A Literature Survey on Comparison Study of Multiple Access Schemes for 5G

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Abstract - Over the past few decades, mobile communication systems have been successively evolved to the fourth generation (4G), i.e., Long Term Evolution (LTE) and LTE-advance (LTE-A). Even for a contemporary communication system, a fundamental issue, i.e., how to serve users' stringent data demands for mobile communication by using limited network resources still exists. The issue stems from two aspects. On one side, the explosive growth in traffic data volume and number of connected devices will continue. From Cisco's annual visual network index reports, the number of broadband subscribers could reach tens billions by 2020, most of which are mobile devices [1]. Besides, mobile users' demand for high-speed data service is increasing exponentially, mainly driven by the advanced mobile devices and multimedia applications. the importance and the arising challenges of spectrum efficiency and energy saving in 4G and 5G systems, this research addresses several radio resource allocation problems for orthogonal frequency division multiple access (OFDMA) and single carrier-frequency division multiple access (SC-FDMA) systems in LTE networks, and non-orthogonal multiple access (NOMA) systems in 5G systems. The main objective of this research is to investigate fundamental characteristics of the resource allocation problems, address the problems by optimization approaches, and provide high-quality algorithmic solutions to optimize system performance.

Keywords - LTE, 5G, MIMO, Multiple Access.

I. INTRODUCTION

Non-orthogonal multiple access (NOMA) has been recently recognized as a promising multiple access (MA) technique to significantly improve the spectral efficiency of mobile communication networks [1-4]. For example, multiuser superposition transmission (MuST), a downlink version of NOMA, has been proposed for 3rd generation partnership project long-term evolution advanced (3GPP-LTE-A) networks.

The key idea of NOMA is to use the power domain for multiple accesses, whereas the previous generations of mobile networks have been relying on the time/frequency/code domain. Take the conventional orthogonal frequency-division multiple access (OFDMA) used by 3GPP-LTE as an example. A main issue with this orthogonal multiple access (OMA) technique is that its spectral efficiency is low when some bandwidth resources, such as subcarrier channels, are allocated to users with poor channel conditions. On the other hand, the use of NOMA enables each user to have access to all the subcarrier channels, and hence the bandwidth resources allocated to the users with poor channel conditions can still be accessed by the users with strong channel conditions, which significantly improves the spectral efficiency. Furthermore, compared to conventional opportunistic user scheduling which only serves the users with strong channel conditions, NOMA strikes a good balance between system throughput and user fairness. In other words, NOMA can serve users with different channel conditions in a timely manner, which provides the possibility to meet the demanding 5G requirements of ultra-low latency and ultra-high connectivity.

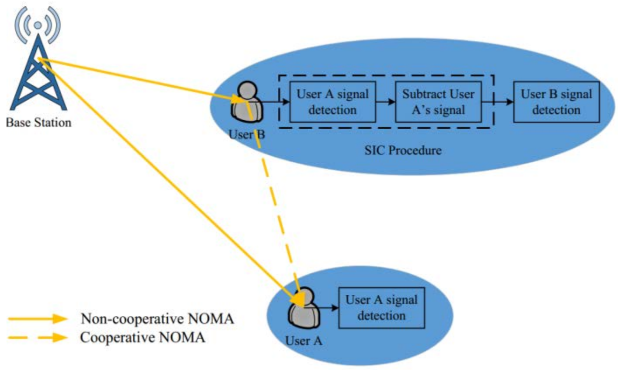

Figure 1.1 a two-user NOMA network that involves non-cooperative NOMA transmission.

A standardized multiple access (MA) scheme is usually considered as the representative feature for a cellular system in each generation, e.g., code division multiple access in 3G, and OFDMA/SC-FDMA in 4G. An appropriate MA scheme enables massive mobile devices accessing the limited network resources efficiently and achieving supreme system performance. Figure 1.1 Demonstrate the NOMA network transmission. This research has addressed several resource allocation techniques for 4G and 5G networks.

