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Research Article

Study on Cooperative Multipoint Communication Precoding Algorithm under SLNR-MMSE Framework

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With the rapid growth of demand for wireless data services and the continuous introduction of new air interface technologies, mobile communication systems continue to face new challenges in supporting high-speed multimedia service transmission and achieving seamless coverage. In order to meet the requirements of the IMS system in terms of bandwidth, peak rate, communication throughput, etc., multiantenna enhancement technology and cooperative multipoint transmission technology have become research hotspots as key technologies. In the study of multiuser system, this paper focuses on the precoding technology based on noncode book, based on the minimum mean square error criterion and the maximum letter leakage noise ratio criterion, studies the precoding technology of different multiuser systems, expounds the collaborative multipoint transmission system, and makes a basic classification. The signal leakage-to-noise ratio precoding algorithm and the minimum mean square error precoding algorithm are analyzed in detail. In view of the shortcomings of these two algorithms, this paper takes the minimum sum of the total mean square error of the system as the optimization goal of the combinations of precoding and power allocation. The precoding algorithm of SLNR-MMSE is proposed. The simulation analysis shows that the proposed algorithm has certain advantages over other algorithms in terms of bit error rate and system capacity. It shows that this study is important for optimizing collaborative multipoint communication system.

1. Introduction

Faced with the rapidly growing demand for wireless data services and the increasingly advanced air interface technology, mobile communication systems continue to accept new challenges in supporting high-speed multimedia service transmission and achieving seamless coverage, as shown in Table 1 [1]. According to the table, the IPv6 of the mobile communication system has the highest growth rate of 75.3%, followed by international exports of broadband, with a growth rate of 22.2%. In order to meet the needs of global mobile communication in the next ten to fifteen years, the International Telecommunication Union has launched the IMT-Advanced International Mobile Communication Enhancement System, hereinafter referred to as the IMT-A project. The IMT-A system is specifically defined as a mobile communication system with capabilities exceeding IMT-2000, capable of providing advanced and extensive telecommunication services based on packet transmission including mobile and fixed network support [2]. The IMT-A system has the following important characteristics: on the basis of maintaining cost efficiency and supporting a wide range of flexible services and applications, it can achieve a high degree of universality worldwide; it has the ability to support mobile services and fixed network services; it can provide higher quality mobile services; its terminals have global applicability; it can provide friendly applications, services, and devices; it can support worldwide roaming capabilities and provide enhanced peak rates and high-quality transmission to meet new business and application requirements.

In the IMT-A system, the most mainstream mobile communication system is the LTE-Advanced system. The introduction of coordinated multipoint (CoMP, coordinated multipoint) communication technology in the LTE-Advanced system can reduce intercell interference and improve

Table 1: Comparison of basic Internet resources in 2017.12–2018.12

	2017.12	2018.12	Annual growth	Nian growth rate (%)
IPV4 (individual)	338,704,640	338,924,544	219,904	0.1
IPV6 (indivual)	23,430	41,079	17,649	75.3
Domain name (indivual)	38,480,355	37,927,527	−552,828	−1.4
.CN domain (indivual)	20,845,355	21,243,478	397,965	1.9
International egress bandwidth	7,320,180	8,946,570	1,626,390	22.2

system capacity, and precoding technology, as the key technology of CoMP, can suppress interference between users [3]. Its basic idea is that it uses the channel state information (CSI) that has been obtained at the transmitting end to obtain the corresponding precoding matrix and then uses this matrix to preprocess the transmitted signal, so as to reduce the system bit error rate and improve the system capacity, that is, the goal, [4]. At present, the precoding algorithms widely studied mainly include linear precoding algorithms and nonlinear precoding algorithms. Due to the poor real-time performance and extremely high complexity of nonlinear precoding algorithms, it is difficult to apply to practical systems [5]. Commonly used linear precoding algorithms mainly include zero forcing (ZF) precoding algorithm, minimum mean square error (MMSE) precoding algorithm, block diagonalization (BD) precoding algorithm, and signal-to-leakage and noise ratio (SLNR).

Among them, the ZF algorithm can eliminate the interference within the user itself but does not consider the influence of noise, which makes the performance of the ZF algorithm poor [6]. The MMSE algorithm considers the influence of noise based on ZF but cannot eliminate the interference between users, which makes the MMSE algorithm not the most ideal precoding algorithm. Although the SLNR algorithm can eliminate the noise and the interference between users to the greatest extent, it cannot eliminate the interference within the user itself [7]. Although the SLNR-ZF algorithm proposed by some scholars can eliminate all interference and improve the performance of the system, the introduction of the ZF algorithm will amplify the channel noise, making the system's antinoise interference ability extremely poor [8].

Based on the characteristics of MMSE algorithm and $SMLSR$ precoding algorithm, we propose SLNR-MMSE precoding algorithm, conduct simulation experiments on MMSE algorithm, SLNR precoding algorithm, and SLNR-MMSE precoding algorithm, and analyze different algorithms.

