International Journal of Research in Engineering and Science (IJRES)
ISSN (Online): 2320-9364, ISSN (Print): 2320-9356
www.ijres.org Volume 10 Issue 9 ǁ September 2022 ǁ PP. 420-424

Study of advantages of Massive MIMO for 5G Communication

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Abstract.
The fifth generation mobile communication network (5G) has received extensive attention and a lot of research from global enterprises, research institutes and universities. Massive MIMO technology is considered as an important technology in future 5G, mainly used to improve the spectrum utilization and channel capacity of communication system. This paper analyses in detail the standardization process of MIMO technology and the technical Advantages of massive MIMO. It mainly applies scenarios, and then introduces from the Perspective of channel measurement and channel modeling. It analyses the channel estimation Technology, pre-coding technology and signal detection technology in massive MIMO system and makes a summary finally.
***Key Words**: MIMO antenna, MIMO, decoupling element, resonator, microstrip patch antenna, 5G.*

Date of Submission: 05-09-2022 Date of acceptance: 20-09-2022

I. INTRODUCTION

The rapid development of wireless mobile communication has led to the explosive growth of the number of mobile users and the scale of related industries. Therefore, the wireless communication system needs to meet the higher data transmission rate and higher system capacity, and the communication system needs to utilize the bandwidth resource efficiently Due to the shortage of spectrum resource, it is very important to improve the spectrum utilization of the system. Traditional MIMO technology can use limited spectrum resource to meet users' demand for system performance. But there are fewer antennas in the base station of traditional MIMO system, and it has limited system performance. As one of the key technologies of future 5G, massive MIMO can meet the needs of future wireless communication business, improve the spectrum efficiency and channel capacity of communication system, and effectively improve link reliability and data transmission rate [1].

1.1 Traditional MIMO technology

MIMO technology was first proposed by Marconi in 1908. It is equipped with multiple antennas on both sending and receiving end to improve the capacity of communication system, transmission rate of system data and transmission reliability. 3GPP LTE Release10 can already support 8 antenna ports for Transmission, that is, 8 single-stream users or 4 dual-stream users for simultaneous transmission.

It is limited by mobile terminal size, power consumption and appearance. If you want to further improve the data transmission capacity, an intuitive way is to increase the number of data streams that are transmitted in parallel or increase the number of base station antenna ports

Table: 1

Standard	MIMO technology	Characteristic
Rel-8	Transmit diversity	Support up to 4 layers of transport
	Space divisimultiplexbeam form	Only support single layer transport
	MU-MIMO	Up to two rank1 UE
Rel-9	Double stream beam forming	SU/ MU flexible switch
		Up to 4 data streams (up to 2 levels per UE) Use the transmission mode of non-code book
		Support channel reciprocity based feedback

Rel-10	High order MIMO	Support up to 8 layers of transport
		High precision feedback based on two level multiparticle codebook
	Uplink MIMO	Support up to 4 layers of transport
Rel-11	CoMP	Multi-cell coordination MIMO
Rel-12	CoMP/3DMIMO	Multi-cell coordination MIMO/ 3D
Rel-13	3DMIMO	Expanded into a three-dimensional (3D) antenna array

1.2 Massive MIMO technology

In 2010, Marzetta, a scientist in Bell laboratory, proposed the concept of massive MIMO in the context of multiple cell and TDD scenario[2]. Thus, some different features of the limited number of antennas in single cell were found. massive MIMO technology refers to that the base station is equipped with a large number of antennas [3], usually a hundred or several hundred antennas, which is several orders of magnitude higher than the number of antennas in the existing communication system. It serves multiple users simultaneously on the same time-frequency resource, and mobile terminals generally adopt the communication mode of single antenna reception. The basic model of massive MIMO is shown in figure1.

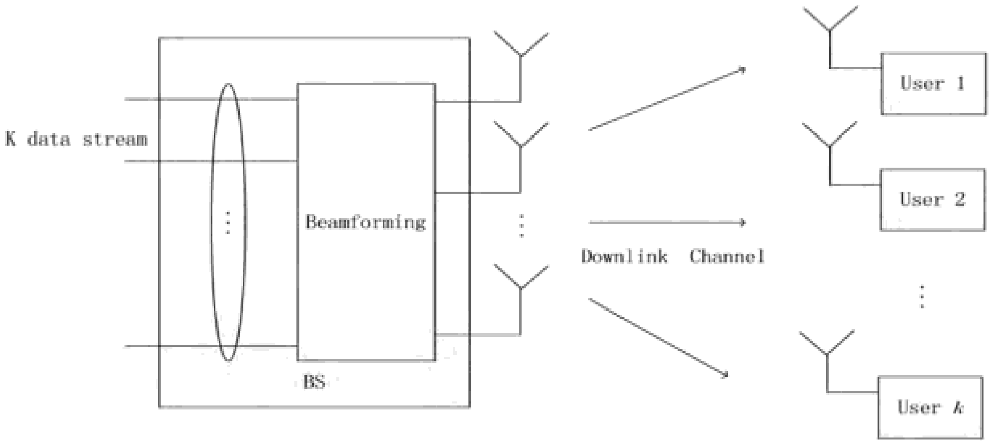

Figure 1 Basic model diagram of massive MIMO

1.3 Technical advantages of massive MIMO

The main advantages of massive MIMO technology are as follows:

(1)The power consumed by the antenna is extremely low. Ideally, under the condition of a certain total transmitting power, the transmitted power used by each antenna is inversely proportional to the number of antennas, and under the condition of a certain transmitting signal to noise ratio, the total transmitting power is inversely proportional to the number of antennas. Therefore, the transmitting power required for each antenna is inversely proportional to the square of the number of antennas. Thus, the power consumed in massive MIMO application is effectively reduced.

