Analysis of Massive MIMO & NOMA of 5G and Future Prospects

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Abstract. Since the 1970s, mobile communication has evolved from analog voice communication to a technology that can provide high-quality mobile broadband services today. The data rate of end users has reached several megabits per second, and the user experience has been continuously improved. In addition, with the increase of new mobile devices, the continuous growth of communication services and the continuous increase of network traffic, the existing wireless technology can no longer meet the needs of future communications. The 5th generation mobile communication system (5G) came into being, and its technological development is still in the exploratory stage. This article discusses the key technologies of 5G, massive MIMO (Multiple input multiple output) and NOMA (Non-orthogonal multiple access), briefly introduces their principles, and analyzes the advantages and potential research directions. Finally, this article looks forward to the development trend of 5G technology.

1. Introduction
In recent years, 5G wireless communication technology has gradually emerged. Its advantages are very obvious mainly as follows and 5G wireless communication technology has a wider coverage, faster transmission time efficiency, and more secure communication. Compared with previous generations of mobile communications, the fifth-generation mobile communications technology (5G) will provide richer services. Different scenarios have different requirements for communication performance. 5G wireless communication technology can be combined with other communication technologies. The comprehensive communication network formed can better respond to various communication needs. This can better make outstanding contributions to the progress of human science and technology [1, 2]. 5G involves a variety of key technologies, and in order to know more about its main technologies for proposing reasonable advice, massive MIMO (Multiple input multiple output) and NOMA (Non-orthogonal multiple access) technologies are selected to be discussed below.

2. Massive MIMO (Multiple Input Multiple Output)

2.1. Brief Introduction
In recent years, wireless communication technology has developed rapidly. At the same time, smart phones have become popular in people's lives. All this has led to an explosive growth in the demand for wireless data transmission. The concept of massive MIMO has entered the field of vision of researchers. Researchers such as Thomas L Marzeta of Bell Labs in the United States first proposed this concept. The construction of massive MIMO system is to increase the data transmission rate by increasing the number of base station antennas [3, 4].
Research has found that the data transmission rate can be greatly improved when the number of base station antennas in a cell tends to infinity. There are many antennas in a massive MIMO system [5]. Compared with the existing MIMO system, the number is about 10-100 times. This can reduce negative effects such as Rayleigh's decline. The number of base station antennas is far more than the number of user equipment (UE). Multiple UEs simultaneously receive services of the same time-frequency resources. In this process, the spatial freedom of the system has been fully utilized.

![Some possible antenna configurations and deployment scenarios for a massive MIMO base station](image)

### 2.2. Advantages

Massive MIMO technology will bring the following series of advantages in the entire 5G system.

1. Compared with a single antenna system, large-scale multi-antenna technology can improve spectrum utilization efficiency and energy utilization efficiency through different dimensions (space domain, time domain, frequency domain, polarization domain).

2. The principle of beamforming technology to reduce interference is to concentrate light beams with extremely small energy in a small area. This technology can be applied to wireless short-distance transmission systems. By focusing the signal strength in the target direction, the reliability of signal transmission is improved. In addition, the technology can also be combined with cell splitting and small cell clusters.

3. The spatial resolution of massive MIMO systems has been significantly improved compared to before. At the same time, the use of this technology can also make deep use of space resources.

Therefore, the research on wireless communication theory of large-scale antenna systems is quite different from traditional MIMO systems. This also puts forward new and more challenging basic theories and key technical issues for researchers.

The following part will briefly introduce channel information acquisition and wireless transmission technology [6].

### 2.3. Information Acquisition Technology

Channel estimation is an important content in wireless communication. It is an important factor influencing the performance of massive MIMO. At the same time, it is the basis of signal detection. Bell Labs once proposed a massive MIMO transmission scheme [4]. In this scheme, the base station receives the pilot signal sent by the user. These signals are mutually orthogonal. These signals are used to estimate the parameter values of the uplink channel. The channel of TDD system has reciprocity. Therefore, it is possible to use this property to estimate the parameter value of the downlink channel. So as to achieve uplink detection and downlink pre-programmed transmission [3].
The acquisition of channel information is a key consideration for the realization of wireless communication. There are more antennas in a large antenna system. At the same time, the number of users is also large. The acquisition of channel information is even more important. The uplink uses a method in which users send orthogonal pilots. The total number of user antennas used for space division transmission increases linearly with participation. At the same time, the pilot overhead also increases. The downlink channel information known by the transmitter is a necessary means to realize downlink multi-user precoding and multi-antenna space division multiplexing. The acquisition of downlink channel information becomes the bottleneck of the system. This is especially true when the number of antennas on the base station side is much greater than the total number of user antennas. For the TDD system, the reciprocity of the air channel is used. In the coherent time, the known uplink channel information is used to estimate the downlink channel information. This can reduce overhead. This overhead includes pilot overhead and CSI feedback overhead. For FDD systems, other problems are faced. The lack of reciprocity between the uplink and downlink channels is one of it. This limits the application of massive MIMO in FDD systems [6].

