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Application of Non-Orthogonal Multiple Access Using Reconfigurable Antenna in 5g Communication

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ABSTRACT

This paper aims to realize a new multiple access technique based on recently proposed 5G communication. Integration of the presented reconfigurable antenna systems with the well-known non-orthogonal multiple access (NOMA) technique causes a significant degradation in sum rate due to the predictable power division in reconfigurable antennas. To circumvent this fundamental limit, a new multiple access technique is proposed. The integration of reconfigurable antenna systems with NOMA is a logical step in leveraging the capabilities of both technologies. The integration of reconfigurable antenna systems with NOMA is a logical step in leveraging the capabilities of both technologies. The technique which is called reconfigurable antenna non orthogonal multiple access (RA-NOMA) is proposed here. Three different cases are considered, i.e., OMA, RAMA-OMA and RA-NOMA with partial and full channel state information (CSI). In the first case, orthogonal multiple access is employed only. In second case RAMA is applied for OMA to enhance the performance of OMA. In the third case, RAMA with full CSI is applied to NOMA for both symmetric and asymmetric channels. All three cases are simulated in MATLAB environments. The simulation plots demonstrate the analytical findings.

Keywords: NOMA, OMA, CSI, RA-NOMA, MATLAB, 5G

INTRODUCTION

The rapid growth of global mobile data traffic is expected to be satisfied by exploiting a plethora of new technologies, deemed as 5th generation (5G) networks. 1G-3G Multiple Access Schemes are FDMA, TDMA and CDMA. Introduced Frequency Division Multiple Access (FDMA) is best suited for 1G communication. Utilized Time Division Multiple Access (TDMA) is for 2G communication and Implemented Code Division Multiple Access (CDMA) was used for 3G communication. Developed Orthogonal Frequency Division Multiple Access (OFDMA) for downlink and Single-Carrier Frequency Division Multiple Access (SC-FDMA) for uplink. These are orthogonal multiple access (OMA) schemes. 5G NR utilizes OFDMA waveform for both uplink (UL) and downlink (DL) transmissions. The emphasis on orthogonal designs in LTE, LTE Advanced, and 5G NR is highlighted. Orthogonal designs offer the advantage of minimizing mutual interference among UEs, contributing to high system performance with relatively simple receivers. NOMA allows multiple User Equipments (UEs) to be co-scheduled, sharing the same radio resources in time, frequency, and/or code. NOMA differs from existing CDMA schemes by exploiting power differences among users and asymmetrically applying Successive Interference Cancellation (SIC) in power and rate allocation. The acknowledgment that

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3GPP has considered NOMA in different applications reflects the industry's recognition of NOMA as a viable and potentially advantageous multiple access technique. The statement regarding the main difference of NOMA schemes for 5G compared to existing CDMA schemes provides a clear focus on the unique characteristics of NOMA, specifically its exploitation of power differences and asymmetric application of SIC. Explore specific use cases or scenarios where NOMA excels compared to orthogonal multiple access schemes. Investigate the impact of varying traffic loads, user mobility patterns, and deployment environments on the performance of NOMA. Discuss potential challenges associated with NOMA, such as complexity in implementation, signaling overhead, and fairness among users. Additionally, keeping an eye on recent advancements and discussions within the research community regarding NOMA could provide insights into the ongoing evolution of this technique. Users are categorized into strong and weak based on their channel gains. This classification is crucial for optimizing power allocation and leveraging the benefits of NOMA. Transmitting higher power to the weak user acknowledges the impact of path loss or channel gain, optimizing the overall system performance. The weak user can decode the desired signal without using Successive Interference Cancellation (SIC) since the signal from the strong user is negligible due to its lower transmission power. Connecting this NOMA-based approach to the evolution of mobile communication, you rightly emphasize the requirements of 5G systems: higher data rates, lower latency, and massive connectivity. Exploring specific use cases or scenarios where the downlink NOMA approach is particularly advantageous. Analyzing how downlink NOMA addresses the challenges posed by higher data rates, lower latency, and massive connectivity in the context of 5G systems.