(2) Channels "hardening". When the number of lines tends towards infinity, the channel matrix can be analyzed by using the theory of random matrix. The singular value of the channel matrix will tend towards the known asymptotic distribution [4], and the channel vector will tend to be orthogonal. The simplest signal processing method is asymptotically optimal.

(3) The effects of thermal noise and small-scale fading are eliminated. With the linear signal processing method, the influence of thermal noise and small-scale fading on the system performance will decrease with the increase of the number of antennas, and the influence of thermal noise and small-scale fading can be neglected compared with the interference between cells.

(4) Spatial resolution is improved. With the increase of the number of base station antennas in massive MIMO system, beam forming can concentrate the transmitted signals to a point in space, that is, the base station can accurately distinguish each user, thus improving the spatial resolution.

1.4 Performance comparison between massive MIMO and traditional MIMO

In 3GPP, MIMO technology generally evolves along the development of single-user MIMO, multi-user MIMO and network MIMO. Compared with traditional MIMO technology, the performance of massive MIMO technology is reflected in many aspects. The performance comparison between traditional MIMO and massive MIMO is presented in table 2.

Table 2.Performance comparison between traditional MIMO and massive MIMO

Technology content	Traditional MIMO	Massive MIMO
The antenna number	≤8	≥100
Channel angular domain value	Uncertain	Certain
Channel matrix	Low requirement	High requirement
Channel capacity	Low	High
Diversity gain	Low	High
Link stability	Low	High
Resistance to noise	Low	High
Array resolution	Low	High
Antenna correlation	Low	High
Coupling	Low	Low
SER	High	Low
Pilot pollution	No	Yes

2.1 Massive MIMO application scenario

Macro cell and micro cell co-exist under the application scenario of 5G massive antenna array. The network is mainly divided into homogeneous and heterogeneous network, while the scenarios are divided into indoor scenarios and outdoor scenarios. It is known from the test of relevant literature that about 70% of mobile communication systems on land are indoor. Therefore, massive MIMO channels can be divided into micro cell base station for indoor or outdoor users and macro cell base station for indoor or outdoor users. At the same time, the micro cell can be used as relay base station to transmit information, and the channel can be divided into macro cell base station and micro cell base station. The number of antennas of base station can be increased infinitely, and the number of mobile user antennas in the cell can also be increased.

2.2 Massive MIMO channel measurement and modeling

When the wireless transmission condition is ideal, the channel vector between transmitter and receiver is gradually orthogonal due to the increase number of antenna of massive MIMO system. The following is the main research and analysis of massive MIMO channel measurement and modeling.

3.1 Massive MIMO channel measurement

The theoretical channel model of massive MIMO system can be effectively verified through the channel measurement in the actual wireless communication environment, and the performance of the entire communication system can be improved by measuring the actual channel [5].

(1) The distributed MIMO channel is measured under the condition of 2.6 GHz micro cell. The measurement method is mainly to use three base stations under distributed MIMO to be equipped with four groups of antenna units, so that the height of its space meets the condition of co-directional Polarization. The last base station is used to configure an antenna unit. A mobile platform consists of a uniform cylindrical array with 64 pairs of dual-polarization antenna units. By analyzing the cross correlation of the massive fading of communication links between different base stations, the massive fading values of the channels at different locations are obtained.

(2) Measurement method of linear array with 128 units. Literature [6] described 26 users transmitting at different stadia under 2.6 GHz and 10 users transmitting at non-stadia, and deployed 128 unit antenna arrays at the base station terminal, and set half wavelength as the antenna spacing, with 7.3m as the length of the antenna array. By verifying the massive MIMO channel under the above configuration, it can be known that the massive antenna array is a wireless communication channel when some invisible scattered or highly variable scattered power values exist, and cannot be regarded as a generalized stationary process. However, since the non-stationary of the antenna array and the effect of near field can remove the correlation between the users, thus providing a relatively stable and low-interference channel environment.

3.2 Massive MIMO channel modeling

Due to the rapid development of 5G technology, massive MIMO channel modeling shows some new features. For example, in the deployment of massive antenna array at the base station terminal, spherical waves should be used to replace plane waves [7] and channel energy should be concentrated in limited space. The channel is no longer independent and identically distributed. With the increasing antenna array at the base station terminal, only different antenna units can see different scatterers, and the fading is characterized by non-static characteristics [8].