A. Orthogonal Multiple Access in LTE

In 4G LTE systems, sometimes also referred to as LTE-A which was standardized in the third generation partnership project (3GPP) two advanced orthogonal multiple access (OMA) schemes, OFDMA and SC-FDMA, have been adopted as the standard MA schemes for downlink and uplink transmission. Both MA schemes are considered as the appropriate technique to support users' diverse quality of service (QoS) requirements, exploit the flexible frequency granularity and achieve high spectral efficiency. The frequency bandwidth can be from 1.25 MHz to 20 MHz. By adopting multiple- input multiple-output (MIMO), LTE-A is able to support a peak data rate in Gbps.

- OFDMA

In LTE downlink, OFDMA is based on the concept of multi-carrier transmission. In the frequency domain, the spectrum is divided into a large number of narrow-band subcarriers (or subchannels). The subcarrier bandwidth equals 15 kHz in both LTE downlink and uplink. The center frequency of each subcarrier is selected such that all the subcarriers are mathematically orthogonal to each other, and thus eliminates the interference between the adjacent subcarriers. The orthogonality avoids the need of separating the subcarriers by means of guard-bands, i.e.,

Placing empty frequency bandwidth between adjacent subcarriers, and therefore saves the bandwidth resource.

B. Non-orthogonal Multiple Access

With the deployment of commercial LTE networks worldwide, 4G is reaching maturity. Looking forward to the future, the rapid growth in traffic data volume and the number of connected mobile devices, and the emergence of diverse application scenarios are still the main driving force to develop the next generation communication system. In recent years, 5G has attracted extensive research and development efforts from the wireless communication community. The performance requirements of 5G systems have been firstly identified to adequately support wireless communications in future scenarios. It is widely accepted that, in comparison to LTE networks, 5G will be able to support 1000-fold gains in system capacity, peak data rate of fiber-like 10 Gbps and 1 Gbps for low mobility and high mobility, respectively, and at least 100 billion devices connections, ultra low energy consumption and latency.

To fulfill these stringent requirements, the design of 5G network architecture will be different from LTE, and the current OMA schemes also need to be evolved. Several non-orthogonal MA schemes are under investigation for 5G. Compared to OMA in LTE, the new MA enables considerable performance improvements in system throughput and capacity of connecting mobile devices. Moreover, the non-orthogonal design of MA provides good backward compatibility with OFDMA and SC-FDMA. demonstrated in figure 1.2.

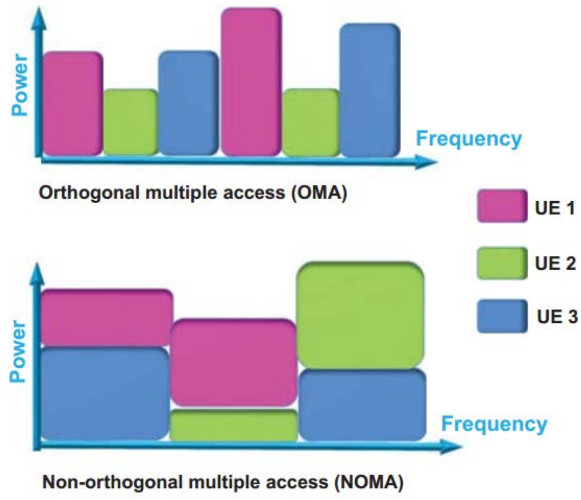

Figure 1.2 OMA and NOMA.

II. SYSTEM MODEL

The concept of non-orthogonal multiple access is that the same frequency resource, e.g., subchannels, RBs, can be shared by multiple-user signals in the code or power domain, resulting in non-orthogonality among user access. By relying on advanced receivers, multi-user detection and successive interference cancellation (SIC) are applied for signal separation at the receiver side.