In response to the increasing demands for higher data rates, lower latency, and massive connectivity in mobile communication systems, both academia and industry have extensively explored several promising technologies. Among these, massive multiple-input multiple-output non-orthogonal multiple access (NOMA), full-duplex (FD) communications, small cells, millimeter-wave communications, and device-to-device communications have garnered significant attention. Traditional orthogonal multiple access (OMA) approaches allocate distinct radio resources, such as time slots, subcarriers, and spatial dimensions, to individual users to prevent inter-user interference (IUI). However, OMA has limitations in fully exploiting the available radio resources, potentially leading to suboptimal spectral efficiency. In contrast, the emergence of NOMA has provided a solution by allowing multiple user transmissions to occur in a shared, non-orthogonal radio resource. This innovation enables more efficient utilization of radio spectrum, leading to substantial improvements in spectral efficiency.

The orthogonality of OMA is the primary issue with this methodology. These studies, on the other hand, place a disproportionate amount of weight on systems that either have a single aerial or a compact array that has a large number of transmitting antennas. When it comes to capacity, the comparison between NOMA and OMA in multiple-input, multiple-output (MIMO) systems is somewhat different. This is especially the case in situations in which the quantity of transmission antennas required to support the user base is more than the number of users. Non-Orthogonal Multiple Access, also known as NOMA, has been drawing the interest of researchers for a very long time due to the fact that it is able to manage a very large number of connections while at the same time optimizing the effectiveness of the spectrum. They are interested by the capability of this system to manage multiple connections at the same time. Through the use of orthogonal multiple access (OMA) strategies, user equipment (UEs) in long-term evolution (LTE) and LTE-Advanced cellular networks are dispersed throughout a broad spectrum of frequency channels. The method of orthogonal frequency division multiple access exemplifies one of these strategies that can be utilised. On the other hand, OMA techniques have low spectrum efficiency, which is something that becomes more noticeable as network density increases. As a consequence of this, the objectives of the 5G network will involve the communication of a significant number of machines in addition to the expansion of mobile broadband. Non-orthogonal multiple access (NOMA) and reconfigurable antennas are two separate but related concepts in wireless communication and technology.

Orthogonal Multiple Access (OMA)

OMA is a multiple access scheme used in communication systems where multiple users share the same frequency channel by allocating orthogonal resources to each user. The goal is to enable simultaneous communication between multiple users without causing interference among them. OMA is particularly important in wireless communication systems where the available frequency spectrum is limited, and efficient utilization is crucial. There are two main types of multiple access schemes: Frequency Division Multiple Access (FDMA) and Time Division Multiple Access (TDMA). OMA is a form of resource allocation that falls under FDMA, where different users are assigned orthogonal resources, typically time slots or frequency bands. Here are two common types of OMA:

Frequency Division Multiple Accesses (FDMA): In FDMA, the available frequency band is divided into multiple sub-channels, and each user is assigned a unique frequency sub-channel. This means that each user's transmission occurs in a separate frequency band, preventing interference between users. FDMA is commonly used in analog communication systems and some digital communication systems.

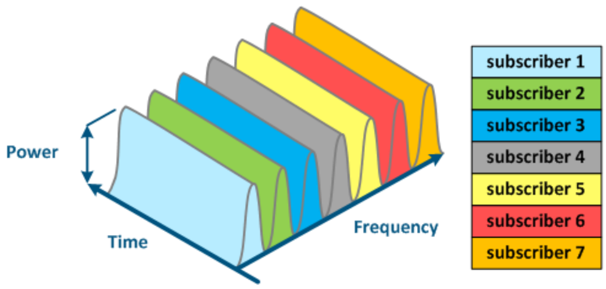

Fig.1: FDMA

Code Division Multiple Access (CDMA): CDMA is another form of OMA where users are assigned unique codes to distinguish their signals. Unlike FDMA, where users are assigned different frequency bands, CDMA allows multiple users to transmit on the same frequency band simultaneously. Each user's signal is spread over the entire frequency band using a unique code, and receivers are able to de-spread the signals using the corresponding codes. CDMA is widely used in digital cellular networks, such as 3G and 4G (e.g., CDMA2000 and WCDMA).