2. State of the Art

2.1. Basic Concepts of Cooperative Multipoint Transmission Technology. As people continue to put forward demands for faster transmission quality, higher transmission quality, and more communication services, the limitation of resources such as frequency and power has increasingly become a bottleneck restricting the development of communication and meeting business needs [9]. Fading and interference are two major challenges faced by researchers in wireless communication systems. Affected by fading, the coverage and reliability of point-to-point wireless transmission are limited [10]. In order to meet the requirements of LTE-Advanced systems, the peak data rate can be increased by increasing the number of component carriers (CCS) and adding transmit or receive antennas in MIMO multiplexing [11]. In the LTER8 release, intercell orthogonal frequency allocation has been confirmed as one of the key enhancement techniques. Scholars and the industry are actively researching its application in CoMP transmission and reception, as well as in 3GPP-related LTE-Advanced systems for multiantenna implementation at the base station and the user end [12]. Cooperative multipoint transmission technology helps improve cell edge user throughput.

2.1.1. Definition and Research Significance of CoMP. Collaborative multipoint CoMP transmission refers to multiple transmission points geographically separated, jointly participating in data transmission of a terminal or jointly receiving data sent by one terminal. The multiple transmission points involved in cooperation usually refer to base stations of different communities. In order to meet the requirements of LTE-A system, the use of coordinated multipoint transmission/reception can enhance the cell edge performance and increase the area that provides high-speed data coverage [13]. There are many ways to cooperate, and CoMP technology can be applied in the following scenarios: cooperation between sectors within a cell to serve users at the edge of the sector; cooperation between cells to provide services for users at the edge of the cell; multiple radio frequency modules (RFRadio Frequency) centralized signal processing; base station and relay node cooperation; eNB (macro base station) and home-eNB (home base station) cooperation [14]. It can be seen that the CoMP technology can be used to operate between different base stations in different cells, or between multiple transmission points in the same cell [15]. Compared with the case of no cooperation, the cell edge users can get better services at this time, so that the throughput of the cell edge users can be improved, thereby improving the performance of the whole system. Table 2 compares the specific characteristics of different types of antenna systems [16].

Also, in uplink transmission, multiple cells can perform joint reception and combine the signals during processing at the receiving end [17]. The coordinated scheduling method can also be used by multiple cells to suppress intercell interference, thereby achieving the effect of improving the signal-to-noise ratio of the received signal. Among them, the signal-to-noise ratio refers to the ratio of the power of the transmitted signal and the power of the noise involved in the

Table 2: Analysis of the characteristics of different types of antenna systems.

Antenna system type	Antenna system features	Test method	Whether to support conduction test	Test challenge
RRU + Antenna	(1) The antenna and the RRU are separated from each other, and the antenna is independent of the RRU and the antenna (2) RF performance requirements are determined at the base station antenna port Definition, conducted RF testing through standard interfaces: 3. The effect of the antenna on RF performance is not considered 4. Antenna, as a network supporting equipment, mainly examines the pattern and circuit performance.	Independent testing of RRU and antenna	Yes	Mature base station type, mature test technology, no challenges.
Integrated active antenna	(1) The antenna is integrated with the RRU, and the nonstandard interface is connected. The antenna design needs to be synchronized with the RF module design: (2) There are few antenna ports, RF performance requirements can be defined in the antenna port, and the test is more complicated; (3) Conduction test of main indicators, adding some OTA tests	Integrated testing and split testing	Yes, the interface is not standard	(1) The conduction test interface is nonstandard, and the RRU RF index cannot reflect the integrated active antenna (2) Some parts require OTA testing, and the testing standards need to be further clarified.
Massive MI MO antenna	(1) The antenna and the base station are deeply integrated, and there are challenges in the independent testing of traditional components; (2) Large-scale antennas and RF channels; (3) 3GPP proposes RF indicator OTA test standard	Whole machine testing becomes mainstream	Depends on machine design	The mainstream design of the whole machine will be difficult to disassemble, there is no external RF interface, and it needs to rely on a large number of OTA tests and test standards. Is under discussion.

process of propagating the signal; that is to say, the greater the signal-to-noise ratio, the stronger the ability to suppress the noise, and the clearer the sound. "CoMP system model" is shown in Figure 1. It is assumed that the downlink CoMP system consists of M base stations (BS, base station) and N users (UE, user), and each base station has NR transmit antennas, and each user has NR root receive antenna, thereby forming a virtual MIMO system of (Mn, xNnp).

2.1.2. Classification of CoMP Systems. From the perspective of the relationship between the nodes that coordinate, CoMP can be divided into Intrasite CoMP and Intersite CoMP. Intrasite CoMP refers to collaboration taking place within a site. At this time, since it is not restricted by the backhaul capacity, a large amount of information exchange can be performed between multiple cells or sectors of the same site. Intersite CoMP, on the other hand, has more requirements on backhaul capacity and delay, because, in this mode, cooperation occurs between multiple sites without identifying the end point. It combines transmission gain and network throughput with higher spectrum utilization [18].

Considering the uplink and downlink of the communication link, CoMP technology can be divided into two categories: uplink multipoint reception and downlink multipoint transmission [19]. Different types of coordination techniques are used in uplink reception, namely, uplink multipoint reception, including coordinated scheduling and beamforming functions. In uplink reception, generally, the user terminal only needs to know the signaling related to the uplink received signal and how it is provided but does not need to know the specific processing procedure of the base station for the signal volume. For uplink multipoint, receiving more consideration means how to process and implement the problem at the base station. Since the processing capability of the base station side is relatively strong, the processing capability of the terminal is limited [20]. How to design the transmission scheme and reduce the processing pressure of the terminal is more important. The industry pays more attention to the related technical research of downlink multipoint transmission.