2.4. Transmission Technology
In massive MIMO wireless communication systems, complete instantaneous channel state information is difficult to obtain. This makes it difficult to optimize the system design. This is also a difficult problem to realize multi-user space wireless resource sharing. Therefore, the massive MIMO transmission technology will be different from the existing MIMO transmission technology. The existing basic transmission scheme is to use the uplink orthogonal pilot and the reciprocity of the uplink and downlink channels of the TDD system. The base station can obtain multi-user uplink and downlink channel parameter estimates, and assumes that the obtained channel parameter estimates are true value, as well as implements multi-user joint uplink reception processing and downlink precoding transmission [4,5].

In this transmission scheme, the base station uses the channel estimation value as the true value for uplink and downlink transmission, and the robustness of transmission cannot be guaranteed. A single user only configures a single antenna, and when the number of users in the system is small, the spectrum efficiency is still low. Uplink signal detection and downlink precoding transmission involve high-dimensional matrix inversion operations, and the system implementation is highly complex. It is difficult to obtain instantaneous channel information for all users in the FDD system, and there are problems with the applicability of the FDD system. When only part of the channel information is known on the base station side, it is an important issue to be solved to realize multi-user sharing of spatial wireless resources and high-performance, high-robustness, and low-complexity massive MIMO wireless transmission [3].

2.5. Future Outlook
In summary, after 4G, mobile communications have higher requirements. Massive MIMO wireless communication greatly improves the spectrum efficiency and power efficiency of wireless communication. It is one of the most promising research directions for broadband green mobile communications.

In short, large-scale multi-antenna technology is a potentially feasible key technology that simultaneously increases system capacity and peak rate, reduces energy consumption and transmission delay. In today's experimental network, the conventional multiple-input multiple-output scheme is no longer suitable for the ever-increasing communication demands, especially the antennas of 4–128. In the 5G large-scale multi-antenna technical solution, the number of base station antennas will greatly increase, and the potential large-scale array will be from 10×10 to 100×100 or even larger. Until now, the design and engineering of large-scale multi-antenna systems have also faced challenges brought by the above-mentioned series of key technical issues [2].
3. NOMA (Non-orthogonal multiple access)

3.1. Brief Introduction

Multiple access technology is a key feature of modern mobile communication systems. To a large extent, multiple access technology is the key feature of each generation of mobile communication technology [7]. In the traditional cellular communication system, Orthogonal Multiple Access (OMA) is mainly used. Using OMA, the information carried by different user signals can be easily separated. However, a flaw of OMA is that the number of available orthogonal resources will limit the number of supported users. In addition, even though orthogonal time-frequency code resources are used, when a signal goes through a channel, its orthogonality is always inevitably destroyed due to time delay, frequency offset and Doppler shift. Therefore, if it is still limited to OMA technology and cannot access more users within limited resources, it will not be able to achieve the spectrum efficiency and large-scale connection requirements of 5G [8].

Non-Orthogonal Multiple Access (NOMA) is an important technology. This technology can realize the multiplexing of limited spectrum resources, which meets the requirements of 5G. At the receiving end, advanced receiver technology is used to separate each user's data [9]. Compared with OMA technology, the use of NOMA technology can significantly increase the transmission rate and system capacity. Therefore, this technology is very consistent with the massive data growth and access demand in the 5G era.

Figure 2. Access Technology Of 3G, 4G and 5G

NOMA has two key technologies. At the user receiving end, continuous interference cancellation technology is used for multi-user detection [10]. Power domain multiplexing is performed at the transmitting end. Power allocation is also performed according to related algorithms [11].

