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A REVIEW ON 5G TECHNIQUES FOR WIRELESS COMMUNICATION SYSTEM

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Abstract

This paper provides an overview in incorporating massive multiple input multiple output (MIMO), non-orthogonal multiple access (NOMA) and adaptive modulation and coding (AMC) in a unified framework. These technologies collectively contribute to improving spectral efficiency, meeting capacity demands, enhancing user fairness, improving coverage and reliability and adapting to varying channel conditions. NOMA achieves higher capacity by serving multiple users in the same time-frequency resources, while massive MIMO allows simultaneous communication with multiple users through spatial multiplexing. AMC plays a crucial role in addressing adapting to varying channel conditions by dynamically adjusting the modulation and coding schemes based on the channel conditions. This ensures that the data rates are optimized for the prevailing channel quality, improving reliability and performance.

Keywords - Massive multiple input multiple output (MIMO), Non-orthogonal multiple access (NOMA), Adaptive modulation and coding (AMC)

1. Introduction

The impending arrival of the fifth generation (5G) of mobile networks heralds an incredible transformation and promises to have a remarkable impact on the world. 5G represents a groundbreaking advancement that seamlessly connects people across the globe, revolutionizing communication and connectivity. The journey began with the advent of 1G, the first wireless phone technology, which was later upgraded to 2G in the early 1990s. This allowed users to exchange text messages between cellular handsets, captivating the world. Subsequently, the introduction of 3G enabled phone calls, text messaging, and internet browsing, facilitating smooth access to vast amounts of data, including videos. To further enhance connectivity, the long-term evolution (LTE) technology was introduced as the standard for 4G networks. LTE proved to be a fast and reliable option, competing with WiMax and establishing a solid foundation for 5G [1]. The prominence of 5G networks extends beyond the realm of traditional telecommunications. It has garnered immense attention from various industries such as manufacturing, smart cities, automotive, tourism, and public utilities. With its arrival, 5G will drive innovation across these sectors, serving as a catalyst for emerging technologies like the Internet of Things (IoT) and Cloud Computing, becoming integral components of our economy and lifestyle [2]. The capabilities of 5G are immense, offering unrivalled connectivity, increased speed, and transformative features that will propel society into a new era of possibilities. At the forefront of enabling these advancements is the non-orthogonal multiple access (NOMA) system, which satisfying the various 5G and beyond needs. The NOMA system is designed to address key aspects like high efficiency and scalability for massive networks, sophisticated optimization and consistent quality. It introduces a range of attractive features and advancements including low latency, ultra-dense service coverage, fair resource allocation, innovative waveform architecture, efficient utilization of available bandwidth, and support for a massive number of connected devices. These features set NOMA apart from earlier multiple access schemes.

2. Literature Review

NOMA

It is the newest addition to multiple access technique proposed for third generation partnership project (3GPP) LTE and effective multiple accesses (MA) approach that can increase spectral efficiency of mobile networks as compare to other multiple access scheme used in 4G like orthogonal frequency-division multiple access (OFDMA) [3]. In an orthogonal scheme like time division multiple access (TDMA) and OFDMA, a perfect receiver can effectively distinguish the desired signal from unwanted signals by utilizing various basis functions. In simpler terms, signals from various users are mutually independent and non-interfering in orthogonal schemes. In TDMA, same frequency channel is shared by several users by taking turns in a time-sharing manner. Each user communicates in rapid succession, utilizing their designated time slots. On the other hand, OFDMA facilitates multi-user communications through OFDM where subcarrier frequencies are carefully selected to be orthogonal to one another. In contrast to OMA, NOMA permits multiple users to share simultaneously a single frequency channel within the same cell, offering several advantages such as improved spectral efficiency, less complex channel feedback, slighter transmission latency [4]. Two realization techniques for NOMA are Direct-Sequence Code Division Multiple Access (DS-CDMA) and Interleave Division Multiple Access (IDMA). DS-CDMA employs user specific spreading sequences for multiple accesses, which can result in rate loss and is not ideal for high-rate applications. In contrast, IDMA addresses this issue by using user specific interleaving for multiple accesses, eliminating rate loss [5]. NOMA serves as a general structure, encompassing various as particular examples, newly proposed 5G multiple access methods. Its compatibility with 5G and beyond wireless systems allows seamless integration. For instance, NOMA can be integrated with TDMA and OFDMA without requiring changes to the resource blocks. NOMA is also referred to as multi user superposition transmission (MUST) and allows coexisting service of two users on identical subcarrier. It has also been incorporated into the future digital TV standard advanced television system committee (ATSC 3.0), known as layered division multiplexing (LDM), enhancing spectral efficiency by superimposing multiple data streams [6]. There are different techniques of NOMA like ALOHA-NOMA combines simplicity of ALOHA with the higher throughput capabilities of NOMA and ability to resolve collisions through SIC receiver. The massive MIMO techniques also combined with NOMA to improve performance of wireless system [7-8]. The improvement in NOMA system also done using modified the approach of multiple access techniques [9-12]. Improvement also associated in solving the core problem of the NOMA system like Pilot contamination reduction interference cancellation [13-14].