2.2. Joint Transmission Technology (JT). In the CoMP communication system, a user terminal can establish communication links with multiple cells. When the joint transmission technology is adopted, the cooperating base

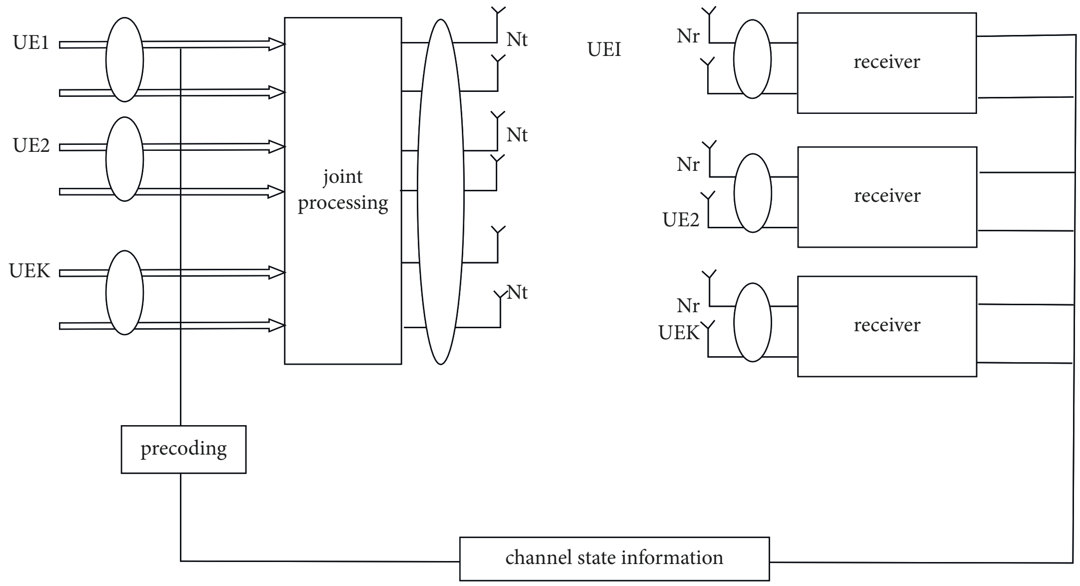

FIGURE 1: CoMP system model.

stations in the CoMP cooperating cluster share the user's data information and simultaneously send a signal carrying the data information to the same user. The joint transmission technology in CoMP can be divided into single-user (SU_CoMP) scenarios and multiuser (MU-CoMP) scenarios. Here, a single-user scenario is used to analyze the basic system model of the joint transmission technology. Assuming that there are T base stations and K users in a multicell system, the system adopts OFDM technology, and the frequency reuse factor is 1. The principle of OFDM technology is to divide the channel into several orthogonal subchannels and convert high-speed data signals into parallel low-speed sub-data streams, modulated to transmission on each subchannel. Each base station is equipped with M transmitting antennas, and each user terminal is equipped with M receiving antennas. The downlink received signal of the kth user is recorded as

$$y_k = \sum_{i=1}^{T} H_{ik} S_{ik} + \sum_{i=1}^{T} \sum_{j \neq k}^{k} H_{ik} S_{ij} + n_k, \tag{1}$$

where H represents the channel matrix between the ith base station and the kth user. M, x_1-dimensional signal sent by the ith base station to the kth user. n represents additive white Gaussian noise with probability density distribution function CN(0, σ_2).

Figure 2 presents a conceptual block diagram of a downlink CoMP system. In this communication system, the user can also be "seen" by the base station by using a channel state information feedback mechanism. In the figure, the white cloud represents information sharing and interaction between CoMP cells. The three cells use joint transmission mode (JT) to transmit information to the user terminal. The three cells adopt their own precoding schemes, which are represented by arrows of three different colors in the figure.

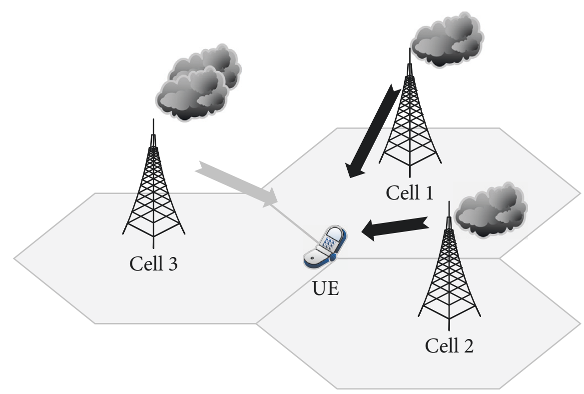

FIGURE 2: Schematic diagram of DL CoMP joint transmission technology system.

