Pilot Contamination Elimination in Massive MIMO Systems

Rui-Chao Hu(✉) and Bing-He Wang

Department of Information Engineering,
Engineering University of CAPF, Xi'an 710086, China
2388411722@qq.com

Abstract. The pilot contamination problem has been the primary limitation of massive multiple input multiple output (MIMO) systems. To improve it, in this paper, we propose a dynamical pilot assignment algorithm based on the priority of user location. First, we obtain the formulation of signal to interference plus noise power ratio (SINR) in uplink channel through minimum mean square error (MMSE) mechanism. Second, an objective function of SINR is defined together with constraint condition of real distance, based on which optimal value (OV) could be achieved. Third, we propose a novel cellular classification algorithm, that is, area with better channels adopts random pilot assignment scheme, and others use the novel algorithm. Last, the proposed algorithm is compared with the traditional algorithm. The results show that the proposed algorithm can effectively reduce the influence of pilot contamination on the communication performance and improve the system SINR and the system capacity.

1 Introduction

With the development of society and the exponential growth of data traffic, the existing communication technology can not meet the needs of people. In order to cope with the challenges of mass mobile terminals to the communications network, Each country competing to study the 5th generation of mobile communication technology (5G) [1, 2]. 5G plans to enter the commercial operation in 2020, compared with 3G and 4G technology, 5G technology is not only the speed of the upgrade, but also to improve the system capacity and improve the spectral efficiency of a qualitative leap, the typical characteristics of "high, speed, low latency" that can provide higher bandwidth and allow more terminal access to meet future communications requirements for high-speed data streams [3–5].

Therefore, in order to make full use of bandwidth resources, improve the spectrum utilization, to achieve low-power green communication, massive multiple input multiple output system (MIMO) technology came into being [6, 7]. As a key technology for the 5G physical layer, massive MIMO is equipped with large-scale antennas at the base station side, making it much larger than the number of single-antenna mobile terminals that can serve simultaneously [8]. Antenna information theory proves that the information transmission capacity of the channel capacity of the communication system with the end of the wireless communication link and the simultaneous use of multiple

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antennas is significantly improved compared with the traditional single antenna system [9]. Therefore, massive MIMO technology can improve the peak rate and band efficiency of the system without increasing the bandwidth, so as to improve the transmission performance of wireless links and meet the needs of high-speed wireless data services and the rapid growth of users. According to the principle of probability statistics, when the number of base station side antennas is much larger than the number of single antenna users, the base station to each user's channel will tend to be orthogonal. As a result, inter-cell interference in adjacent cells will tend to disappear, and huge array gain will be able to effectively improve the SINR of each user, enabling the simultaneous scheduling of more users at the same time-frequency resources [10, 11]. However, massive MIMO technology to achieve the above goal is to accurately obtain the channel state information (CSI) as the premise, the base station side of the antenna only to obtain accurate CSI, in order to carry out effective data transmission, so as to achieve the purpose of improving system capacity. However, in the actual massive MIMO system, because the number of single-antenna mobile terminals (MT) in the cell is huge, in order to make the communication of each user not interfere with each other, it is necessary to ensure the orthogonality of each user's pilot sequence, That is, the number of orthogonal pilot sequences should be greater than or equal to the number of cells and the number of MT in the cell, the product is huge and the requirements for the communication equipment are extremely high. Therefore, it is inevitable to use the same pilot sequence to achieve normal communication, which leads to the pilot signal interference that pilot contamination has become the bottleneck of normal communication [12]. In the literature [12] demonstrates the effect of pilot contamination on system performance. In the non-cooperative multi-cell scenario, the interference between the noise and the cell is negligible with the increase of the number of base stations. However, the signal interference caused by the same pilot sequence between the cells still exists, which seriously affects the massive MIMO system communication performance; In the literature [13], it is assumed that the intra-cell pilot is orthogonal and the inter-cell pilot is fully multiplexed, and the closed expression of mean square error (MSE) is deduced. It is concluded that the length of the pilot sequence τ has little effect on the closed expression of MSE as the number of antennas M increases, and the uplink pilot power control method is proposed to improve the multiuser reachability and rate performance of each cell. But the article assumes that in the case of a one-dimensional plot, there is no discussion of the multidimensional cell scenario; In the literature [14] proposed inter-cell cooperative communication transmission scheme, the pilot transmission slot of the target cell and the data transmission time slot of the adjacent interference cell are shifted, so as to avoid the interference of the pilot information and the data information. The massive MIMO system, the pilot and data information is huge, how to accurately offset the time slot to send, especially in the fast moving scene, the implementation of more difficult; In the literature [15], according to the traditional method of randomly assigning the pilot sequence, the algorithm is proposed to continuously assign the pilot sequence according to the channel quality. Compared with the traditional random assignment pilot sequence, the performance is improved. But the article did not further classification of the district, so the system communication performance is limited.

