Talking about the innovation and development of Massive MIMO technology for 5G communication

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Abstract: After the development of multiple generations of mobile communication technologies, the current wireless network is a complex hybrid network with coexistence of multiple standards. With the continuous growth of wireless data services in the 5th generation mobile communication technology, the development and research of new technologies have gradually entered a heated stage. Among them, the most promising technology is the use of massive MIMO technology in the base station, which can greatly increase the spectral efficiency and channel capacity by orders of magnitude. This paper firstly introduces the theoretical basis and performance of Massive MIMO, and then analyzes the methods of channel measurement, modeling, and channel information acquisition and output step by step. Coding and other key technologies, and then according to its technical characteristics, analyzes the technical advantages of Massive MlMO and the challenges it faces, and finally makes a summary.

1. Introduction

In order to maximize the performance of the communication system, reasonable scheduling and resource allocation is a key technical means. When the number of base station antennas is small, the channel fluctuates greatly due to the randomness of fading. The base station performs scheduling according to the channel quality difference of multiple user terminals, so as to obtain the multi-user diversity gain. There are two ways to obtain the multi-user diversity gain: natural channel fluctuation and artificial channel fluctuation. With the increasing number of antennas, the multi-user diversity gain will gradually decrease [1]. In downlink transmission, the increase in the number of base station antennas will cause the transmission power to be distributed to each sub-array, reducing the random fluctuation of the channel, and thus the user scheduling gain will also be affected. In the study of uplink transmission, the same conclusion can be obtained as in downlink transmission. This phenomenon of reducing channel state fluctuation due to an increase in the number of antennas is called channel hardening.

Most scenarios face the problems of complex wireless environment, dense buildings, uneven distribution of heights and lows, tight frequency resources, large number of users, high mobility, and large traffic demands [2]. This brings a more severe test to the planning and construction of 5G wireless base stations. The proposal of Massive MIMO technology provides an effective method to solve this problem. There are many types of devices based on Massive MIMO technology, and devices with different numbers of radio frequency channels (TR numbers) differ in terms of cost, capacity, coverage, and support capability for business scenarios. In actual deployment, it should be considered comprehensively in different scenarios such as equipment cost, user value, terminal distribution, and service distribution, taking into account capacity and coverage, and using a variety of equipment forms to build a hierarchical network to create a low-cost and high-quality 5G boutique network [3].

2. Introduction to Massive MIMO Technology

As a key technology of 5G, Massive MIMO technology plays a crucial role in meeting the service requirements of clVlBB, uRLLC and mMTC in the three major application scenarios of 5G.

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Massive MIMO deploys dozens or even hundreds of antenna-scale antenna arrays at the base station and uses beamforming technology to construct different beams facing multiple target customers, thereby effectively reducing the interference between different beams and realizing the utilization of space resources. Fully excavated. Massive MIMO technology can effectively utilize precious and scarce frequency band resources and increase network capacity dozens of times [4]. The channel capacity of the SISO system can be expressed asfor (1)

$$C = W\log_2(1 + S / N) \tag{1}$$

Among them, W represents the channel bandwidth, and S/N represents the received signal-to-noise ratio. This formula gives the maximum rate of error-free transmission of the system in an additive white Gaussian noise channel. At this time, no matter what channel coding method and modulation scheme are used, the system capacity can only be approached but cannot be surpassed. As an insurmountable upper bound, the system capacity has become a bottleneck in modern communication systems [5].

The proposal of Massive MIMO technology breaks the Shannon limit and can effectively improve the system channel capacity. Its basic principle is to use multiple transmitting and receiving antennas at the transmitter and receiver of wireless communication at the same time, making full use of space resources and the multipath propagation characteristics of electromagnetic waves. Wireless transmission and signal processing technology, establish a parallel transmission mechanism, so as to obtain better diversity gain, multiplexing gain, array gain, interference cancellation gain, etc., to achieve a substantial increase in coverage and capacity. The Massive MIMO system is shown in Figure 1.