GFDM

It is a generalized form of OFDM, which retains most of the advantageous properties of OFDM while deducting its limitations and discuss that the limitations due to the carrier aggregation in an OFDM system is minimized by using GFDM system, since it provides a very low out-of-band radiation. GFDM uses circular filtering instead of linear filtering used in OFDM, which minimizes the prototype filter transient intervals and hence the latency. Because of this, it can provide for low latency applications like internet of things (IoT) and M2M. It is also robust to loss of orthogonality and limits the inter carrier interference (ICI), by filtering the subcarriers using a well designed prototype filter [15].

FBMC

Filter band multi carrier system utilizes a set of filters along with the OFDM technique, replacing the traditional Cyclic Prefix (Cp) in the transceiver. By eliminating the Cp, the system becomes more advantageous and outperforms the conventional OFDM system. FBMC exhibits weaker side lobes and reduced Inter-Carrier Interference (ICI), making the Cp unnecessary and leading to improved bandwidth utilization. FBMC effectively addresses the issues of synchronization errors and dispersion independently, allowing for individual processing of channel assessment and detection for each subcarrier. This capability enhances the system's ability to manage and detect errors and dispersion within the transmission [16].

UFMC

The Universal filter multi carrier (UFMC) modulation design is considered well suited for 5G as it combines features from both FBMC and OFDM. Unlike FBMC, UFMC applies filtering to a cluster of sub-carriers rather than each subcarrier individually, resulting in reduced side lobes and increased system efficiency. This design allocates the bandwidth into several sub-bands, which are then distributed among the sub-carriers [17].

AMC in 5G system

With the growing demand for wireless communications and advancements in technology enhancing the utilization of frequency bands has become a crucial challenge. AMC offers an effective solution to address this issue. The primary goal of this technique is to enhance link spectrum utilization, decrease system bit error rate, maintain constant transmission power, minimize interference to other users and cater to the diverse requirements of different data types. The fundamental principle involves adjusting coding and desired modulation methods based on current channel quality within system limit, thereby maximizing data transmission rate while maintaining data quality. In AMC system, when the channel conditions are excellent, higher order modulation and coding schemes such as 64 QAM are employed to boost transmission efficiency and spectrum utilization. Conversely in poor channel conditions, lower coding and modulation schemes like QPSK are used to reduce inter symbol interference and reduce BER, ensuring accurate data transmission and overall throughput. Recent research on AMC focuses on

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OFDM and MIMO technologies. Combining AMC with OFDM, a key technology in LTE/5G enhances system flexibility and AMC's reliability. MIMO utilizes multiple transmit and receive antennas to optimize space resources. AMC based MIMO allows each transmission channel to achieve high capacity, effectively increasing data transmission rates. Thus, the integration of AMC with various technologies has become a vital approach to enhance transmission efficiency. AMC technology has been widely adopted in mainstream cellular system standards and international organizations such as IEEE and 3GPP have incorporated AMC into wireless communication technology standard [18].

M-MIMO Systems for 5G

In traditional MIMO systems, the maximum number of antenna elements employed is limited to 8 at both the transmitter and receiver sides, forming an 8x8 MIMO system. However, in the context of M-MIMO and its implementation in 5G new radio, the base station (BS) can support up to 256 antennas, while user equipment (UE) can have up to 32 antennas. This increase in the number of antenna elements allows for notable enhancements in throughput and coverage within cellular networks. The use of multiple antenna elements helps counteract the higher path loss experienced at higher frequencies. By combining energy from these elements in a specific direction, the system can effectively overcome the challenges posed by high frequencies. This incorporation of beam forming techniques into MIMO enables radio energy to be concentrated within smaller angular sectors, leading to a substantial improvement in spectral efficiency [19].