Based on the literature [15] pilot scheduling scheme, this paper proposes an improved pilot sequence allocation method. Firstly, the channel estimation is carried out by using the least mean square error method. Then, the detection signal is received by the matched filter (MF) at the receiving end, and then the SINR expression. It is concluded that the SINR is mainly limited by the large-scale coefficients of the channel when the base station side antenna tends to infinity, and the deduced conclusion satisfies the probability statistics principle. In order to solve the problem of system pilot pollution, a mathematical model with distance as the constraint condition and SINR as the objective function is established. The convex optimization method is used to solve the optimal value of the objective function, and then the cell is classified according to the user area level to achieve the user within the district intelligent allocation of pilot sequences. The theoretical and simulation results show that this method has obvious effect in improving the SINR and system capacity, and can effectively reduce the influence of pilot contamination, and has good theoretical value and significance.

2 System Model

The massive MIMO multi-cell multi-user time-division duplex system, which is composed of L positive hexagonal cells, each cell number is $1, 2, \cdots, L$, each cell is composed of a base station with M antenna and K single antenna users, to meet the conditions of $K \leq M$. In order to facilitate the analysis of the problem, so that the middle of the cell as the target cell, the cell within the pilot sequence is completely orthogonal, the inter-cell pilot sequence is fully multiplexed. As shown in Fig. 1.

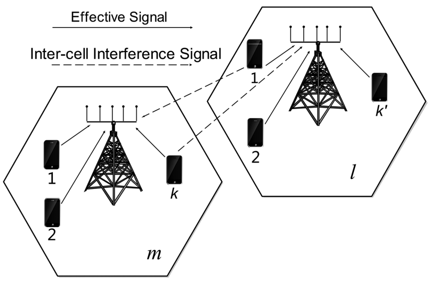

Fig. 1. Massive MIMO system model

The system channel vector is $\boldsymbol{H}_{lmp} \in \boldsymbol{C}^{M \times 1}$, which represents the channel vector of the p-th user in the m-th cell to the base cell of the l-th cell. The expression is:

$$\boldsymbol{H}_{lmp} = \eta_{lmp}\sqrt{\xi_{lmp}} \quad (1)$$

In the formula (1), η_{lmp} represents the large scale fading coefficient in the channel, which indicates the slow change of the mean value of the received signal over a certain period of time with the propagation distance and the environment [16]. ξ_{lmp} represents the small-scale fading factor in the channel, satisfying $\xi_{lmp} \sim CN(0, \boldsymbol{I}_M)$, and characterizes the rapid fluctuation of the received signal after a short or short distance [16]. Assuming the pilot sequence $\boldsymbol{\Psi} = [\boldsymbol{\psi}_1, \boldsymbol{\psi}_2, \cdots, \boldsymbol{\psi}_k]^{\mathrm{T}} \in \boldsymbol{C}^{k \times \tau}$, the pilot sequence length is τ, and the pilot sequences of the users in the cell are orthogonal to each other, i.e., $\boldsymbol{\Psi}\boldsymbol{\Psi}^{\mathrm{H}} = \boldsymbol{I}_K$. In the uplink pilot transmission phase, the user in the cell sends the pilot signal to the respective service base station. If the base station l is the target base station, the received pilot signal is:

$$\boldsymbol{Y}_l = \sum_{l=1}^{L} \sum_{p=1}^{K} \boldsymbol{H}_{lmp} \boldsymbol{\psi}_{lp} + \boldsymbol{N}_l^{\mathrm{UL}} \tag{2}$$