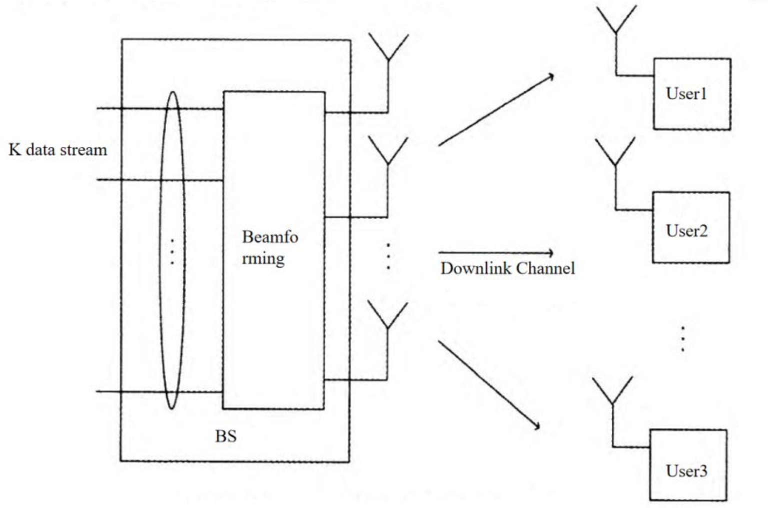

Figure 1 Schematic diagram of Massive MIMO system

3. Key Technologies of Massive MIMO

3.1. Channel information acquisition

At present, the channel modeling work of Massive MIMO has achieved corresponding results, and the relevant components are mainly two cases: stochastic modeling and geometric modeling. On the one hand, the CBSM class cannot effectively display the two key characteristics of the near-field effect and non-stationarity of Massive MIMO radio wave propagation, and the complexity of the modeling is also low to medium; on the other hand, the GBSM class can correspondingly The relevant important features of Massive MIMO are described [6-7], and its complexity is relatively high. The future development direction of this technology is generally to combine the Massive MIMO channel measurement results with the characteristics of 5G application scenarios, and on the basis of summarizing the advantages and disadvantages of CBSM and GBSM, obtain the Massive MIMO channel characteristics as much as possible. Obtain the best compromise between modeling accuracy and complexity.

3.2. Signal Detection

An important part of the research on the actual characteristics of Massive MIMO is to measure the channel. With the progress of channel measurement in recent years, massive MIMO can effectively improve the spectral efficiency. The spectral efficiency and the number of antennas show Positively correlated growth trend. According to the quasi-orthogonality between the channels corresponding to different antennas of the MassiveMIMO base station, in order to obtain a relatively high capacity, it can also be performed by using low-complexity linear processing.

Measurement of spherical waves and non-stationary properties. Massive MIMO makes the generalized stationary characteristic no longer because the plane wave approximation is no longer applicable, the power is unbalanced, and the K-factor of the Rician channel is unbalanced between different antennas. The MassiveMIMO channel measurement faces many challenges: on the one hand, due to the non-stationarity of the MassiveMIMO array in the antenna axis and the time axis, the fluctuation is relatively strong, and there is a great obstacle to the measurement of related parameters. On the other hand, because most of the measurements are carried out in the case of uniform arrays, other types of arrays need to be considered, such as plane arrays, cubic arrays, etc., which are all due to the space constraints in the actual array. The traditional linear detection algorithms mainly include: maximum ratio merging detection algorithm, zero-forcing detection algorithm, minimum mean square error detection algorithm, etc. The performance comparison of three typical detection algorithms is shown in Table 1.

