input:
System Parameters: K, L, and S;
The constructed EWIG: $G = (U, P)$.
Output:
Pilot allocation: $\{p_{\langle l,k\rangle}\}$, for $1 \le l \le L$, $1 \le k \le K$.
1: Initializalion:
2: $\{l_1, k_1, j_2, k_2\} = \arg\max_{\{l,k,l',k',l \neq l'\}} \zeta_{\langle l,k\rangle,\langle l',k'\rangle}$.
3: $\{p_{\langle l,k\rangle}\} = 0$, $p_{\langle l_1,k_1\rangle} = 1$, $p_{\langle l_2,k_2\rangle} = 2$.
4: $\Omega = \{\langle l_1, k_1\rangle, \langle l_2, k_2\rangle\}$.
5: **while** $\exists p_{\langle l,k\rangle} = 0$ **do**
6: $\delta_{\langle l,k\rangle} = \sum_{\langle l',k'\rangle \in \Omega, l \neq l'} \zeta_{\langle l,k\rangle,\langle l',k'\rangle}$.
7: $\langle l_0, k_0\rangle = \arg\max_{\langle l,k\rangle}\{\delta_{\langle l,k\rangle} : \langle l,k\rangle \notin \Omega\}$.
8: $\Lambda = \{s : \forall k, p_{\langle l_0,k\rangle} \neq s, 1 \le s \le S\}$.
9: $\eta_T = \sum_{\langle l,k\rangle \in \Omega, p_{\langle l,k\rangle} = T} \zeta_{\langle l_0,k_0\rangle,\langle l,k\rangle}$.
10: $p_{\langle l_0,k_0\rangle} = \arg\min_T\{\eta_T : s \in \Lambda\}$.
11: $\Omega = \Omega \cap \{\langle l_0, k_0\rangle\}$.
12: **end while**
13: **return** $\{p_{\langle l,k\rangle}\}$.

Fig.5 Algorithm for Wgc-Pd [1]

There are other scheme also combining multiple methods together to achieve better performance in MIMO system, such as a method combing SPRS and WGC-PD together as it mentioned in [14]. In the situation while there are lots of cooperating cells, however, PC will become severe again meanwhile the time for calculation will also be longer. In our scheme, we added cell classification base on this scheme, it will have a better performance than the original method.

3. Simulation and Results

On the basis of WGC PD + SPRS, we make a better improvement, we combine the WGC-PD+SPRS scheme with cell classification scheme and we deny it as CSW scheme .By running the proposed scheme-CSW scheme on MATLAB and analyzing the simulation, we can view the performance of the proposed scheme. We show our following simulation parameters in the following:

During the simulation, first we randomly generate users distribution which allocate pilots to users randomly .Then, according to user's large scale fading factor and threshold parameter ,we separate the center users and the edge users which is cell classification. And then apply both WGC-PD method and SPRS method to do the pilot allocation in order to reduce PC. Finally, we compare the SINR and the uplink achievable rate in two different situations, one situation is changing the number of the cooperating cells while the number of the users is fixed, the other situation is changing the number of the users while the number of the cells is fixed. And based on these two situations, we observed the systems performance of the proposed scheme. Also it should be noted that We keep the relationship of user number K in single cell and pilot sequence number Q equals to 1.5K = Q.

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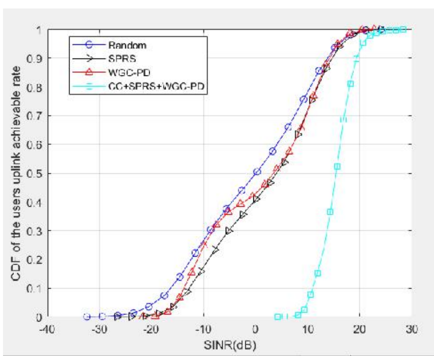
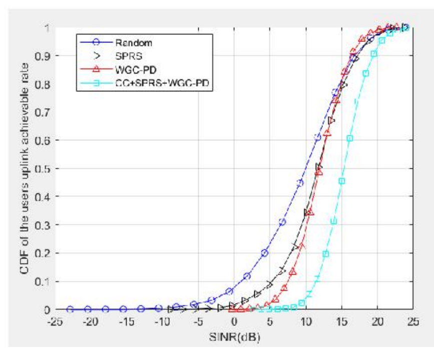
parameter	value
Number of user in one cell K	10 20
Number of cells L	15 19 30
Number of pilot sequence S	k≤S≤KL
Loss of spectural efficiency P>o	0.05
Antenna's number in a BS M	32~2048
The threshold parameter θ	θ=0.1
Transmission power δp	5~30dB
The shadowing fading σ	8dB