This scheme applies superposition coding (SC) to superpose multiple UEs' signals at the transmitter, and performs SIC at the receiver to separate and decode multi-user signals. Throughout this research, simply use "NOMA" to denote this power-domain non-orthogonal MA scheme. Figure 2 shows an illustration for single-cell OMA and NOMA in the power (as well as frequency) domain. In OMA, each UE has exclusive access to the radio resource, whereas each subchannel in NOMA can accommodate more UEs. In OMA, the maximum number of UEs who can concurrently access the subchannels is limited by the number of subchannels. Compared to OMA, the number of the simultaneously multiplexed UEs in NOMA can be largely increased. Dynamic switching between OMA and NOMA is considered in some works. In practical scenarios, a hybrid scheme can be designed so that NOMA or OMA is only performed when it enables better performance over the other scheme.

As shown in Figure 2.1, a BS serves two UEs by using the same subchannel. UE 1 is geographically much closer to the BS than UE 2, thus we assume that use 1 has a stronger link to the BS, with better channel condition than UE 2. At the transmitter, the BS is supposed to transmit signals x1 and x2 for two UEs, respectively. After SC in NOMA, xi and x2 are superposed to a signal x which is broadcasted to both receivers.

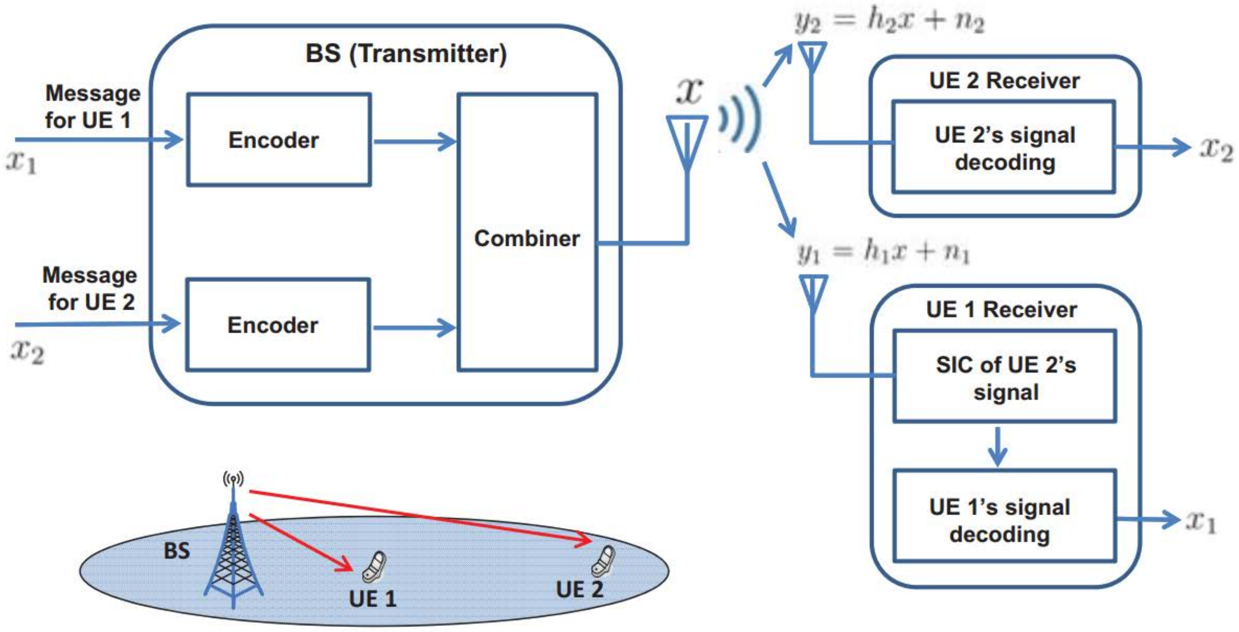

Figure 2.1 superposition coding and SIC receiver.