3. Technologies

3.1. MMSE Precoding Algorithm. The channel inversion precoding technique based on the minimum mean square error criterion (MMSE) is the same as the channel inversion precoding technique based on the zero-forcing criterion and is suitable for a receiver with one antenna case. Considering the influence of noise on signal transmission, MMSE-CI precoding makes a tradeoff between user cochannel interference and noise influence, but its performance is still not very ideal. The precoding technology based on the Signal to Leakage and Noise Ratio (SLNR) criterion will maximize the SLNR of each user as the optimization goal, eliminating the need to use the Signal to Interference and Noise Ratio (SINR) as the optimization goal. Noise Ratio is a difficult coupling problem, and the generalized Rayleigh quotient is used to obtain the user's precoding matrix. Better system performance is obtained without being affected by the number of transmit and receive antennas. The minimum mean square error precoding matrix W_{MMSE} is

$$W_{\mathrm{MMSE}} = FH^H\left(HH^H + \beta I\right) - 1$$
$$= FH^H\left(HH^H + \frac{\sigma^2}{E_0}I\right)^{-1},$$
$$F = \mathrm{diag}\left(f_1, f_2, \ldots, f_k, \ldots, f_{Nn_R}\right), \tag{2}$$
$$f_k = \sqrt{\frac{n_R}{\left[\left(HH^H\right) - 1\right]_{k,k}}}, \quad 1 \le k \le N_{n_R}.$$

The role of F is to ensure the standardization of transmit power, H is the channel matrix, the introduction of the normalization factor β can eliminate the interference of noise, σ_2 is the noise power, E is the signal power, and I is the identity matrix.

3.2. SLNR Precoding Algorithm. In the traditional SLNR precoding scheme, the precoding vector is obtained based on the premise that the transmitter performs equal power allocation for each user data. But in an actual communication system, the channel state of each user is different and time-varying. Therefore, allocating power according to the channel states of different users can improve system performance. At present, the existing research is divided into the purpose of improving the transmission efficiency Targeted power allocation schemes and schemes aimed at improving transmission reliability. Among them, the schemes of power allocation based on the SINR value of each antenna and power allocation based on the SINR value of each user improve the data transmission rate of the system. The power allocation iterative algorithm for maximizing the system capacity takes the system capacity as the optimization goal and realizes the maximization of the system capacity through the iterative process. In the power ratio allocation algorithm to improve the reliability of communication transmission, the system bit error rate (BER) can be reduced by using the trace of the channel matrix as an indication to perform power allocation and performing power allocation based on the per-user SLNRI value. The two power allocation algorithms have obvious BER performance improvement under high signal-to-noise ratio, but the performance improvement is not obvious at low signal-to-noise ratio, even lower than the traditional equal power allocation scheme. Table 3 contains the SNR/SINR expressions of the basic precoding techniques under massive MIMO.

SLNR is the ratio of the signal power received by the target user to the leakage power and noise power of the target user. Signal-to-interference-plus-noise ratio (SINR) can be used to characterize the transmission quality of a signal in a communication link. The SINR signal-to-noise ratio at the receiver of the kth user is

$$\mathrm{SLNR}_k = \frac{\left\|H_k W_k\right\|^2}{\sum_{i=1, i\neq k}^{N}\left\|H_i W_k\right\|^2 + n_R\sigma_k^2}$$
$$= \frac{\left\|H_k W_k\right\|^2}{\left\|\overline{H_k} W_k\right\|^2 + n_R\sigma_k^2}. \tag{3}$$

Table 3: SNR/SINR expressions of basic precoding techniques under massive MIMO.

Precoding	Perfect CSI	Imperfect CSI
IF system	$\rho\alpha$	
ZF precoding	$\rho(\alpha - 1)$	$(\zeta^2\rho(\alpha-1)/(1-\zeta^2)\rho + 1)$
MF precoding	$(\rho\alpha/\rho + 1)$	$(\zeta^2\rho\alpha/\rho + 1)$

Note. M, $K->M/K=a$, CSI: Downlink Channel State Information SINR: Signal to Interference and Noise Ratio, IF: Interference Free System SNR: Signal to Noise Ratio, MF: matched filter ZF: zero forcing.

The channel matrix $\overline{H_k}$ for all users except the hth user can be expressed as

$$\overline{H_k} = \left[H_1^H, \ldots, H_{k-1}^H, H_{k+1}^H, \ldots, H_N^H\right]^H, \tag{4}$$

where $\|H_k W_k\|^2$ is the signal power of the hth user, $\|\overline{H_k} W_k\|^2$ is the leakage power of the kth user leaked to all other users, and $nR\sigma_2$ is the noise power received by the kth user.

When using SINR as an optimization criterion, a precoding matrix needs to be designed to maximize the SINR of each user. It can be seen from (3) that the SINR of user i is related to the precoding matrices of all other users; that is, the precoding matrices of each user are coupled to each other in each other's SINR expressions, which brings difficulties to solving the precoding matrix. Scholars such as Mirette Sadek proposed a precoding algorithm based on signal leakage plus noise ratio. Table 4 analyzes the performance comparison of the integrated system under different powers.

The SLNR expression of user i is

$$\mathrm{SLNR}_i = \frac{E\left(\left\|H_i W_i S_i\right\|^2\right)}{Ni\sigma 2 + E\left(\sum_{k=1, k\neq i}^{k}\left\|H_k W_i S_i\right\|^2\right)}$$
$$= \frac{\left\|H_i W_i\right\|^2}{N_i\sigma^2 + \sum_{k=1, k\neq i}^{k}\left\|H_k W_i\right\|^2}. \tag{5}$$

It can be seen from (5) that the SLNR expression of user i does not have the coupling problem of precoding matrices between users. When designing precoding with the goal of maximizing the SLNR of user i, if the channel information of user i is known at the transmitter, the precoding matrix for each user can be directly designed. The problem of maximizing the SLNR of the ith user can be expressed as

$$W_i^o = \arg\max_{W_i \in C^{Nt\times 1}} \frac{\left\|H_i W_i\right\|^2}{N_i\sigma^2 + \sum_{k=1, k\neq i}^{k}\left\|H_k W_i\right\|^2}. \tag{6}$$

Among them, W_i^o represents the optimal precoding matrix of user i under this criterion.