4 Channel state information acquisition technology

Bell Labs proposed a transmission scheme for the TDD mode of massive MIMO system. Mobile users in cellular networks (usually single antenna) transmit orthogonal pilot signals to base station terminal, by receiving the pilot signal to the target base station. According to the value of CSI of the uplink estimated by the channel, the reciprocity of the uplink and downlink of TDD system is used, and the CSI of the downlink is characterised by conjugate transpose of CSI of the uplink. Thus the detection of uplink signal and downlink precoding are transmitted. When the number of cell users increases, the pilot cost estimated by the channel will also increase, especially in the case of medium and high speed mobile communication, the pilot cost will occupy most of the time -frequency resources. Therefore, when the pilot frequency of TDD transmission mode is limited, it is of great practical value to study the CSI technology of massive MIMO. Compared with FDD mode, TDD mode can provide a more ideal method to obtain CSI.

5 Massive MIMO precoding technology Studies have shown that the massive MIMO precoding technology plays a crucial role in breaking the bottleneck of the downlink capacity of the system. Nowadays, in the downlink transmission of massive MIMO [9], the technology of signal processing of transmitter is largely used to transform the complexity of massive MIMO system from terminal side to base station side. At present, there are mainly linear and nonlinear precoding algorithms, linear is composed of ZF, MF precoding and Block Diagonalization (BD), while non-linear is composed of Dirty Paper Coding (DPC), auxiliary grid method, Vector Perturbation (VP) and so on.

5.1 Linear preceding

The current linear and non-linear precoding techniques have been extensively studied, enabling the massive MIMO preceding technique to mitigate the impact of pilot pollution on system performance. The typical linear precoding algorithm will be emphatically introduced below.

(1) ZF zero-forcing precoding. In the literature [10], it proposed that ZF precodingshould adopt channel parameters replaced by pseudo-inverse matrix. In the literature [11], the ratio α of the number of base station antennas M to the number of terminals K is constant. By simultaneously increasingM and K, the matrix Trace { (GHG) -1 } can be astringed to 1 / (α -1), whereAH represents the Hermite conjugate transpose of matrix A.

(2)The computational complexity of the algorithm. In the massive MIMO, GHG/M gradually approaches MF matched filtering. The inverse operation of k *k dimension matrix in ZF preceding will increase the identity matrix. By simplifying the inverse operation of the matrix, the performance of ZF preceding tends towards that of MF preceding. In the case of antenna array expansion, MF preceding matrix will be infinitely close to ZF

.

(3)Preceding based on MMSE. The allocation of training sequence needs to be considered when designing the preceding scheme in the multi-cell massive MIMO system. The MMSE preceding scheme proposed in literature [12] can reduce pilot pollution. Compared with the single-cell scenario, the MMSE preceding matrix A opt is obtained by the optimal solution of the target function. The target function is established mainly by the mean square error of the signal received by the same cell user and the mean square interference between the users of the cross cell.

5.2 Nonlinear preceding

Nonlinear preceding is composed of vector disturbance (VP) [13], DPC and auxiliary network methods [14]. When M and K are not very large in cell, nonlinear preceding can show some advantages. The approximate expression of SNR in VP with complete CSI is mentioned in literature [15].

6 Massive MIMO system signal detection algorithm

Base station distributes time-frequency resources to different users and provides services to a large number of users. In the massive MIMO system of multi-cell and multi-user, when the cell terminal sends the transmitted signal to the cell base station, the base station can detect the uplink signal received by the space signature.

6.1 Linear detection

When the cell base station is equipped with massive antenna array, the performance of MRC receiver can reach the optimal linear receiver (OLR) performance if the condition of lower signal to interference plus noise ratio (SINR) is satisfied, but it is lower than OLR under the condition of high SINR. In the case of large interference, the performance of OLR will be optimized compared with that of typical MMSE receiver system.

6.2 Nonlinear detection

(1)Algorithm based on tree structure (TB). Spherical decoding (SD) [16] can be said to be a typical nonlinear detection algorithm, and SD is actually a maximum likelihood (ML) decoder. The disadvantage of the SD algorithm is that it only takes into account the points within a specific radius and it should expand the radius to find any signaling point. In the existing low complexity TB, adding only the most valuable nodes can effectively reduce the search complexity.

(2)Random Step (RS) method. The principle of the algorithm is: select an initial vector, evaluate its peripheral vector NNeigh, take MSE as the condition, select MSE as the minimum vector, repeat the above process Niter times.

II. CONCLUSION

Massive MIMO technology is considered by the industry as a key technology in future 5G. It can significantly improve the channel capacity, energy efficiency and spectrum efficiency of wireless communication system. This paper analyses the standardization process of MIMO technology in detail, and the performance advantages of massive MIMO compared with traditional MIMO. It analyses and compares the application scenarios, channel measurement and channel modelling of massive MIMO, and analyses the channel estimation technology, pre-coding technology and signal detection technology in massive MIMO system. In the future, due to higher requirements for hardware complexity by massive MIMO, pilot pollution limits the improvement of system performance, and there are still many challenges to be completed.

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