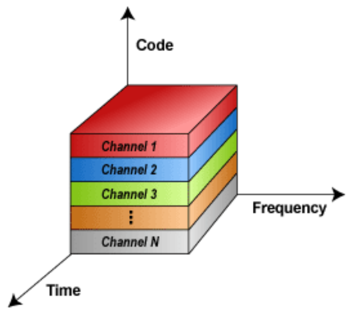

Fig.2: CDMA

OMA is essential in modern wireless communication systems, especially in the context of cellular networks, where multiple users need to share the limited radio frequency spectrum efficiently. It allows for increased capacity and simultaneous communication among multiple users while minimizing interference. Different variations of OMA are employed in various wireless communication standards to optimize resource allocation and improve overall system performance.

Non-Orthogonal multiple access (NOMA)

NOMA is an advanced multiple access technique used in wireless communication systems, including 4G and 5G networks. It departs from traditional orthogonal multiple access (e.g., Frequency Division Multiple Access or Time Division Multiple Access) and allows multiple users to share the same time and frequency resources. In NOMA, users are assigned power levels and/or codebooks in such a way that they can share the same spectrum resources simultaneously, and their signals are superimposed. Figure 1 provides a visual representation of the general architecture of the NOMA. The idea of SIC can be seen as the primary concept that underpins this strategy. This is one of the ways in which conventional orthogonal multiple access varies from non-orthogonal multiple access (NOMA). NOMA, which stands for non-orthogonal multiple access, has recently been recognized as one of the fundamental enabling technologies required to handle the high demands that are placed on networks beyond 5G. This recognition came about only recently. In contrast to orthogonal multiple access (OMA), non-orthogonal multiple access (NOMA) enables users to share the same resource blocks (RBs) concurrently and separates users based on the different power levels they each hold. NOMA is also known as concurrent resource sharing (OMA). In NOMA, the superposition coding (SC) algorithm is utilised at the transmitter, and the successive interference cancellation (SIC) algorithm is implemented at the receiver in order to decode user signals. This concept serves as NOMA's foundational tenet. Several users' information streams can be multiplexed with the help of orthogonal multiple access (OMA) techniques.

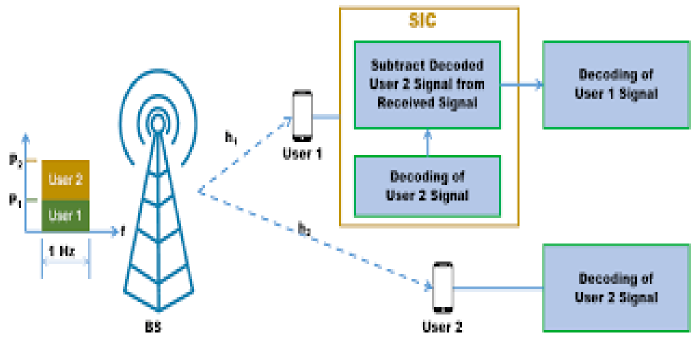

Fig.3: Architecture of NOMA

These approaches involve the utilisation of orthogonal resources in the time, frequency, or coding domain (TDMA, FDMA, CDMA, or OFDMA). In contrast to OMA, NOMA multiplexes data from a variety of users while making use of the same resource block (RB) in terms of time, frequency, and code. This is done in order to save bandwidth. As a direct consequence of this, the available bandwidth is being utilised in an extraordinarily efficient manner (BW).

Successive interference cancellation (SIC)

SIC is used at the receiver to decode the signals from multiple users. NOMA is designed to increase spectral efficiency and provide better user fairness by serving both strong and weak users in the same resource block. Reconfigurable Antennas: Reconfigurable antennas are antennas that can change their characteristics, such as radiation patterns, frequency bands, or polarization, in response to varying operational requirements. These antennas can adapt to different communication scenarios, making them suitable for applications with dynamic environments, multiple frequency bands, or different coverage requirements. Reconfigurable antennas are employed in wireless communication systems to improve signal quality, reduce interference, and enhance the flexibility of wireless devices.