Table 1 Performance comparison of different linear algorithms

Algorithm	Performance	The complexity	Applicable scene
Mrc	Difference	Low	Scenarios with a large number of antennas
Zf	Middle	Generally	Scenarios with high signal-to-noise ratio
Mmse	Excellent	High	Common scenarios for the number of antennas

4. Advantages and Challenges of Massive MIMO Technology

4.1. Massive MIMO technology advantages

The characteristic of MassiveMIMO is to combine the design scheme of traditional MIMO channel (such as MMSE criterion) and the characteristics of more channel coefficients to be estimated, thus forming a part of the new framework and method. It mainly includes the following types: The channel estimation accuracy can be improved by utilizing the sparse characteristics of Massive MIMO channels and advanced signal processing algorithms. Improve the accuracy of channel estimation. Using data aid for channel estimation can enhance the accuracy of Massive MIMO channel estimation by incorporating an iterative receiver. However, if you want to get better estimation performance, you need to make more demands on the data and its complexity, because the increase in the number of users and the length of the data will increase the complexity.

4.2. Massive MIMO Technology Innovation Challenge

In order to maximize the performance of the communication system, reasonable scheduling and resource allocation is a key technical means. When the number of base station antennas is small, the channel fluctuates greatly due to the randomness of fading. The base station performs scheduling according to the channel quality difference of multiple user terminals, so as to obtain the multi-user diversity gain. There are two ways to obtain the multi-user diversity gain: natural channel fluctuation and artificial channel fluctuation. As the number of antennas increases, the multi-user diversity gain will gradually decrease. The accuracy of the channel information and the stability of the algorithm [13]. The economic benefits that Massive MIMO technology can bring depends largely on the accuracy of channel information estimation and the degree of time delay of the information. Feedback overhead is also an important research area. In addition, due to the complex practical application environment, the limited speed of information feedback, and many unavoidable signal interference factors, the algorithm is unstable, which seriously affects the exertion of the advantages of Massive MIMO technology. Therefore, the practical experience of algorithm stability should also be increased by increasing research and practice.

This phenomenon of reducing channel state fluctuation due to the increase in the number of antennas is called channel hardening [14]. The number of base station antennas in a massive MIMO system is huge, and the channel fluctuation is limited, so the multi-user diversity gain is not obvious. However, in a single-cell environment, the importance of multi-user scheduling for the purpose of multi-user diversity gain will gradually decrease. In addition to multi-user scheduling in massive MIMO systems, resource allocation is also an important research content in this technical field. At present, some research results mainly consider the bit, power and subcarrier allocation method of massive MIMO-OFDM system with feedback channel under non-ideal conditions, and make full use of the diversity gain of the array antenna to allocate resources reasonably, thereby greatly improving the system capacity. At the same time, the resource allocation problem of massive MIMO systems can also be solved from the perspective of power allocation.

Pilot frequency pollution is mainly due to the fact that relatively similar cells use the same pilot frequency sequence at the same time, and this repeated use is the root cause of pollution. Of course, the pilot pollution is not newly born due to Massive MIMO technology, but it is undeniable that Massive MIMO technology deepens this pollution level. In terms of how to deal with the pilot frequency pollution, relevant scholars have given constructive opinions, and the method of shifting the pilot frequency sequence can be adopted. The principle of the method is to make adjacent cells use pilot sequences in completely different positions in the frame. In this way, although it seems that the same pilot frequency sequence is used, there are actually differences, so that even if multiple users use it at the same time in a similar cell, the phenomenon of pilot frequency pollution will not occur.

5. Conclusions

Difficulties in Massive MIMO include downlink precoding. During basic theoretical research, Massive MIMO uses all-digital precoding to achieve optimal system performance. For the solution to the above problem, it is necessary to adopt a novel modulo-digital hybrid precoding scheme. The traditional all-digital precoding is decomposed into a cascade of two parts: one part is digital baseband low-dimensional precoding, which can eliminate interference between users through a small number of radio frequency links; the other part is analog radio frequency high-dimensional precoding, which can be Numerous analog phase shifters to increase antenna array gain. This is the basic idea of magic hybrid precoding modulo-digital hybrid precoding. Significantly reducing the number of radio frequency links and processing complexity with less performance loss is the advantage of analog-digital hybrid precoding over full digital precoding, which can further reduce costs and improve system power efficiency. According to its own advantages and characteristics, analog-digital hybrid precoding has gradually become the main research direction of Massive MIMO downlink precoding, but there are still many technical problems that have not yet been solved.

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