In the formula (2), $\boldsymbol{N}_l^{\mathrm{UL}}$ is the additive white Gaussian white noise received by the base station l, which is a $M \times \tau$-dimensional matrix, satisfying the independent identically distributed and $\boldsymbol{N}_l^{\mathrm{UL}} \sim CN\left(0, \delta_N^2\right)$. $\boldsymbol{\Psi}_{lp} \in \boldsymbol{C}^{l \times \tau}$ is the pilot signal transmitted by the user p in the l-cell and satisfies $\boldsymbol{\Psi}_{lp} \boldsymbol{\Psi}_{lp}^{\mathrm{H}} = \tau$. After the base station side completes the estimation of the uplink channel, the downlink channel is the conjugate transpose of the uplink channel according to the reciprocity of the TDD system model channel. Assuming that $\boldsymbol{H}_{ml}$ is the channel vector of the m-cell user to the base station of l and satisfies $\boldsymbol{H}_{ml}^{\mathrm{DL}} = H_{ml}^{\mathrm{H}}$, The signal from the base station received by the user in the l-th cell is:

$$\boldsymbol{Y}_l^{\mathrm{DL}} = \sqrt{\rho_f} \sum_{l=1}^{L} \sum_{p=1}^{K} \boldsymbol{H}_{ml}^{\mathrm{H}} x_{mp} + \boldsymbol{N}_{mp}^{\mathrm{DL}} \tag{3}$$

In Eq. (3), ρ_f represents the average SINR of the downlink data, $\boldsymbol{N}_{mp}^{\mathrm{DL}}$ satisfies the independent identically distributed and $\boldsymbol{N}_{mp}^{\mathrm{DL}} \sim \left(0, \delta_{mp}^2\right)$, x_{mp} is the data vector sent by the base station of m to the user of p. For the massive MIMO systems, accurate access to channel state information determines the receiver to correctly detect and resume the transmit signal. In this section, the channel is estimated by the least mean square error method. According to the MMSE estimation criterion, the cost function formula is [16]

$$J_{\mathrm{MMSE}} = E\left(\boldsymbol{H}_l - \hat{\boldsymbol{H}}_l\right)\left(\boldsymbol{H}_l - \hat{\boldsymbol{H}}_l\right)^{\mathrm{H}} \tag{4}$$

In Eq. (4), the partial derivation of $\hat{\mathbf{H}}_l$, when the function formula is zero, the MMSE estimation result is:

$$\hat{\boldsymbol{H}}_l^{\mathrm{MMSE}} = Y_l \left(\boldsymbol{\Psi}^{\mathrm{H}} R_{\boldsymbol{H}_l \boldsymbol{H}_l} \boldsymbol{\Psi} + \sum_{l \neq m}^{L} \boldsymbol{\Psi}^{\mathrm{H}} R_{\boldsymbol{H}_l \boldsymbol{H}_m} \boldsymbol{\Psi} + \delta_N^2 \boldsymbol{I}_\tau \right)^{-1} \boldsymbol{\Psi}^{\mathrm{H}} R_{\boldsymbol{H}_l \boldsymbol{H}_l} \tag{5}$$

In Eq. (5), $R_{\boldsymbol{H}_l\boldsymbol{H}_l}$ represents the autocorrelation coefficient of the channel, and $R_{\boldsymbol{H}_l\boldsymbol{H}_m}(l \neq m)$ represents the cross-correlation coefficient of the channel. During the uplink transmission, the receiver uses the matched filter to obtain the detected signal as:

$$\hat{Y}_l = \hat{\boldsymbol{H}}_l Y_l = \left(\boldsymbol{H}_l + \sum_{m \neq l}^{L} \boldsymbol{H}_m + \frac{\boldsymbol{N}_l \boldsymbol{\psi}^{\mathrm{H}}}{\tau}\right)\left(\sum_{l=1}^{L}\sum_{p=1}^{K} \boldsymbol{H}_{lmp}\boldsymbol{\psi}_{lp} + \boldsymbol{N}_l\right) \tag{6}$$

