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Study and Analysis of Frequency Reuse for MU Massive MIMO Systems

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***Abstract* - The high-speed data rate is the demand of current wireless communication. The speed of data depends on the utilization of resources and technology. In the current decade, the massive MIMO system is proposed in terms of multiple antennae and various diversity of frequency selection. The selection and utilization of frequency increase the efficiency of the allocated spectrum. The resource of the spectrum is limited; now, use the concept of frequency reuse. The frequency reuse increased channel allocation and enhanced the data rate. The reuse of frequency raised some problems in terms of interference and signal interference noise. These noise values degraded the fairness and throughput of communication models. The conventional communication beamforming cannot support the concept of massive MIMO for multiuser in this paper study and analysis of massive MIMO with the different conditions of frequency allocation scheme. Also, present the review of massive MIMO algorithms and limitation for the next-generation wireless communication.**

Keywords - Wireless Communication, OFDM, MIMO, Frequency Reuse, MU, 5G

I. INTRODUCTION

Orthogonal frequency division multiplexing (OFDM) is a promising wireless communication technology that provides high spectral efficiency and robustness against frequency selectivity. It has already been included in several communication standards, including the IEEE 802.11 wireless local area networks (WLAN). The combination of OFDM with multi-input multi-output (MIMO), a technique capable of offering multiplexing and diversity gains via multiple antennas, exploits the potential of both techniques. The so-termed MIMO-OFDM has already been put into commercial use in the downlink of long-term evolution (LTE)[1, 3]. It is also considered to be the most competitive candidate for next-generation mobile communications. Index modulation is a recently emerging concept that is characterized by conveying the information bits with the indices of the active constellation symbol carriers[4, 6]. Precoding is a potential technique to overcome the detection complexity issue at the downlink receivers. Based on the CSI at the transmitter, precoding provides high capacity and full transmit diversity[2, 5]. Meanwhile, the co-channel interference (CCI) among antennas/users can also be completely eliminated, the signal flows at different antennas/users, therefore, can be orthogonal, which enables low-complexity detection at the receiver and also empowers the application of space division multiple access (SDMA) in multi-user MIMO (MU-MIMO) systems[7]. Thus, precoding has been considered one of the core technologies for the downlink of massive MIMO systems. Previous efforts to combine precoding with SM in single-carrier MIMO systems have been well discussed in point-to-point and broadcast channels, which select the receiver-side active antennas to carry information and are reported to have improved performance relative to conventional pre-coded single-carrier MIMO schemes. The above-mentioned works exploit the space domain degree of freedom to perform index modulation and indicate a promising future of the PIM schemes. [10-12].

There has been a tremendous interest in IM schemes over the past few years. IM is a high spectrum- and energy-efficient yet simple digital modulation technique, which utilizes the indices of the building blocks of the corresponding communication systems to convey additional information bits[13]. IM systems provide alternative ways to transmit information in contrast to traditional digital modulation schemes that rely on the modulation of the amplitude/phase/ frequency of a sinusoidal carrier signal for transmission, as widely considered in the field of communications over the past 50 years. Radically, IM schemes can map information bits by altering the on/off status of their transmission entities such as transmit antennas, subcarriers, radio frequency (RF) mirrors, transmit light-emitting diodes (LEDs), relays, modulation types, time slots, precoder matrices, dispersion matrices, spreading codes, signal powers, loads and so on[14, 15, 16]. In other words, IM creates completely new dimensions for data transmission. Since the indices of these building blocks can be used to transmit information through an on/off keying mechanism, IM schemes can transfer the saved transmission energy from the inactive transmit entities to the active ones, and this results in an improved error performance compared to the traditional schemes that use the same total transmission energy[17, 20]. The rest of the paper organized as section II. Related work. In section III, discuss the problem formulation in section IV comparative result of MIMO different techniques, and finally discuss conclusion and future work.