the complex channel gain for UE k and n_k is additive white Gaussian noise for UE k. Assuming that $|hi|^2$ then the signals which can be decoded at UE 2 can most likely be decoded by UE 1 as well [29]. At the receiver side, UE 1's receiver first decodes the interfering signal x2 from y1. After subtracting x_2, the signal x_1 intended for UE 1 is decoded from h1 x_1 + n_1. At UE 2's receiver, no interference cancellation takes place, and the signal of interest, x_2, is directly decoded from y_2 by treating x_1 as noise. Apart from the power-domain NOMA, there are some other candidate non-orthogonal MA schemes are under investigation for 5G, e.g., sparse code multiple access (SCMA), multi-user shared access (MUSA), and pattern division multiple access (PDMA).

III. RELATED WORK

B. Wang, K. Wang, Z. Lu, T. Xie and J. Quan, [1] With the development of mobile Internet and Internet of things (IoT), the 5th generation (5G) wireless communications will foresee explosive increase in mobile traffic. To address challenges in 5G such as higher spectral efficiency, massive connectivity, and lower latency, some non-orthogonal multiple access (NOMA) schemes have been recently actively investigated, including power-domain NOMA, multiple access with low-density spreading (LDS), sparse code multiple access (SCMA), multiuser shared access (MUSA), pattern division multiple access (PDMA), etc. Different from conventional orthogonal multiple access (OMA) schemes, NOMA can realize overloading by introducing some controllable interferences at the cost of slightly increased receiver complexity, which can achieve significant gains in spectral efficiency and accommodate much more users. In this research, we will discuss basic principles and key features of three typical NOMA schemes, i.e., SCMA, MUSA, and PDMA. What's more, their performance in terms of uplink bit error rate (BER) will be compared. Simulation results show that in typical Rayleigh fading channels, SCMA has the best performance, while the BER performance of MUSA and PDMA are very close to each other. In addition, we also analyze the performance of PDMA using the same factor graph as SCMA, which indicates that the performance gain of SCMA over PDMA comes from both the difference of factor graph and the codebook optimization.

A. Osseiran et al,[2] METIS is the EU flagship 5G project with the objective of laying the foundation for 5G systems and building consensus prior to standardization. The METIS overall approach toward 5G builds on the evolution of existing technologies complemented by new radio concepts that are designed to meet the new and challenging requirements of use cases today's radio access networks cannot support. The integration of these new radio concepts, such as massive MIMO, ultra dense networks, moving networks, and device-to-device, ultra reliable, and massive machine communications, will allow 5G to support the expected increase in mobile data volume while broadening the range of application domains that mobile communications can support beyond 2020. In this article, we describe the scenarios identified for the purpose of driving the 5G research direction. Furthermore, we give initial directions for the technology components (e.g., link level components, multinode/multiantenna, multi-RAT, and multi-layer networks and spectrum handling) that will allow the fulfillment of the requirements of the identified 5G scenarios.

F. Boccardi, R. W. Heath, A. Lozano, T. L. Marzetta and P. Popovski, [3] New research directions will lead to fundamental changes in the design of future fifth generation (5G) cellular networks. This article describes five technologies that could lead to both architectural and component disruptive design changes: device-centric architectures, millimeter wave, massive MIMO, smarter devices, and native support for machine-to-machine communications. The key ideas for each technology are described, along with their potential impact on 5G and the research challenges that remain.