The resulting signal to interference ratio of the uplink is:

$$\mathrm{SINR}_u = \frac{M^2 \eta_{ll}^2 \delta_x^2}{M^2 \delta_x^2 \sum\limits_{m \neq l}^{L} \eta_{im}^2 + \delta_n^2 \left(M_{\eta_{ll}} + M \sum\limits_{m \neq l}^{L} \eta_{lm} + \frac{\delta_n^2}{\delta_\psi}\right)} \tag{7}$$

Because in the massive MIMO system, the number of base station antennas is large, to meet $M^2 \gg M$, so when the number of base station antenna M tends to infinity, the uplink SINR limit:

$$\lim_{M \to \infty} \mathrm{SINR}_u = \frac{\eta_{ll}^2}{\sum\limits_{m \neq l}^{L} \eta_{lm}^2} \tag{8}$$

In Eq. (8), η_{ll} represents large-scale fading in the cell, and η_{lm} represents the large-scale fading coefficient between the cells. It can be seen that the SINR of the channel will be mainly limited by the large-scale fading coefficient as the number M of the base station increases gradually.

3 Intelligent Assignment Pilot Sequence Scheme Based on User Area Location Priority

In the massive MIMO systems, large-scale fading coefficients can be constructed for the model [8]:

$$\eta_{lmp} = \frac{\zeta_{lmp}}{\left(r_{lmp}/R\right)^{\alpha}} \tag{9}$$

In the formula (9), ζ_{lmp} represents the shadow fading and satisfies the lognormal distribution, that is, $10\lg\left(\zeta_{lmp}\right) \sim C(0, \delta_{shadow})$ and r_{lmp} represent the geometric distance between the p-th user of the m-th cell and the base station of the l-th cell, R is the cell radius, α is path loss factor. In order to study the convenience of the problem, it is assumed that the massive MIMO system has 7 cells, each cell has 8 users, the intermediate cell is the target cell, and the communication is carried out under the visual condition. Taking the base station distance of the user in the cell into the intermediate cell as the constraint condition, the system signal to interference ratio is the objective function, and the optimal value of the objective function is solved.

$$f(r_{lmp}) \lim_{M\to\infty} \mathrm{SINR}_u,\ (r_{lmp} > 0)\ s.t.\ f(r_{lmp})_{\min} \tag{10}$$

In the Eq. (10), $\lim_{M\to\infty} \mathrm{SINR}_u$ indicates that the number of antennas configured in the target cell tends to be infinite when the number of antennas in the target cell approaches infinity, and $f(r_{lmp})_{\min}$ represents the channel poor area in the target cell. The existence and uniqueness of $(r_{lmp}, f(r_{lmp})_{\min})$ are proved below.

Proof: By the function expression $f(r_{lmp})$ know:

$$\begin{aligned} f(r_{lmp}) &= \lim_{M\to\infty} \mathrm{SINR}_u \\ &= \frac{\eta_{ll}^2}{\sum_{m\neq l}^{L} \eta_{lm}^2} = \frac{\sum_{m=1}^{L}\sum_{p=1}^{K}\left[\frac{\zeta_{lmp}}{(r_{lmp}/R)^3}\right]^2}{\sum_{m\neq l}^{L}\sum_{p=1}^{K}\left[\frac{\zeta_{lmp}}{(r_{lmp}/R)^3}\right]^2} = \frac{\sum_{p=1}^{7}\left[\frac{1}{(r_{llp}/R)^3}\right]^2}{\sum_{m\neq l}^{7}\sum_{p=1}^{8}\left[\frac{1}{(r_{llp}/R)^3}\right]^2} \\ &= \frac{\sum_{p=1}^{7} r_{llp}^{-6}}{\sum_{m\neq l}^{7}\sum_{p=1}^{7} r_{lmp}^{-6}} \geq 6 \end{aligned}$$

(If and only $r_{lmp} = R$ is the equation holds, and that the minimum value is unique). It can be seen that the interference ratio of the target cell and the interference cell in the overlapping area of the hexagonal circumscribed circle is the smallest, and the ratio of the signal to noise ratio is the smallest. As shown in Fig. 2.