Transition from 4G to 5G

The throughput of the region needs to be raised in order to satisfy the expectations that were described earlier, which may be stated as follows: Bandwidth (Hz) (Hz) Spectrum efficiency, measured in bits per hertz per cell, is equal to area throughput, measured in bits per km2. The math given above points to the following three strategies as potential ways to boost area throughput: 1) Increase the amount of bandwidth that is allocated. 2) Increase the efficiency of the spectrum. 3) Raising the density of the cell networks. The most recent improvement in mobile communication is known as the fifth generation, or 5G, and it is prepared to reliably supply throughput that is always improving by updating technologies that boost area throughput. Low-frequency bands with a bandwidth less than 6 GHz have a high population density, which results in interference between cells and frequent handoffs. As a direct consequence of this, the potential for additional improvement in cell density and bandwidth resources inside 4G cellular networks has hit its limiting point. Millimeter wave (mm Wave) frequency is used instead of sub-6 GHz frequency in 5G networks, which results in an enhanced bandwidth. It is possible to raise the cell density to accommodate a greater number of users in the same amount of space by making use of a more advanced method of multiple accesses, such as non-orthogonal multiple accesses (NOMA). M-MIMO is going to be utilized by 5G networks, which are going to operate in the mm Wave range. Further interesting technologies, including as cooperative relaying systems (CRS), non-orthogonal multiple accesses (NOMA), and beam shaping with lens aerial array, are recommended for use with the existing 5G networks.

RELATED WORK

Usmonov, Botir, Shukurillaevich, and others [1] provide an explanation of the concept of five different technologies. An analysis of the capabilities, advantages, and limitations offered by the several iterations of mobile wireless technology that are currently in widespread use has been carried out. The study examines the birth and development of multiple generations of mobile wireless technology, as well as the relevance of these generations and the advantages they have over one another. During the past few decades, mobile wireless technologies have gone through four or five stages of technological revolution and progress, starting with 1G and ending with 4G. The advanced deployment of 4G and 5G technologies is currently the primary focus of research being conducted in the field of mobile wireless technology.

Rajaa Elouafadi and his colleagues [2] provided an explanation of NOMA. It has been demonstrated that device-to-device communications (also known as D2D communications) and non-orthogonal multiple access (also known as NOMA) are both viable choices for fifth generation (5G) networks. This is due to the fact that they have the ability to boost the effectiveness of the spectrum as a whole, which helps to generate this result. Given that the two approaches are merged to offer better benefits and satisfy some of the requirements and use cases for Internet of Things (IoT) and 5G implementations, the cooperative NOMA solution is a more alluring option than the traditional NOMA solution. In this article, we will give a performance comparison analysis that will be based on the average throughput as well as the likelihood of outages.

Yuanwei Liu [3] and his colleagues did in-depth study on the standards for wireless capacity, and the results of that research are detailed in this article. This article presents the findings obtained by them as a result of their investigation. Fifth-generation (5G) networks are having trouble supporting heavy heterogeneous data traffic due to the rapidly growing wireless capacity needs imposed by enhanced multimedia applications. These needs are being caused by the fact that enhanced multimedia applications are becoming more sophisticated. This is because the apps themselves are responsible for dictating the conditions that must be met (such as ultrahigh-definition video, virtual reality, and so forth). In addition to the drastically rising need for user access that is necessary for the Internet of Things, these conditions must also be satisfied. These issues are made a great deal more difficult by the fact that the development of 5G networks is still in the early stages. Non-orthogonal multiple access, often known as NOMA, is a potential technique that can accommodate multiple users within a single orthogonal resource block.

M. Rabie and colleagues [4] in their research paper reported that PLC systems which use non-orthogonal multiple access (NOMA), which is more commonly referred to as NOMA, are recommended by the authors of this paper to implement cooperative relaying and decode-and-forward protocols. If this were to be done, not only would user fairness improve, but throughput would also increase. In addition, we perform research on conventional cooperative relaying (CCR) PLC systems in order to provide an objective assessment of the capabilities of the system that is being offered. This objective is accomplished by deriving exact mathematical formulas for the average capacity, which are then checked through the utilisation of Monte Carlo simulations once they have been developed.