II. LITERATURE REVIEW

The wireless communication in the field of battle in concern of performance and air environments noise. In the journey of wireless communication, various methods are proposed for the enhancement of the performance. Some authors and researchers discuss the future generation of wireless communication in concern of index modulation and do some work discuss here.

Junyuan Wang, Huiling Zhu, Nathan J. Gomes, and Jiangzhou Wang Et al. [1] They focus on a fixed-beam based multiuser massive MIMO system, where each user is served by a beam allocated to it. To maximize the sum data rate, a greedy beam allocation algorithm is discussed under the practical condition that the number of radiofrequency chains is smaller than the number of users.

Erik G. Larsson, Ove Edfors, Fredrik Tufvesson and Thomas L. Marzetta Et al. [2] They have highlighted the large potential of massive MIMO systems as a key enabling technology for future beyond 4G cellular systems. The technology offers huge advantages in terms of energy efficiency, spectral efficiency, robustness and reliability. It allows for the use of low-cost hardware both at the base station as well as at the mobile unit side. At the base station, the use of expensive and powerful, but power-inefficient, the hardware is replaced by the massive use of parallel low-cost, low-power units that operate coherently together.

Song Noh, Michael D. Zoltowski, Youngchul Sung and David J. Love Et al. [3] The discussed algorithm designs the pilot beam pattern sequentially by exploiting the properties of Kalman ltering and the associated prediction error covariance matrices and also the channel statistics such as spatial and temporal channel correlation. The resulting design generates a sequentially-optimal sequence of pilot beam patterns with low complexity for a given set of system parameters.

Lu Lu, Geoffrey Ye Li, A. Lee Swindlehurst, Alexei Ashikhmin and Rui Zhang Et al. [4] They present a comprehensive overview of state-of-the-art research on the topic, which has recently attracted considerable attention. They begin with an information-theoretic analysis to illustrate the conjectured advantages of massive MIMO, and then They address implementation issues related to channel estimation, detection and precoding schemes. They particularly focus on the potential impact of pilot contamination caused by the use of non-orthogonal pilot sequences by users in adjacent cells. They also analyze the energy efficiency achieved by massive MIMO systems and demonstrate how the degrees of freedom provided by massive MIMO systems enable efficient single-carrier transmission.

Volker Jungnickel, Konstantinos Manolakis, Wolfgang Zirwas, Berthold Panzner, Volker Braun, Moritz Lossow, Mikael Sternad, Rikke Apelfröjd and Tommy Svensson Et al. [5] They discussed a smart combination of small cells, joint transmission coordinated multipoint (JT CoMP), and massive MIMO to enhance the spectral efficiency with affordable complexity. They review recent achievements in the transition from theoretical to practical concepts and note future research directions. They show in measurements with macro-plus-small-cell scenarios that spectral efficiency can be improved by flexible clustering and efficient user selection, and that adaptive feedback compression is beneficial to reduce the overhead significantly.

Zhen Gao, Linglong Dai, De Mi, Zhaocheng Wang, Muhammad Ali Imran and Muhammad Zeeshan Shakir Et al. [6] They discussed a digitally-controlled phase-shifter network (DPSN) based hybrid precoding/combining scheme for mmWave massive MIMO, whereby the low-rank property of mmWave massive MIMO channel matrix is leveraged to reduce the required cost and complexity of transceiver with a negligible performance loss. One key feature of the discussed scheme is that the macro-cell BS can simultaneously support multiple small-cell BSs with multiple streams for each small-cell BS, which is essentially different from conventional hybrid precoding/combining schemes typically limited to single-user MIMO with multiple streams or multi-user MIMO with the single stream for each user.

Gang Wu, Chenyang Yang, Shaoqian Li and Gefforey Ye Li Et al. [7] The methodology in analyzing the SE-EE relationship has been summarized, and energy-efficient resource allocation has been addressed from the optimization perspective. Many open issues in designing energy-efficient 5G systems, such as massive MIMO, D2D and UDN, have been provided.