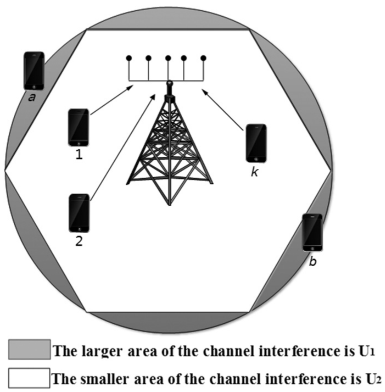

Fig. 2. Smart pilot assignment scheme in massive MIMO systems based on priority of user location

In the round, the user in the shaded area, such as user a, user b, the interference is relatively serious, because in this overlapping area, the user is far from the target cell base station, the user to the base station pilot signal fading more serious, but, The user of this area is relatively close to the neighboring cell base station, the pilot signal between users is not orthogonal, the base station can not obtain the channel state information accurately, resulting in more serious interference, seriously affecting the communication performance.

Assume that U_1 is the shaded area in the cell and U_2 is the hexagonal region in the cell. Based on the principle of user priority allocation, the U_1 precedence is higher than U_2, and the orthogonal pilot sequence is preferentially assigned to the U_1 area user.

In order to obtain the maximum signal-to-noise ratio in the shaded area where the interference is more severe, the pilot signals are arranged in descending order: $\boldsymbol{\Psi}_{\mathrm{D}}^{\mathrm{DOWN}} = [\boldsymbol{\psi}_1, \boldsymbol{\psi}_2, \cdots, \boldsymbol{\psi}_k]$, satisfying $\boldsymbol{\psi}_1 \geq \boldsymbol{\psi}_2 \geq \cdots \geq \boldsymbol{\psi}_k \geq 0$. Also in accordance with the quality of the channel will be the user in ascending order: $\mathrm{U}_1^{\mathrm{UP}} = [u_1, u_2, \cdots, u_k]$, to meet $0 \leq u_1 \leq \cdots \leq u_{k-1} \leq u_k$. The users $u_l (l = 1, 2, 3, \cdots, k)$ and $u_m (m = a, b, \cdots, k')$ (where $u_m \in \mathrm{U}_1, u_l \in \mathrm{U}_2$) in the target cell are defined by the distance between the user and the base station in the target cell, respectively,

$$u_l = r_{llp}, p = 1, 2, 3, \cdots, k \tag{11}$$

$$u_m = r_{llp'}, p' = a, b, \cdots, k' \tag{12}$$

Under the above conditions, Fig. 2 shows a scheme for intelligently assigning pilot sequences based on user region priorities. Assuming that the base station is aware of the large-scale fading coefficient of each user, the base station can locate the user's position through the large-scale fading coefficient, using the Eq. (9), where the relationship between the large-scale fading coefficient and the distance satisfies $\eta_{lmp} \rightarrow r_{lmp}^{-\alpha}$. By comparing the distance between the user and the base station, the cell users are divided into U_1 and U_2. After the classification of the community users, and then consider the community user pilot classification problem. The user allocates the pilot sequence intelligently within the $\sqrt{3}R/2 \leq r \leq R$ range, and the remaining users in the cell randomly allocate the remaining pilot sequences. Define the random variable $N = U_1$ the number of regional users, use the allocation algorithm proposed in this paper to calculate the value of N, the convergence condition is that each user assigned to the respective pilot sequence, if the number of users within U_1 is N_1, the target cell The first N_1 pilot signals arranged in descending order of the pilot signal strength are sequentially assigned to the first N_1 subscribers arranged in ascending order of the channel quality, and the area U_2 with better channel quality is randomly assigned to the remaining user. The specific allocation scheme is shown in the table.