NOMA also faces some problems. First, the non-orthogonal transmission receiver is very complicated, and its design requires a great improvement in the signal processing technology of the chip. In addition, the power domain multiplexing technology is still in the research stage, and there is still a lot of work to be done in the future.

3.2. Advantages

The advantages of NOMA are reflected in the following aspects [8], including the following four main benefits.

3.2.1. Channel capacity.

Through the method of tagging, NOMA technology can distinguish different users, so that different users can reuse resources in the time domain and frequency domain. Compared with OMA technology, NOMA technology can be closer to the capacity boundary of multi-user systems [12]. In addition, NOMA technology has more obvious advantages in terms of fairness between users, flexibility of scheduling and the sum of transmission rates.
3.2.2. Improve spectrum efficiency and cell edge throughput.
In NOMA, users share non-orthogonal time-frequency resources. NOMA can guarantee greater user fairness.

3.2.3. Big connection.
In NOMA, conventional time-frequency resources no longer strictly limit the number of users. In the case of insufficient resources, NOMA can significantly increase the users number connected at the same time, so it can support large-scale connections.

3.2.4. No need for accurate channel state information.
In the power domain NOMA, since the channel state information is only used for power allocation, the accuracy requirements for the channel state information are reduced. As long as the channel change speed is not fast enough, incorrect channel status information will not seriously affect system performance.

3.3. Future Research Direction
Some promising research directions for NOMA in the future are as follows [8].

3.3.1. Combination with MIMO.
By combining NOMA and MIMO. The spatial diversity gain or multiplexing gain of the MIMO system can be used to further improve the spectral efficiency. The transmission power allocation of NOMA in the power domain is allocated according to the user channel gain. However, the representation of channel gain is different in different scenarios, such as a scalar form in a single antenna system, and a matrix form in a MIMO scenario. This increases the difficulty of determining the user's channel state, which in turn leads to difficulties in the implementation of this technology.

3.3.2. Receiver design.
For the mMTC scenario in 5G, the complexity of the receiver based on the maximum a posteriori probability (MAP) may become too high. Therefore, Gaussian approximation of interference and some approximate solutions are proposed. The complexity of the receiver is significantly reduced by these schemes. For SIC-based receivers, propagation errors will cause system performance degradation. Therefore, a good receiver design is necessary.

3.3.3. Full duplex NOMA.
Its principle is to use NOMA transmission in both the uplink and the downlink. This operation ensures the spectrum sharing between uplink and downlink users and can increase the capacity of the system. Strong co-channel interference are also caused by full-duplex NOMA. Specifically, for downlink transmission, its user signals will be strongly interfered by uplink user signals; for uplink transmission, the reliability of base station reception will be reduced due to residual self-interference caused by full-duplex NOMA. Therefore, how to effectively suppress co-channel interference is the difficulty of using FD-NOMA.

4. Discussion on Future Trends of 5G Technology
Nowadays, 5G technology has become a key research topic in the communication field gradually. With the development of science and technology, 5G technology will become more and more mature. From the current mobile network technology, the following three points are the development trend of 5G wireless communication technology [13].

(1) Improve wireless transmission technology. In order to improve the utilization of network resources, people will use more advanced wireless transmission technology. After that, the utilization rate of network resources will be significantly increased to more than ten times that of the previous generation of mobile communication technology.
(2) Explore the new architecture. New architectures, such as high-density cell structures, will appear during the development of 5G technology. These new structures can improve the performance of wireless network systems to a certain extent.

(3) Explore frequency resources. The further development of the previous generation of mobile communication technology is limited by the shortage of frequency resources. In the development of 5G technology, frequency resources such as visible light, millimeter waves and high frequency bands are very valuable for exploration [1].

5. Conclusion
5G is now commercially available, but it has not yet been fully popularized. Compared with the previous generation of wireless communication technology, 5G has obvious advantages. This advantage is shown in resource utilization, transmission rate and spectrum utilization. This article briefly introduces and analyzes the two key technologies of 5G, Massive MIMO and NOMA, and concludes that these two technologies are not yet mature, and there are still many aspects that need to be studied. As the research continues to deepen, the future 5G technology is worth looking forward to. This article is more about discussion and analysis, but the deficiency lies in the lack of experimental simulation. Subsequent research will focus on combining several 5G related technologies to improve 5G users' experience, transmission delay, and wireless network coverage performance.

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