Kan Zheng, Long Zhao, Jie Mei, Bin Shao, Wei Xiang and Lajos Hanzo Et al. [8] the state of the art of LS-MIMO systems, First, they discuss the measurement and modeling of LS-MIMO channels. Then, some typical application scenarios are classified and analyzed. Key techniques of both the physical and network layers are also detailed. A range of channel measurements and channel models were presented, complemented by a variety of open research issues. Then, a pair of practical application scenarios were discussed, namely HomoNets and HetNets. The design of sophisticated TPCs and detection schemes is vital for achieving the potential gains promised by LS-MIMO systems.

Jeffrey G. Andrews, Stefano Buzzi, Wan Choi, Stephen Hanly, Angel Lozano, Anthony C.K. Soong and Jianzhong Charlie Zhang Et al. [9] It has highlighted, it is a long road ahead to truly disruptive 5G networks. Many technical challenges remain spanning all layers of the protocol stack and their implementation, as well as many intersections with regulatory, policy, and business considerations.

Emil Bjornson, Erik G. Larsson and Thomas L. Marzetta Et al. [10] The Massive MIMO technology use a nearly infinite number of high-quality antennas at the base stations. By having at least an order of magnitude more antennas than active terminals, one can exploit asymptotic behaviors that some special kinds of wireless channels have. This technology looks great at first sight, but unfortunately, the signal processing complexity is off the charts and the antenna arrays would be so huge that it can only be implemented in millimeter wave bands. They identify ten myths and explain why they are not true.

Dongming Wang, Yu Zhang, Hao Wei, Xiaohu You, Xiqi Gao and Jiangzhou Wang Et al. [11] The state-of-the-art research progress on the wireless transmission theory and technology in LSAS have been summarized, which covers the theoretical analysis of the spectral efficiency, CSI acquisition, uplink and downlink wireless communication, and resource allocation. Besides, this paper also presented potential research topics. Although there have already been some experimental large-scale MIMO systems, and the 3GPP standard organization is also promoting the evolution of relevant technology, a large number of theoretical and engineering problems should be addressed.

Chen Sun, Xiqi Gao, Shi Jin, Michail Matthaiou, Zhi Ding and Chengshan Xiao Et al. [12] They discussed a beam division multiple access (BDMA) transmission scheme that simultaneously serves multiple users via different beams. By selecting users within non-overlapping beams, the MU-MIMO channels can be equivalently decomposed into multiple single-user MIMO channels; this scheme significantly reduces the overhead of channel estimation, as well as, the processing complexity at transceivers. For BDMA transmission, they work out an optimal pi-lot design criterion to minimize the mean square error (MSE) and provide optimal pilot sequences by utilizing the Zadoff-Chu sequences.

Eduardo Castaneda, Adao Silva, Atılio Gameiro and Marios Kountouris Et al. [13] Several transmission technologies and precoding techniques have been developed in order to exploit the spatial dimension so that simultaneous transmission of independent data streams reuse the same radio resources. The current performance of MU-MIMO processing is still limited in 4G cellular communication systems. This is because user terminals do not perform interference estimation, and in all cases, only CSI feedback for the SU-MIMO mode is employed.

Tadilo Endeshaw Bogale and Long Bao Le Et al. [14] They discussed algorithm is explained as follows. First, they formulate the channel estimation problem as a weighted sum mean square error (WSMSE) minimization problem containing pilot symbols and introduced variables. Second, for fixed pilot symbols, the introduced variables are optimized using minimum mean square error (MMSE) and generalized Rayleigh quotient methods.

Daniel C. Araújo, Taras Maksymyuk, André L. F. de Almeida, Tarcisio Maciel, João C. M. Mota and Minho Jo Et al. [15] There is great potential in scaling up the number of antennas at the BS in "beyond LTE" wireless communication standard. It allows us to improve spectral efficiency and to implement parallel low-cost power amplifiers while making the system more robust and reliable. For next-generation wireless communications, they discussed futuristic scenarios where Massive MIMO meets potential applications such as wireless backhaul for small cells or interference management in network-assisted D2D communications.

