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Research on Multi User MIMO Scheduling Algorithm Based on Hybrid Beamforming in 5G Communication

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Abstract: ***Massive MIMO is one of the core technologies in 5G communication, and multiple input multiple output signals can effectively improve the spectral efficiency and user communication quality in communication transmission. This article elaborates on the principle of effective channel transmission from two dimensions: user downlink channel and communication vector function, and designs a millimeter wave MIMO hybrid beamforming model based on this. The article analyzes the design principle, implementation steps, and algorithm complexity of millimeter wave hybrid beamforming model, and uses the hybrid beamforming model to design a specific implementation method for multi-user MIMO scheduling; Based on the model, determine the antenna weighting vectors for bidirectional alternating optimization of the transmitting and receiving terminal arrays, provide the algorithm flow for digital analog hybrid beamforming, and ultimately achieve balanced scheduling for multi-user MIMO. The simulation results show that the scheduling algorithm proposed in this paper has the advantages of fast convergence speed, low computational complexity, and high baseband transmission efficiency.***

Keywords: 5G communication; Hybrid beam; Multi-user; MIMO; Scheduling algorithm; Machine learning.

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1. Introduction

In 5G communication systems, multi-user MIMO (Multiple Input Multiple Output) technology is one of the key technologies to enhance network capacity and user experience. The multi-user MIMO scheduling algorithm based on hybrid beamforming further enhances the efficiency of this technology [1-3]. Hybrid beamforming is a technology that combines digital beamforming and analog beamforming. In 5G systems, especially in the millimeter wave frequency band, hybrid beamforming technology is widely used to enhance the directionality and coverage of signals [4-9]. By adjusting the phase and amplitude in the antenna array, the beam can be directed towards specific users or areas, thereby improving signal quality and reducing interference [10-13]. The multi-user MIMO scheduling algorithm is responsible for determining which users should be served at a certain moment and how to allocate resources (such as time, frequency, power, etc.) to these users. In the multi-user MIMO system based on hybrid beamforming, the scheduling algorithm needs to consider the constraints of beamforming, such as the width, direction and shape of the beam [14-16]. The multi-user MIMO scheduling algorithm based on hybrid beamforming is an important research direction in 5G communication systems. By comprehensively considering factors such as user grouping, resource allocation, beam optimization, and cross layer optimization, the throughput, coverage, and user experience of the system can be significantly improved [17-19].

5G massive MIMO technology is one of the key technologies in 5G communication, with significant advantages and development potential. The principle is to use a large number of antennas to form multiple independent channels at the transmitting and receiving ends, achieve parallel signal transmission, and improve channel capacity and spectral efficiency. Its main advantages are: improving system capacity and spectrum efficiency, supporting simultaneous transmission of more data streams; Enhance anti-interference capability and improve signal reliability; Reduce energy consumption, achieve high-speed data transmission while reducing energy consumption; Improve spectrum utilization and optimize spectrum resource management [20-22]. The 5G massive MIMO technology is mainly achieved through increasing the number of antennas, utilizing spatial diversity, and adopting multi-user detection techniques. Specifically, this technology utilizes a large number of antennas to form multiple independent channels at the transmitting and receiving ends, achieving parallel signal transmission and significantly improving the system's channel capacity and spectral efficiency [23]. Meanwhile, through key technologies such as space-time coding, spatial diversity, multi-user detection, channel estimation, and feedback mechanisms, 5G massive MIMO technology can further improve the capacity, speed, and reliability of communication systems, meeting the growing demand for wireless communication. In addition, this technology also improves the power efficiency of the system, enhances anti-interference ability, reduces energy consumption, and improves spectrum utilization through techniques such as beamforming and beam control [24].

2. Principle of Massive MIMO Beneficial Transmission in 5G Communication

Assuming that a typical Massive MIMO wireless communication system base station in 5G communication is equipped with m communication antenna units, and the system base station simultaneously serves j network users with n (n>1) equipped antennas, theoretically the value of m is much greater than n and tends to infinity. Under this assumption, the communication signal S_j received by j users is represented as:

$$S_j = \sqrt{SNR_{avg}} c_j S_0 + n_j \tag{1}$$

Among them, SNR_{avg} represents the average signal-to-noise ratio level during signal transmission, c_j represents the downlink channel of the *jth* user [15-16], S_0 and n_j respectively represent the original signal emitted by the base station and the Gaussian white noise in the system transmission environment [17]. By integrating the received signals of all n users into a column vector, the overall signal of the network user end can be obtained:

$$S = [S_1^T, S_2^T, \cdots\cdots, S_k^T]^T = \sqrt{SNR_{avg}} c_{tal} S + n_{tal} \tag{2}$$

Among them, c_{tal} and n_{tal} represent the overall communication downlink channel and the overall system environmental noise, respectively. When the network user end is a single antenna, signal interference only exists between users. However, with the introduction of MIMO multiple antennas, there will also be signal interference between antenna modules of the same user signal receiving system. Therefore, only under favorable transmission conditions can interference from multiple antennas within communication between communication users and within a single user communication be eliminated simultaneously [25].