Pilot Contamination Reduction in M-MIMO System

Pilot contamination in the M-MIMO system arises due to the use of non-orthogonal training sequences. These non-orthogonal training sequences have a substantial impact on the channel estimate, leading to degraded pre-coding matrices and severe inter cell interference. As a result, the system's throughput becomes limited to a small value, even with an increasing number of base station antennas. Pilot transmission is completed at non overlapping times in each cell.

To address these issues and enhance the capability and robustness of the M- MIMO system, two efficient pilot contamination reduction schemes are proposed based on the TDD (Time Division Duplex) M- MIMO system model: the directional pilot scheme and the MCP (Maximum Contaminated Pilot) scheme. These reduction schemes significantly improve the performance of the M- MIMO system and mitigate the impact of pilot contamination [13].

In the context of 5G wireless networks, there are numerous challenges to address in order to efficiently support large scale heterogeneous traffic and users. To meet these evolving demands, novel modulation and multiple access (MA) schemes are currently under development. With the continuous expansion of this research field, it becomes increasingly crucial to thoroughly analyse and evaluate the various approaches being proposed [14].

Utilizing M-MIMO in low-frequency bands would be ideal, but it faces practical challenges due to the large form factor size of the antenna arrays. To overcome this limitation, modular M- MIMO offers a promising solution. It involves distributing a large active antenna array into smaller standardized antenna modules, akin to Lego-type building blocks. This approach allows the benefits of M-MIMO to be harnessed in low frequency bands, such as sub-1 GHz, without being constrained by spatial limitations [21].

3. Summary of literature review

S. NO.	Author	Title	Publisher	**Findings & Relevance**	**Research Gap**
1	Z. Ding *et al* **2017**	Application of Non-Orthogonal Multiple Access in LTE and 5G Networks	IEEE	(1) NOMA permits multiple users to share simultaneously a single frequency channel within the same cell at the same time/frequency/ code, but with different power levels. (2) The user with the stronger channel condition needs to first detect the message for its partner, then subtract this message from its observation and finally decode its own information. This procedure is called **SIC**. (3) The message to the user with the weaker channel condition is allocated more transmission power, which ensures that this user can detect its message directly by treating the other user's information as noise.	(1) Since multiple users share the same time, frequency and spreading code, so co-channel interference is strong in NOMA systems (2) Once an error occurs in SIC, all other user information will likely be decoded erroneously. (3) Channel estimation errors are caused by the imperfect design of channel estimation algorithms and noisy observations and are damaging to NOMA networks.
2	Z. Ding, X. Lei, G. K. Karagiannidis, R. Schober, J. Yuan and V. K. Bhargava **2017**	A Survey on Non-Orthogonal Multiple Access for 5G Networks: Research Challenges and Future Trends	IEEE	NOMA can be integrated with massive MIMO and other wireless technologies.	The performance gain of this combination can be realized only if the massive MIMO BS has perfect channel state information (CSI).

3	R. Varshney, P. Jain and S. Vijay 2018	Massive MIMO Systems In Wireless Communication	IEEE	Merger of OFDM with MIMO enhances data rate and channel capacity.	CSI error may seriously affect the performance in massive MIMO system.
4	R. Swaroop and A. Kumar 2020	A brief study and analysis of NOMA techniques for 5G	IEEE	Compares NOMA and non-orthogonal waveform modulation techniques to be used in 5G.	Permits restricted decoding and eliminating interference capability
5	Y. Wang, W. Liu and L. Fang 2020	Adaptive Modulation and Coding Technology in 5G System	IEEE	To adjust the coding and modulation methods according to the current channel quality changes.	It is applicable only when channel state information is known.
6	Khwandah, S.A., Cosmas, J.P., Lazaridis 2021	Massive MIMO Systems for 5G Communications	SPRINGER	(1) By increasing the number of antennas, the power is better focused in a narrower beam (Beam forming). (2) Beam forming results in significantly less wasted power in the coverage area. (3) It results in less interference and increases the spectral efficiency	(1) Huge quantity of antennas on the BS consequences high complication of the channel state information extraction. (2) Pilot Contamination limits the achievable throughout.

4. Conclusion

Due to the several advantages of NOMA assisted wireless communication, it is considered the technology of the era. In this paper we have reviewed different wireless technology used in wireless communication. The integration of massive MIMO, NOMA and AMC enhances the performance of wireless communication system. NOMA and M- MIMO both enhances spectral efficiency by enabling more efficient utilization of spectrum resources. NOMA achieves this by multiplexing multiple users in the power domain, while M- MIMO utilizes multiple antennas to support multiple users simultaneously. The use of adaptive modulation and coding scheme enhances the system reliability, capacity, and robustness.

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