Fig.6 Simulation Parameter

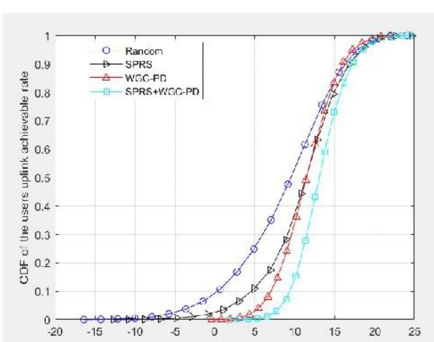
The figures shows the cumulative distribution function (CDF) of uplink SINR for different schemes. With the same SINR valued SINR1,the CDF is random > SPRS>WGC-PD>CC+SPRS+WGC-PD, which means this scheme has the least users whose SINR are less than value SINR1.When the number of cell L increase, the advantages of proposed scheme become obvious, which means the more cells in a cellular system, the better the performance of the proposed scheme, and the more obvious of its advantages. Fig.7 shows the relationship between CDF and SINR in different scheme. From the figure, we can find that with the same CDF of the average uplink achievable rate applied, the SINR in our proposed CC+WGC-PD+SPRS scheme is larger than than any other proposed schemes in the graph. By comparing to the WGC-PD + SPRS scheme in the left graph, our schemes has significant advantage on SINR especially after the uplink achievable exceed 0.1bps/Hz. Thus the proposed scheme is superior to the WGC-PD+SPRS scheme, and has more efficacy than other schemes.



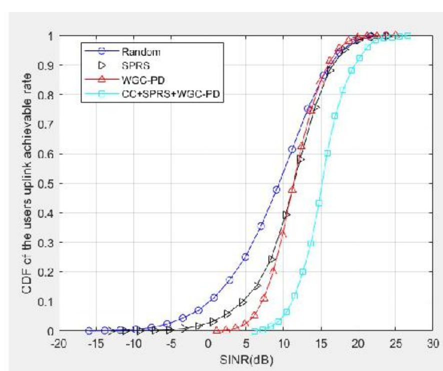
(a)SINR versus CDF when L = 30



(b) SINR versus CDF when L = 15



(c) L=19 M=512 K=10 S=15



(d) L=19 M=512 K=10 S=15

Fig.7 Shows the Relationship between Cdf and Uplink Achievable Rate r.the Advantage of the Proposed

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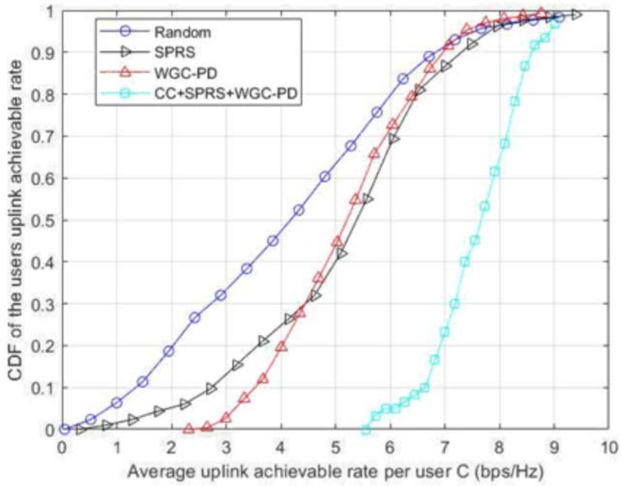

Fig.8 Hievable Rate Versus CDF

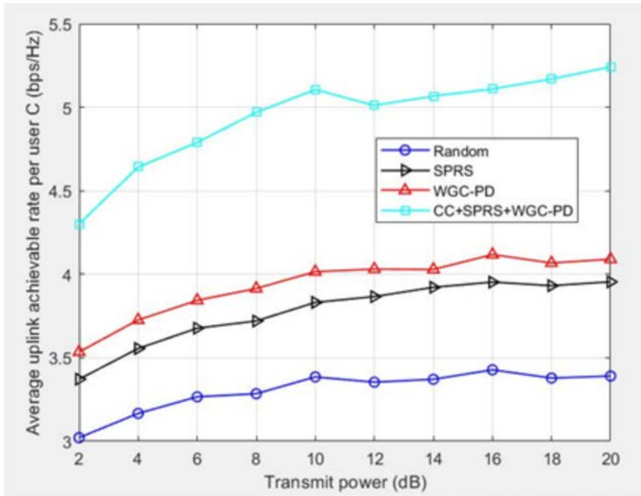

Fig.9 Transmit power versus

Scheme is obvious. The average uplink achievable rate per user of the proposed scheme star from 5.5bps/Hz,which is far more higher than other schemes. And when Rate comes to about 9 bps/Hz, the CDF curves are all methods nearly reaching 1.