Input: Pilot sequence: $\psi_1, \psi_2, \cdots, \psi_k$, $k = 1, 2, \cdots, K$

(1) Pilot assignments to users of the target cell

for k=1:K

if $|d| \in \{\sqrt{3}/2R, \mathrm{R}\}$

$\mathrm{U} \in \mathrm{U}_1$

else

$\mathrm{U} \in \mathrm{U}_2$

end

end

(2) U_1 area users in ascending order of interference intensity, $\mathrm{U}_1^{\mathrm{up}} : [u_{11}, u_{12}, \cdots, u_{1K}]$

U_2 area users are randomly arranged: $[u_{21}, u_{22}, \cdots, u_{2K}]$

(3) U_1 area user pilot assignment

for k=1:N

ψ_k : $\psi_i \to u_{1i} (i = 1, 2, \cdots, K)$

end

U_2 area user pilot assignment

for k=N+1:K

ψ_k : $\psi_i \to u_{2j} (i = j 或 i \neq j . i, j = 1, 2, \cdots, K)$

end

Output: Interference cell user pilot ψ_k , $k = 1, 2, \cdots, K$

4 Experimental Simulation and Result Analysis

This section uses the Monte Carlo method to simulate the scheme of assigning the pilot sequence based on the user region priority. Simulation conditions: L is a hexagonal cell composed of cellular communication network. Each cell consists of a base station and K single antenna users that are located at the center of the M antenna. Surrounded by other communities in the middle of this area for the analysis of communication performance of the target cell [4, 16]. The number of cells is L, The cell radius is R, the number of antennas configured at the base station side of the cell is M, the number of users in each district is K, the path loss factor is α, the logarithmic shadow fades is δ_{shadow}, the critical distance value is $\sqrt{3}/2R \leq r \leq R$, the pilot sequence length is τ. The channel model is quasi-static Rayleigh fading channel, the system parameters in Table 1.

Table 1. System simulation parameters

L	R	M	K	α	δ_{shadow}	r	τ
7	500	$40 \leq M \leq 500$	8	3	8 dB	$\sqrt{3}/2R \leq r \leq R$	16

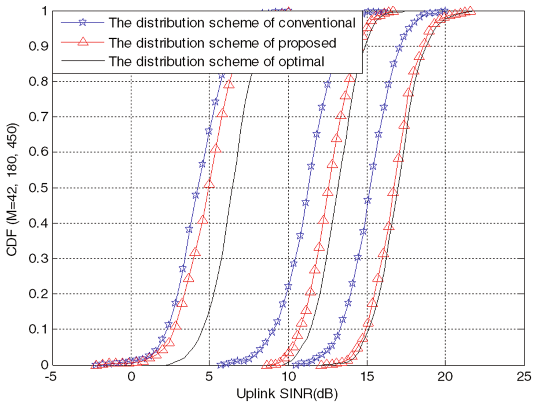

Fig. 3. CDF vs. SINR in uplink training

Figure 3 is the simulation of the probability of the uplink signal to noise ratio. It can be seen from Fig. 3 that the increase in the number of base station antennas can effectively improve the upstream SINR of the system. When the number of base station antennas is M = 42, the priority scheme is improved by about 0.5 dB and the optimal pilot scheme is about 2 dB higher than the traditional pilot scheme. This is because the number of antennas in the area is less and the number of dynamic users in the region is less. In the shadow area of Fig. 2, the interference of the channel area is less, and the antenna at the base station can better estimate the channel state information. However, as the number of base station end days increases, such as M = 180, and the exponential growth of dynamic users, the channel interference in the shaded area in Fig. 2 is large, and the pilot information received by the base station is not only from the target cell There are nearby users in the neighborhood.