Ning Wang, Ekram Hossain, and Vijay K. Bhargava Et al. [16] Solutions based on the General Algorithm Modeling System (GAMS) optimization solver and fast heuristics are also discussed for cell association in the per-small-cell WBBA scenario. It is shown that when all small cells have to use in-band wireless backhaul, the system load has more impact on both the sum log-rate and per-user rate performance than the number of small cells deployed within the macro cell range. They discussed joint CA-WBBA algorithms have an optimal load approximately equal to the size of the large-scale antenna array at the macro BS. The cell range expansion (CRE) strategy, which is an efficient cell association scheme for HetNets with perfect backhauling, is shown to be inefficient when in-band wireless backhauling for small cells come into play.

Kianoush Hosseini, Wei Yu and Raviraj S. Adve Et al. [17] This paper compares two important downlink multicell interference mitigation techniques, namely, large-scale (LS) multiple-input multiple-output (MIMO) and network MIMO. They consider a cooperative wireless cellular system operating in time-division duplex (TDD) mode, wherein each cooperating cluster includes B base-stations (BSs), each equipped with multiple antennas and scheduling K single-antenna users.

Jiankang Zhang, Bo Zhang, Sheng Chen, Xiaomin Mu, Mohammed El-Hajjar and Lajos Hanzo Et al. [18] They discussed an effective pilot contamination elimination scheme for multi-cell time division duplexing based orthogonal frequency division multiplexing systems, by carefully designing a sophisticated amalgam of downlink (DL) training and 'scheduled' uplink (UL) training. During the DL training stage, each base station (BS) transmits the DL pilot symbols (PSs) to its mobile stations (MSs) for them to estimate their frequency-domain channel transfer functions (FDCHTFs), which are then embedded in the UL PSs by 'pre-distorting' the PSs with the estimated FDCHTFs.

Mingjie Feng and Shiwen Mao Et al. [19] They begin with an analysis of the benefits and challenges of massive MIMO systems. They then investigate the multi-layer techniques for incorporating massive MIMO in several important network deployment scenarios.

Moussa Ayyash, Hany Elgala, Abdallah Khreishah, Volker Jungnickel, Thomas Little, Sihua Shao, Michael Rahaim, Dominic Schulz, Jonas Hilt, and Ronald Freund Et al. [20] They describe the general characteristics of Wi-Fi and VLC (or LiFi) and demonstrate a practical framework for both technologies to coexist. They explore the existing research activity in this area and articulate current and future research challenges based on their experience in building a proof-of-concept prototype VLC HetNet.

Salah Eddine Hajri, Mohamad Assaad and Giuseppe Caire Et al. [21] They consider the problem of user scheduling and pilot assignment in TDD multicell multiuser Massive MIMO systems. While in TDD systems, the channel is acquired using uplink pilots, they discussed a scheme that utilizes additional downlink probing to improve the spectral efficiency. The idea is to dynamically assign mobile users to different clusters based on the directions of their channels through the use of downlink reference beams.

Xudong Zhu, Linglong Dai, Zhaocheng Wang and Xiaodong Wang Et al. [22] A weighted graph coloring-based pilot decontamination (WGC-PD) scheme is discussed to mitigate PC for multi-cell massive MIMO systems. Specifically, based on limited cooperation among cells, an edge-weighted interference graph (EWIG) is firstly constructed to depict the potential PC relationship among users, whereby two users in different cells are connected by a weighted edge indicating the strength of potential PC when they reuse the same pilot.

Jun Zhu, Robert Schober and Vijay K. Bhargava Et al. [23] They consider secure downlink transmission in a multi-cell massive MIMO system with matched-filter precoding and artificial noise (AN) generation at the base station (BS) in the presence of a passive multi-antenna eavesdropper. They investigate the resulting achievable ergodic secrecy rate and the secrecy outage probability for the cases of the perfect training and pilot contamination. Thereby, they consider two different AN shaping matrix, namely, the conventional AN shaping matrix, where the AN is transmitted in the null space of the matrix formed by all user channels, and a random AN shaping matrix, which avoids the complexity associated with finding the null space of a large matrix.