3.3. SLNR-MMSE Precoding Algorithm. Although the SLNR precoding algorithm can eliminate noise and other users' interference to the greatest extent, it cannot eliminate the user's own internal interference. The MMSE precoding algorithm can remove the interference within the user itself.

Table 4: Comparison of integrated system performance under different powers.

Total power (w)		60	70	80	90	100	160
Channel capacity (10^6/bit)	Adaptive power	9.2827	9.2893	9.4966	9.5781	9.6685	9.7671
	Equal power	9.1101	92373	9.3462	9.4294	9.4937	9.5542
Radar mutual Information (10^2/bit)	Adaptive power	1.0849	1.1311	1.1783	1.2166	1.2553	1.2958
	Equal power	0.9873	1.0408	1.0843	1.1152	1.1407	1.1636

The MMSE precoding algorithm is introduced into the SLNR precoding algorithm, and an improved SLNR-MMSE algorithm is proposed, which can theoretically eliminate the interference and noise between users and within users themselves. From (3), it can be known that the signal leakage-to-noise ratio precoding matrix of all users is

$$W_{\mathrm{SLNR}} = [W_{\mathrm{SLNR-1}}, W_{\mathrm{SLNR-2}}, \ldots, W_{\mathrm{SLNR-}N}]. \tag{7}$$

Step 1. Firstly, the multiuser CoMP channel matrix composed of N users is decomposed, and the decomposed channel is N mutually independent and parallel single-user CoMP user matrix H2 $(1 < h \leq N)$.

Step 2. Multiply the above-mentioned N independent user matrices H with the corresponding SLNR precoding matrix $W_{\mathrm{sLNR\text{-}k}}$ to obtain the corresponding equivalent channel matrix $H_{\mathrm{sLNR\text{-}k}}$, and the calculation formula of the matrix is as follows:

$$H_{\mathrm{SLNR-}k} = H_k \times W_{\mathrm{SLNR-}k}, \quad 1 \leq k \leq N. \tag{8}$$

Step 3. Perform MMSE precoding on N equivalent channel matrices $H_{\mathrm{sENR\text{-}k}}$, respectively, to obtain a new precoding matrix $W_{\mathrm{MMSE\text{-}k}}$ as

$$\begin{aligned} W_{\mathrm{MMSE-}k} &= F_k H^H_{\mathrm{SLNR-}k}\left(H_{\mathrm{SLNR-k}} H^H_{\mathrm{SLNR-}k} + \frac{\sigma^2}{E_0} I\right) - 1, \\ F_k &= \mathrm{diag}\left(f_1, f_2, \ldots, f_\alpha, \ldots, f_{Nn_R}\right), \\ f_\alpha &= \sqrt{\frac{n_R}{\left[\left(W_k W_k^H\right) - 1\right]_{\alpha,\alpha}}}, \quad 1 \leq \alpha \leq N_{n_R}. \end{aligned} \tag{9}$$

The function of F_k is to ensure the standardization of the transmit power.

Step 4. Multiply $W_{\mathrm{SLNR\text{-}K}}$ with the original SLNR precoding matrix to WSLNR-MMSE-K, so the required SLNR-MMSE precoding matrix WSLNR + MMSE is

$$\begin{aligned} W_{\mathrm{SLNR-MMSE-}k} &= W_{\mathrm{SLNR-}k} \times W_{\mathrm{MMSE-}k}, \\ W_{\mathrm{SLNR-MMSE}} &= [W_{\mathrm{SLNR-MMSE-1}}, \ldots, \\ &\quad W_{\mathrm{SLNR-MMSE-}k}, \ldots, W_{\mathrm{SLNR-MMSE-}N}]. \end{aligned} \tag{10}$$

It can be seen from the above that combining the SLNR and MMSE algorithms can effectively eliminate the interference and noise between users and within the users themselves, reduce the bit error rate of the system, and improve the system capacity.

4. Experimental Results and Analysis

Taking improving the reliability of communication transmission as the starting point, it is intended to reduce the bit error rate (BER) of the system. Because the total mean square error (MSE) of the system can reflect the bit error rate performance of the system. Based on the MMSE criterion, this paper proposes an iterative optimal algorithm (OPA) and a suboptimal algorithm (SPA) that combine SLNR precoding and power allocation with the goal of minimizing the total MSE of the system. The algorithm is suitable for the scenario of single base station and multiple users and the scenario of joint transmission by multiple base stations.

4.1. Model Construction

4.1.1. Scenario of a Single Base Station with Multiple Users. In a single base station multiuser scenario, the base station communicates with K users simultaneously. Cochannel interference exists between individual users. As shown in Figure 3, the base station has N_t transmitting antennas, and the user end has N_i $(i = 1, \ldots, K)$ receiving antennas. The data sent by the base station to each user is a single stream. s_k represents the data sent by the base station to the kth user, and s_k is a scalar. p_k represents the power factor assigned by the base station to the kth user. At first, it is multiplied by the power allocation factor P:, and then the base station performs AND coding operation on the different user data after the power allocation. w_k represents the precoding matrix of the kth user, and its dimension is $N_t \times 1$. each.