M. Taherzadeh, H. Nikopour, A. Bayesteh and H. Baligh,[4] Multicarrier CDMA is a multiple access scheme in which modulated QAM symbols are spread over OFDMA tones by using a generally complex spreading sequence. Effectively, a QAM symbol is repeated over multiple tones. Low density signature (LDS) is a version of CDMA with low density spreading sequences allowing us to take advantage of a near optimal message passing algorithm (MPA) receiver with practically feasible complexity. Sparse code multiple access (SCMA) is a multi-dimensional codebook-based non-orthogonal spreading technique. In SCMA, the procedure of bit to QAM symbol mapping and spreading are combined together and incoming bits are directly mapped to multi-dimensional codewords of SCMA codebook sets. Each layer has its dedicated codebook. Shaping gain of a multi-dimensional constellation is one of the main sources of the performance improvement in comparison to the simple repetition of QAM symbols in LDS. Meanwhile, like LDS, SCMA enjoys the low complexity reception techniques due to the sparsity of SCMA codewords. In this research a systematic approach is proposed to design SCMA codebooks mainly based on the design principles of lattice constellations. Simulation results are presented to show the performance gain of SCMA compared to LDS and OFDMA.

A. Benjebbour, Y. Saito, Y. Kishiyama, A. Li, A. Harada and T. Nakamura, [5] As a promising downlink multiple access scheme for future radio access (FRA), this research discusses the concept and practical considerations of non-orthogonal multiple access (NOMA) with a successive interference canceller (SIC) at the receiver side. The goal is to clarify the benefits of NOMA over orthogonal multiple access (OMA) such as OFDMA adopted by Long-Term Evolution (LTE). Practical considerations of NOMA, such as multi-user power allocation, signalling overhead, SIC error propagation, performance in high mobility scenarios, and combination with multiple input multiple output (MIMO) are discussed. Using computer simulations, we provide system-level performance of NOMA taking into account practical aspects of the cellular system and some of the key parameters and functionalities of the LTE radio interface such as adaptive modulation and coding (AMC) and frequency-domain scheduling. We show under multiple configurations that the system-level performance achieved by NOMA is higher by more than 30% compared to OMA.

L. Dai, Z. Wang and Z. Yang, [6] In the last two decades, digital television terrestrial broadcasting (DTTB) systems have been deployed worldwide. With the approval of the fourth DTTB standard called Digital Television/ Terrestrial Multimedia Broadcasting (DTMB) by International Telecommunications Union (ITU) in December 2011, the research on first-generation DTTB standards is coming to an end. Recently, with the rapid progress of advanced signal processing technologies, nextgeneration DTTB systems like Digital Video Broadcasting-Terrestrial-Second Generation (DVB-T2) have been extensively studied and developed to provide more types of services with higher spectral efficiency and better performance. This article starts from the brief review of the first-generation DTTB standards and the current status of emerging second-generation DTTB systems, then focuses on the common key technologies behind them instead of describing the specific techniques adopted by various standards. The state-of-the-art, technical challenges, and the most recent achievements in the field are addressed. The future research trends are discussed as well. In addition, the scheme of integrating DTTB and Internet is proposed to solve the crucial problem of information expansion.

IV. POBLEM STATEMENT

It is important to point out that NOMA can be applied to general uplink and downlink scenarios with more than two users. However, the use of superposition coding and SIC can cause extra system complexity, which motivates the use of user pairing/clustering, an effective approach to reduce the system complexity since fewer users are coordinated for the implementation of NOMA. However, in some NOMA systems, it is very challenging to determine how best to dynamically allocate users to a fixed/dynamic number of clusters with different sizes. It is important to point out that the resulting combinatorial optimization problem is in general NP-hard and performing an exhaustive search for an optimal solution is computationally prohibitive. Therefore, it is important to propose new low-complexity algorithms to realize optimal user clustering.

V. CONCLUSION

In these research discussed and analyzed several major NOMA schemes for 5G from the aspects of some basic principles and key features like receiver complexity, engineering feasibility, and so on. Compared to conventional OMA, NOMA allows controllable interferences to realize overloading at the cost of a tolerable increase of receiver complexity. Therefore, the demands of spectral efficiency and massive connectivity for 5G can be partially fulfilled by NOMA. opportunities and future research tends for the design of NOMA, it may the most compatible for the future generation wireless and cellular access scheme.

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