Qing Xue, Xuming Fang and Cheng-Xiang Wang Et al. [24] They discussed a single-user multi-beam concurrent transmission scheme for future mmWave networks with multiple reflected paths. Based on spatial spectrum reuse, the scheme can be described as a multiple-input multiple-output (MIMO) technique in beamspace. The theoretical and numerical results show that the discussed beamspace SU-MIMO can largely improve the achievable rate of the transmission between an MTX and an MRX and, meanwhile, can maintain the connectivity.

Tri Minh Nguyen, Vu Nguyen Ha and Long Bao Le Et al. [25] They develop an iterative algorithm to solve the transformed problem where optimization of power allocation and the number of antennas is performed, and then pilot assignment optimization is conducted sequentially in each iteration. To tackle the first sub-problem, they employ a successive convex approximation (SCA) technique to attain a solvable convex optimization problem.

Zhongshan Zhang, Xiyuan Wang, Keping Long, Athanasios V. Vasilakos and Lajos Hanzo Et al. [26] This paper is intended to offer a state-of-the-art survey on LS-MIMO research, to promote the discussion of its beneficial application areas and the research challenges associated with BF aided wireless back-haul, LS-MIMO channel modeling, signal detection, and so on. Additionally, a joint group power allocation and a pre-beamforming scheme called JGPAPBF is discussed to substantially improve the performance of LS-MIMO-based wireless back-haul in heterogeneous networks.

Song Noh, Michael D. Zoltowski and David J. Love Et al. [27] They consider the problem of training sequence design that employs a set of training signals and its mapping to the training periods. They focus on reduced-dimension training sequence designs, along with transmitting precoder designs, aimed at reducing both hardware complexity and power consumption.

Peng Wang, Yonghui Li, Lingyang Song and Branka Vucetic Et al. [28] They introduce the propagation characteristics of E-band signals, based on which some potential fixed and mobile applications at the E-band are investigated. In particular, they analyze the achievability of non-trivial multiplexing gain in fixed point-to-point E-band links and discussed an E-band mobile broadband (EMB) system as a candidate for the next generation mobile communication networks. The channelization and frame structure of the EMB system are discussed in detail.

Yongpeng Wu, Robert Schober, Derrick Wing Kwan Ng, Chengshan Xiao and Giuseppe CaireEt al. [29] They investigate secure and reliable transmission strategies for multi-cell multi-user massive multiple-input multiple-output (MIMO) systems with a multi-antenna active eavesdropper. They consider a time-division duplex system where uplink training is required and an active eavesdropper can attack the training phase to cause pilot contamination at the transmitter.

Anastasios K. Papazafeiropoulos and Tharmalingam Ratnarajah Et al. [30] They derive the deterministic equivalents of the signal-to-interference-plus-noise ratios (SINRs), which capture the effect of delayed CSIT, and make the use of lengthy Monte Carlo simulations unnecessary. Furthermore, the prediction of the current CSIT after applying a Wiener filter allows evaluating the mitigation capabilities of MMSE and RZF. Numerical results depict that the discussed achievable SINRs (MMSE/RZF) are more efficient than simpler solutions (MRC/MRT) in delayed CSIT conditions and yield a higher prediction at no special computational cost due to their deterministic nature.