3. Design of Millimeter Wave MIMO Hybrid Beamforming

As a common signal transmission and data information processing technology in the current communication field, beamforming technology mainly processes the original signal beam into a narrowband beam through signal weighting processing, and concentrates the energy on the main target user point, thereby improving the communication signal-to-noise ratio of the receiving user and enhancing the quality of signal transmission [6]. Considering the overall architecture of the hybrid beamforming system, the RF link, antenna subarrays, analog phase instruments of the system, and user RF antennas are all connected in a one-to-one manner. The data stream transmission first goes through the digital encoder F_{BB} with a dimension of $N_{RT} \times N_S$, and then goes through the F_{RF} processing of the analog encoder with a dimension of $N_{RT} \times N$. Due to the limitations and constraints of the internal structure and phase shifter of the analog encoder, the conditions are as follows:

$$F_{RF} = \{f_1, f_2, \cdots\cdots, f_{N_{RF}}\} = \begin{pmatrix} f_1 & \cdots & 0 \\ \cdots & \cdots & \cdots \\ 0 & \cdots & f_{N_{RF}} \end{pmatrix} \tag{3}$$

Among them, f_i is the control vector of the *i-th* signal transmission subarray.

4. Research on Multi User MIMO Scheduling Algorithm Based on Hybrid Beamforming

For millimeter wave MIMO hybrid beamforming systems, the primary consideration in comprehensive communication scheduling is to improve the overall data throughput of the system based on matching users and subarrays. Therefore, based on the proportional fairness algorithm scheme, this article proposes a hybrid beam semi orthogonal fair scheduling algorithm to achieve balance between channel resource occupancy and signal transmission [26]. In the determined signal scheduling period T, select the sample user group according to the principle of maximizing the power of the user's received signal, and count the total number of times the user is scheduled. Then, based on the predetermined threshold value, perform centralized scheduling for the users with fewer times of scheduling. When matching users at the signal transmission end, the sub array belonging to the base station uses a codebook Bi to modulate the beam signal. Considering the interference and semi orthogonality between beams, the two orthogonal beams pi and pj satisfy the following conditions:

$$\left|\langle p_i, p_j \rangle\right| \le \tau, \tau =\in (0,1) \tag{4}$$

At this point, the codebook B_i is generated by the following formula (15):

$$B_i = \begin{cases} \{p_i, \left|\langle p_i, p_j \rangle\right| \le \tau\}, p_i, p_{i-1} \in B_{i-1}, i, j \ge 2 \\ B_0, i = 1 \end{cases} \tag{5}$$

Among them, B_0 is the initial codebook of the system. By combining the codebook B_i with the orthogonal beams p_i and p_j, it is possible to perform mixed beam matching on the subarrays, reducing inter antenna interference without increasing the total cost of data information transmission. When scheduling signals for multiple users, it is necessary to set threshold values in advance to achieve the ultimate goal of balanced and fair scheduling [8].

5. Comparison of Spectral Efficiency of Hybrid Beamforming

To verify the performance of the hybrid beamforming scheme, the spectral efficiency of the proposed hybrid beamforming scheme and the two-stage optimization scheme were compared under the conditions of 2, 4, and 6 *RF* links, respectively. Other implementation conditions include a number of 16 antenna subarrays, 32 codewords, and the requirement that the number of signal receiving links is equal to the number of transmitting links [9]. The frequency efficiency comparison of different RF link schemes is shown in Figure 1 below:

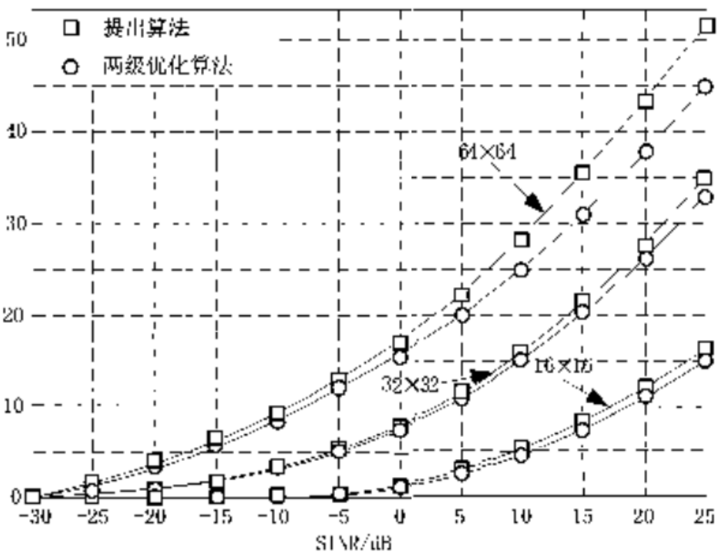

Figure 1: Comparison of Spectral Efficiency of Different RF Link Solutions

As shown in the spectrum efficiency curve in Figure 1, when the number of *RF* links is 2, the spectrum efficiency changes of the two schemes approach each other as the signal-to-noise ratio increases; And when the number of *RF* links is 4, the advantages of the proposed scheme begin to emerge as the signal-to-noise ratio increases; When the number of *RF* links is 6 and the signal-to-noise ratio exceeds 5, the frequency efficiency of the hybrid beamforming scheme begins to show, indicating that as the number of antenna arrays increases, the proposed scheme has better data signal transmission performance [10].

6. Conclusion

The era of 5G communication has arrived, and how to balance communication speed and user fairness while ensuring communication quality under high-speed wireless network conditions has become an urgent problem to be solved. Multi user MIMO technology is currently one of the core technologies in 5G communication. Therefore, this article proposes a communication scheduling algorithm based on hybrid beamforming. Simulation comparison results show that the proposed algorithm has significant advantages in comprehensive performance and algorithm complexity, which can ensure the smooth implementation of multi-user MIMO communication.

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