In the traditional MIMO, because the number of antennas is low and the spatial reuse rate is low, the beamforming is not concentrated, so it can not accurately judge whether the pilot signal is sent by the local user or other cell users. However, the base station uses large-scale MIMO technology, Although it can reduce the interference of the pilot information within the cell, but the inter-cell pilot interference still exists [11], the traditional pilot allocation scheme, without taking into account the regional area of the user channel quality of the actual situation, the district users priority Level equal treatment, so the system letter to noise ratio to enhance the effect is not obvious. In this paper, we fully consider the above problems, so the proposed algorithm is verified by mathematical analysis and simulation: the system uplink signal to interference and noise ratio of traditional pilot distribution scheme has improved significantly, about the optimal pilot distribution scheme on the basis of 0.5 dB of the gain. When the number of antennas continues to increase, such as $M = 450$, the proposed frequency distribution algorithm and the optimal pilot distribution algorithm curve almost coincide, better reflects the superiority of the proposed algorithm.

Figure 4 is a simulation of the number of base station antennas and the user spectrum efficiency curve. As can be seen from the figure, whether the traditional pilot scheme or the user priority intelligent pilot distribution scheme, the increase in the number of antennas in the base station side of the cell will increase the efficiency of single-user spectrum, and it can be seen that when the number of base station antennas The rate of growth of single-user spectrum efficiency is less than the growth rate of base station-side antennas. This is because the number of antennas is small, the number of antennas is limited to the user spectrum efficiency growth bottleneck, but when the number of antennas is high, the pilot pollution is limited to the user spectrum efficiency growth bottleneck.

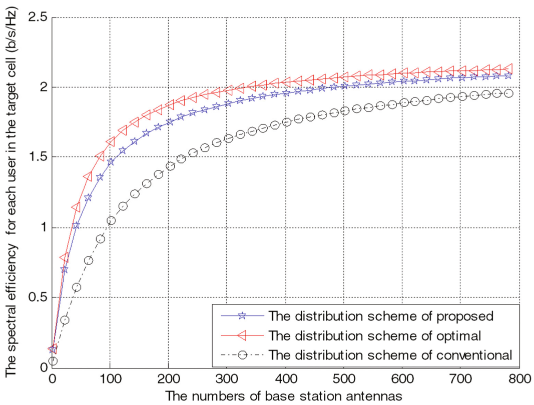

Fig. 4. Spectrum efficiency vs. the numbers of base station antennas

The traditional pilot allocation scheme has not limited the interference of the actual signal, the spectrum efficiency is limited and quickly reached the saturation, which seriously affected the system throughput. In this paper, the algorithm is proposed to improve the orthogonality of the user's pilot signal by taking into account the actual reality of the adjacent cell pilot pollution and the actual interference of the users in different areas of the cell, and then classifying the users according to the cell area priority. Single-user spectrum efficiency is significantly improved. It can be seen from the figure that when the number of base station antennas is M = 128, the proposed pilot frequency allocation algorithm is the most obvious, about 0.5bps/Hz, and the number of days continues to increase. The spectral efficiency variation curve of the algorithm is close to the optimal pilot distribution algorithm curve.

As can be seen from the above analysis, the class I cell user U_1 (shadow area) intelligently assigns the pilot sequence based on the user region priority, and the class II cell user U_2 (non-shaded area) randomly assigns the pilot sequence. The results of MATLAB software show that the proposed scheme can effectively improve the uplink

SINR of the system and the single-user spectrum efficiency in the case of $\sqrt{3}R/2 \leq r \leq R$ (R is the radius of the cell), also significantly improved, further confirming the accuracy of theoretical analysis.

5 Conclusion

In this paper, a pilot sequence scheduling method for mitigating pilot pollution of large-scale MIMO systems is proposed based on the scheme of intelligent allocation of pilot sequences based on user region priority. Under the premise of satisfying the normal communication of each user in the cell, the distance between the user and the base station is the constraint condition, the system signal to interference ratio is the objective function, and the corresponding mathematical model is established to deduce the adjacent distance of the channel quality. In this way, the cell is divided into two types according to the channel quality, the channel quality is better allocated to the pilot sequence, the channel quality is poorly distributed in the region, and the communication between the neighboring cells is reduced. The proposed frequency sequence scheduling scheme can effectively improve the system capacity and single-user spectrum efficiency under the condition of satisfying the quality of service of the user, and reduce the influence of pilot pollution on the communication performance of large-scale MIMO system.

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