III. PROBLEM FORMULATION

The maximizing of throughout wireless communication is a great challenge due to the increasing rate of the user and limited resources of channel and spectrum. The proper utilization of spectrum and channel used various methods and algorithms, but it still suffered from the problem of bit error rate and co-channel interference. Some points of problem-related to multi-input multi-output in index modulation mention here[3-7]. Every communication system can be theoretically considered as a special case of IM; however, the term of IM is explicitly used to cover the family of communication systems that consider other transmit entities than amplitudes/frequency/phases to convey information. Although early attempts have been made to explore the potential of IM-based schemes during the beginning of this century. As of today, this wave is increasingly spreading and speeding up. SM, which considers IM for the transmit antennas of a MIMO system, has attracted tremendous attention over the past few years and introduced new directions for the implementation of MIMO systems. Although having very strong and well-established opponents such as vertical Bell Laboratories layered space-time (V-BLAST) [9] and space-time coding (STC) systems [10], SM schemes have quickly shown their true potential in terms of spectral and energy efficiency and, consequently, have been regarded as possible candidates for next-generation small/large-scale and single/multi-user MIMO, full-duplex (FD), cooperative and cognitive radio (CR) systems. SM has been the front-runner of IM techniques and has also trigged the spread of IM to orthogonal frequency division multiplexing (OFDM) first, and then to other systems. The scheme of OFDM-IM [8] has shown that IM is not unique to the transmit antennas of MIMO systems and it has opened the door for the introduction of many other IM-based schemes in the recent 1-2 years. More importantly, recent studies have shown that OFDM-IM can offer appealing advantages over classical OFDM, which is an integral part of today's many wireless communication standards and is considered as a strong waveform candidate for 5G wireless networks. Fortunately, IM has found new application areas by considering other transmit entities of communication systems such as time slots, precoding matrices, modulation types, and so on.

IV. Comparative Performance Analysis

TABLE I. Comparative Performance Analysis

Sr. No.	Method	BER	SNR	Node Density	Subcarrier	Carrier Bandwidth	SNR Threshold
1.	Generalized OFDM-IM Schemes	1x10^-3	5	1x10^-5	0.1	200 Mhz	0 dB
2.	PIM-MIMO-OFDM	1.1x10^-4	4.5	-	0.17	200 Mhz	0.55 dB
3.	MBM-LM	1x10^-3	6	-	-	250 Mhz	0.68 dB
4.	Traditional method	1x10^-5	-	1x10^-3	-	-	0.70 dB
5.	FEC code anchored robust based method	-	5	-	0.49	200 Mhz	0.69 dB
6.	TI-MBM-LM	1.2x10^-3	6.2	1x10^-3	0.52	300 Mhz	0 dB
7.	RAU selection algorithm	-	7.8	1x10^-3	-	250 Mhz	0 dB
8.	Cell-Free Massive MIMO with shadowing correlation-based method	1.5x10^-5	-	1x10^-5	-	-	0.98 dB
9.	Traditional method	1x10^-4	2.7	-	0.69	200 Mhz	0 dB
10.	RAU selection algorithm	-	6	1x10^-3	0.85	-	0 dB
11.	Traditional method	-	-	1x10^-4	-	-	0.90 dB
12.	Cell-Free Massive MIMO with shadowing correlation-based method	1x10^-3	-	-	-	300 Mhz	0.50 dB
13.	TX+RX I/Q	1x10^-3	8	1x10^-6	0.37	200 Mhz	0 dB

V. CONCLUSION & FUTURE WORK

In this paper, the study of massive MIMO systems for high-speed data transfer networks. Paper also focuses on the concept of frequency reuse and resource allocation. The concept of frequency reuse deals in a different mode of beamforming, such as universal frequency reuse, fixed frequency reuse and adaptive frequency. The study of communication of MIMO systems indicates that the fixed frequency-based beamforming is better than other methods of frequency use. The concept of frequency reuse faced a problem of intercell interference and degraded the outage probability of data. For the betterment of frequency used, various authors used the concept of multi-cell frequency reuse. The massive MIMO offers huge advantages in terms of energy efficiency, spectral efficiency, robustness and reliability. It allows for the use of low-cost hardware both at the base station as well as at the mobile unit side. At the base station, the use of expensive and powerful, but power-inefficient, the hardware is replaced by the massive use of parallel low-cost, low-power units that operate coherently together. There are still challenges ahead to realize the full potential of the communication models.

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