The signal after the user's precoding operation is transmitted through the N_t antennas at the base station. This paper assumes that the channel experienced by the multiuser MIMO system is a Rayleigh fading channel. H_k represents the channel from the base station to the kth user, which is a $N_t \times N_k$ dimensional matrix. At the user end, a $1 \times N_t$-dimensional decoding matrix M_k is used to restore the original signal.

4.1.2. CoMP JP Scenario. In the joint transmission mode of the coordinated multipoint transmission system (CoMP), the coordinated base stations can cooperate through the central control unit. At this time, the central control unit performs joint precoding and cooperates with the base station to perform joint processing and joint transmission on the served users. At the user end, several cooperating base stations can be considered as a whole. This scenario and the

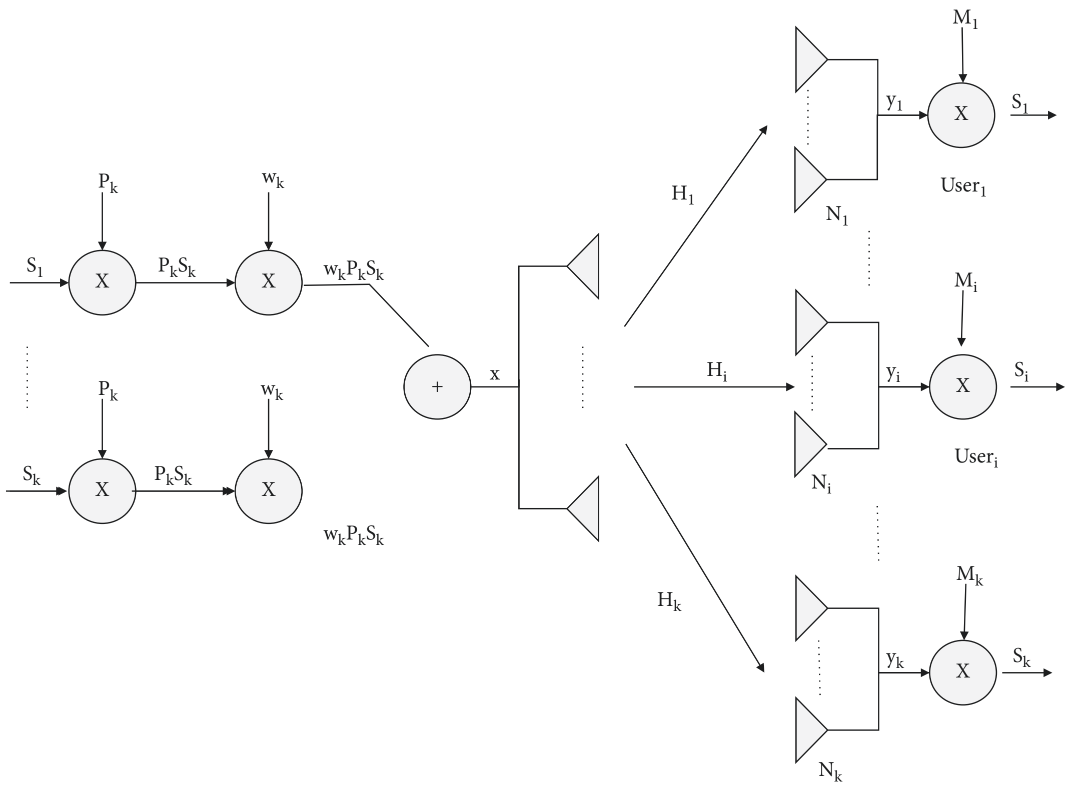

Figure 3: Multiuser MIMO system model diagram (including power allocation, precoding, and decoding process).

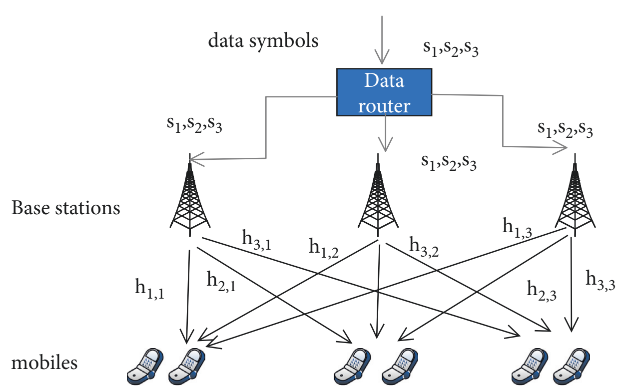

Figure 4: Schematic diagram of CoMPJP scenario.

Table 5: Simulation parameter table.

Simulation vegetables	Numerical value	Simulation parameters	Numerical value
Number of cells	3	Base station transmit power	1 w
Number of transmit antennas per base station	3	Average signal-to-noise ratio	0–30 dB
User number	3	Channel model	Flat Rayleigh
Number of receiving antennas per user	2	Modulation	QPSK

scenario analyzed in the previous subsection can be reduced to the same pattern. Taking the coordinated transmission of three base stations for three users at the same time as an example, the system block diagram is shown in Figure 4.