Fig.9 shows the curves of rate R against transmit power. When the transmit power is 2dB,the achievable rate of the proposed scheme which is 5.3bps/Hz ,clearly higher than that of WGC-PD,SPRS and random. And with the increase of transmit power, the rates of these four schemes all slightly improved. But the proposed scheme's keep the high rate all the time. So the CC+WGC-PD+SPRS scheme has the better performance than others.

We have generated two simulations (fig.10&fig.11)above that mainly test the efficacy of cell classification method. Those two graphs are generated under the condition that total number of cells equal to 15. It is demonstrated that with the same number of antennas applied in BS, the average uplink achievable rate is increasing about 16.67% in the proposed CSW method by comparing to the method WGC-PD + SPRS, which is without the cellular classification method.

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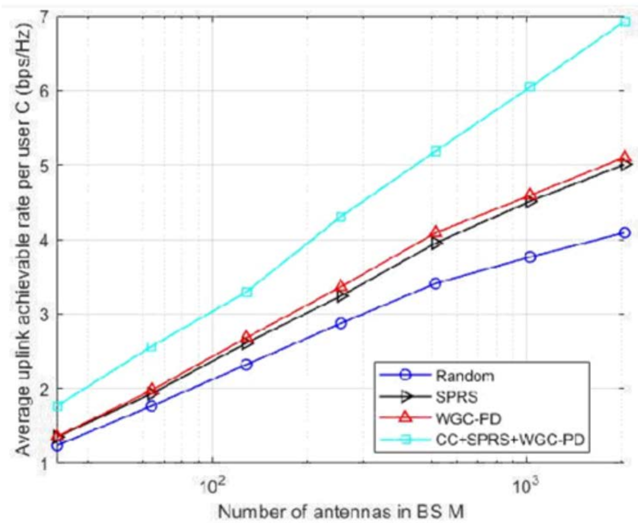

Fig.10 L=15 K=10 S=15

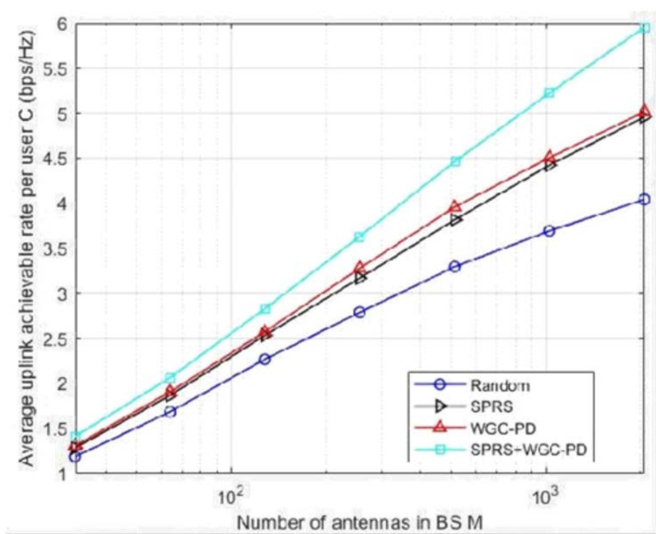

Fig.11 15 K=10 s=15 Figure 11: l=15 K=10 s=15

4. Conclusion and Prospect

On the basis of WGC-PD + SPRS, we combine the WGC-PD+SPRS scheme with cell classification scheme and run the proposed scheme-CC+WGC-PD+SPRS scheme on MATLAB. By analyzing the simulation, we can see that the proposed scheme is able to significantly mitigate pilot contamination the under the constraint of limited pilot resources.

However, the proposed scheme still have room to improve. The proposed scheme can be adjusted in the grouping strategy to be more accurate. To be specific, the same pilot could be used by the edge users in different cells if the distance between then is far enough to ignore the pilot contamination. In this way, pilot resource could be reduced to some extant.But the complexity of the algorithm still needs to be considered.

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