In the JP scenario of the coordinated multipoint system, it is assumed that there are B coordinated base stations in total, and each base station is configured with N_t transmit antennas. The number of users that the base station cooperatively serves is K. The user end has N_i $(i = 1, 2, \ldots, K)$ receiving antennas. s_k represents the single-stream data sent by the cooperating base station to the kth user and is a scalar. p_{bk}^2 represents the power allocated by the bth base station to

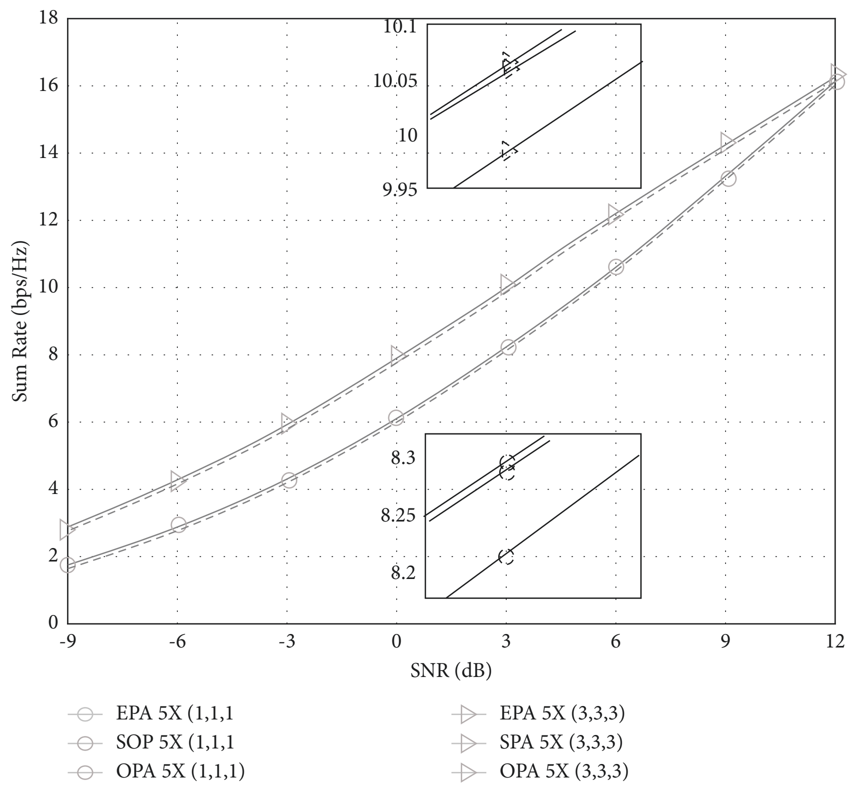

FIGURE 5: Total and partial transfer rates of EPA, SPA, and OPA under 5X (3, 3, 3) and 5 x (1, 1, 1) system configurations.

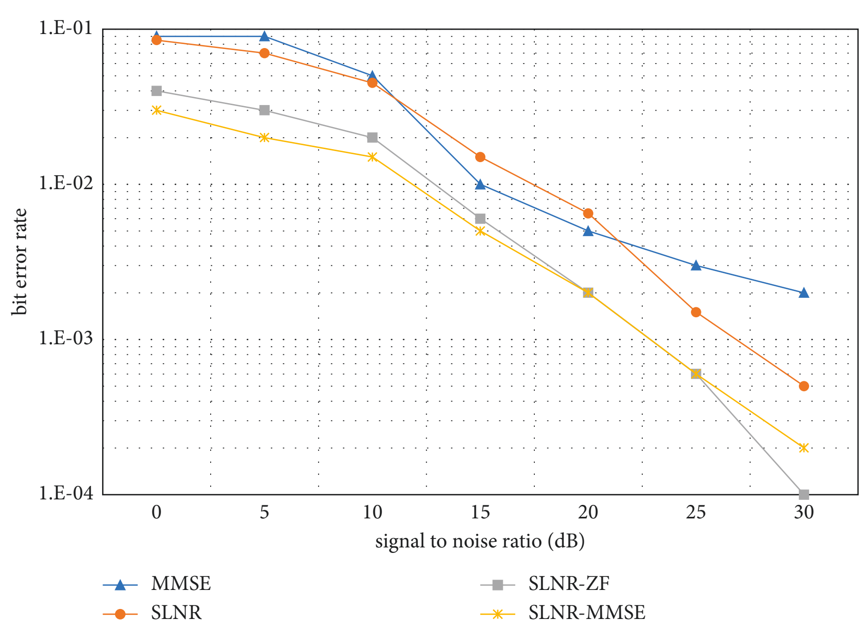

FIGURE 6: Bit error rate before and after the improvement of the SLNR precoding algorithm when the antenna configuration is 3×2.

the kth user data. P_{bk} is the power allocation factor of the bth base station for the kth user data. For the bth base station, s_k is first multiplied by the power allocation factor P_{bk}, and then the postscaled user data is subjected to a precoding matrix. W_{bk} represents the precoding matrix of the bth base station for the kth user, and its dimension is $N_t \times 1$. The signals after each base station precoding operation for each serving user are transmitted through N_t antennas at the base station. H_{bk} represents the channel from the base station to the kth user, which is an $N_k \times N_t$ dimensional matrix. At the user end, a $1 \times N_k$-dimensional decoding matrix M_k is used to restore the original signal.

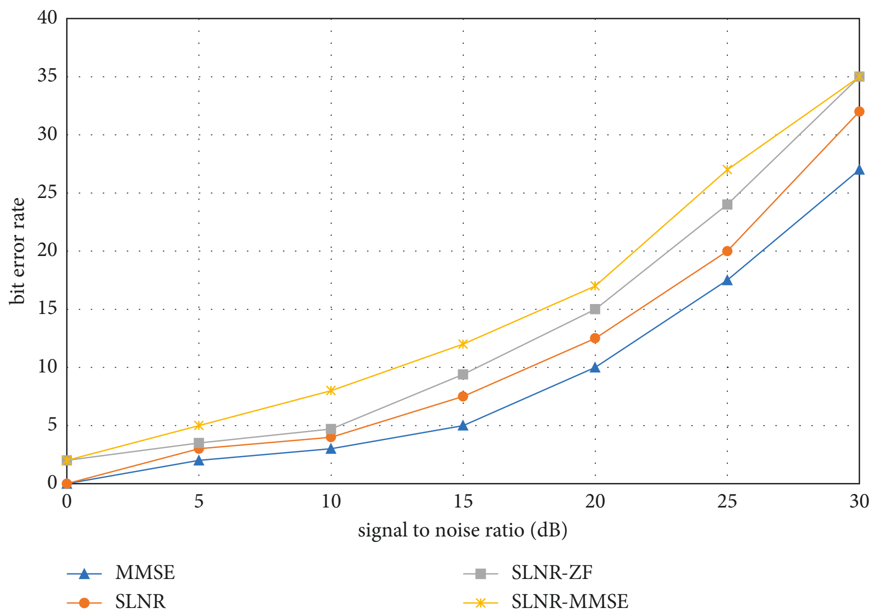

FIGURE 7: Bit error rate before and after the improvement of SLNR precoding algorithm when the antenna configuration is 3×2.

4.2. Algorithm Simulation and Performance Analysis. This experiment is carried out in the MATLAB simulation environment. The simulation parameters are derived from 3GPP TR36.814, the number of cells is 3, the number of users is 3, the receiving antenna of each user is 2, and the channel is a flat Rayleigh channel. The specific simulation parameters are as follows shown in Table 5.

By comparing the bit error rate and the total transmission rate of the three algorithms of equal power allocation (EPA), optimal iterative power allocation (OPA), and suboptimal power allocation (SPA), the performance is analyzed. The simulations were performed using two system configurations, 5x (3, 3, 3) and 5x (1, 1, 1). That is, the number of transmitting antennas at the transmitting end is 5, and the number of users served by the system is 3. The numbers in parentheses represent the number of receiving antennas at the user end that the system simultaneously serves in different configurations.

Figure 5 and Table 5 compare the total transmission rate performance of equal power allocation, suboptimal power allocation, and iterative power allocation schemes. It can be seen from the simulation results that the total rate curves of the three are close to coincidence. It can be seen from the partial enlargement of the simulation results that, compared with the equal power allocation, the suboptimal power allocation and iterative power allocation schemes have less system capacity loss. When the system configuration is 5x (3, 3, 3), the total rate of the three power allocation schemes is better than the corresponding power allocation scheme when the system is configured with 5x (1, 1, 1). This is due to the receive diversity gain due to the increase in the number of receive antennas.

Figure 6 is a bit error rate diagram before and after the improvement of the SLNR precoding algorithm when the antenna configuration is 3×2. As can be seen from Figure 6, in the range of 0–30 dB, with the increase of the signal-to-noise ratio, the bit error rate of each precoding algorithm presents a decreasing trend. The bit error rates of SLNR-MMSE and SLNR-ZF precoding algorithms are significantly lower than those of MMSE and SLNR, and the BER performance of SLNR-MMSE is significantly better than that of SLNR-ZF when the signal-to-noise ratio is in the range of 0–20 dB; SNR is in the range of 20–30 dB, and the bit error rate performance of SLNR-MMSE is similar to that of SLNR-ZF.

Figure 7 is the system capacity diagram before and after the improvement of the SLNR precoding algorithm when the antenna configuration is 3×2. As can be seen from Figure 7, in the range of 0–30 dB, with the increase of SNR, the system capacity of the MMSE, SLNR, SLNR-ZF, and SLNR-MMSE precoding algorithms shows an increasing trend. The system capacity of SLNR-MMSE precoding algorithm is obviously higher than that of MMSE, SLNR, and SLNR-ZF.

5. Conclusion

The new generation of communication technology is constantly innovating to drive the development of the industry, and a new era of mobile Internet has arrived. LTE has become the main technical direction of future mobile communication development, and commercial deployment has been carried out on a global scale in terms of application, and in terms of technology, it is smoothly evolving to the LTE-A system. In order to meet the requirements of the ITU for the IMT-A system, key technologies such as carrier aggregation, multiantenna enhancement technology, relay, and coordinated multipoint transmission have been incorporated into the LTE-A protocol by the 3GPP organization. In this paper, the CoMP technology is systematically classified and studied from the perspective of the relationship between the coordinating nodes, from the perspective of uplink and downlink transmission and whether the base station shares user data and focuses on the downlink CoMP joint transmission in the scene.

Based on the research on the classical precoding algorithm in CoMP system, this paper proposes the SLNR-MMSE algorithm for the defects of MMSE and SLNR algorithm, which can eliminate the interference and noise between users and users themselves and further improve the performance of the system. Through simulation analysis, it is concluded that SLNR-MMSE has certain advantages over other algorithms in terms of bit error rate and system capacity.

Data Availability

The labeled data set used to support the findings of this study is available from the author upon request.

Conflicts of Interest

The author declares that there are no conflicts of interest.

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