PROPOSED WORK AND RESULTS

Orthogonal multiple access is suitable for 3G-4G wireless communication but it has many drawbacks to use it in 5G. For 5G communication system higher data transfer rate can be facilitated with non-orthogonal multiple access.

Combining NOMA with reconfigurable antennas

NOMA focuses on the multiple access technique; while reconfigurable antennas address the physical layer of the wireless communication system. The integration of these two technologies can offer several benefits: Interference Mitigation: Reconfigurable antennas can be adjusted to steer or nullify specific directions, reducing interference from other users in a NOMA setup. This can improve the reliability and performance of NOMA-based systems. Enhanced Channel Capacity: Reconfigurable antennas can be used to optimize the channel conditions for different users, enabling better resource allocation in NOMA, thus increasing the overall channel capacity.

Adaptive Beam-forming

Reconfigurable antennas can employ adaptive beam forming techniques to improve signal-to-interference-plus-noise ratio (SINR), which is crucial in NOMA systems for successful successive interference cancellation. An adaptive beam former is a signal processing system used in array processing applications, such as radar, sonar, wireless communication, and microphone arrays. The primary goal is to enhance the reception or transmission of signals from a specific direction while suppressing interference or noise from other directions.

Coverage and Frequency Agility

Reconfigurable antennas can adapt to different frequency bands and coverage scenarios, making them compatible with the varying needs of NOMA users. In summary, combining non-orthogonal multiple access (NOMA) with reconfigurable antennas can lead to more efficient and adaptive wireless communication systems. NOMA optimizes the resource allocation and interference management among multiple users, while reconfigurable antennas enhance signal quality and adapt to changing communication environments. This integration is especially relevant in 5G and beyond, where spectral efficiency and flexibility are essential.

In this research work three candidates has been employed to know the sum transfer rate with respect to signal-to-noise ratio. First one is OMA, second is again OMA but this time it is facilitated with reconfigurable antenna and third one is NOMA with reconfigurable antenna. All three candidates have been defined in MATLAB environment virtually and simulation has been carried out. Simulation result is shown in figure 5. Simulation is done on the basis of steps explained in the flow chart shown in figure 4.

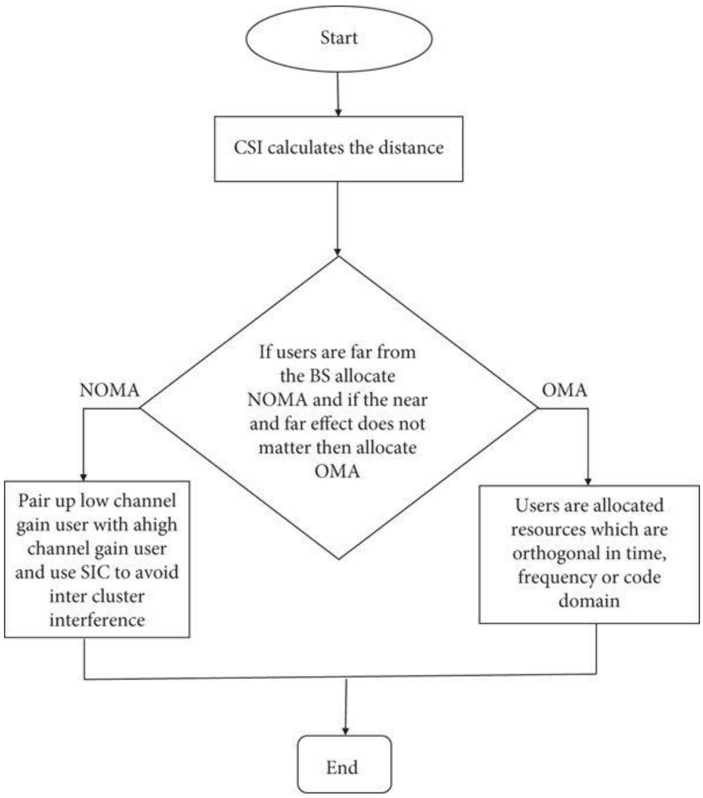

Fig.4: Flow chart

It is clear from figure 5 that sum transmission rate is higher in case of RA-NOMA than OMA and RAMA-OMA. It means RA-NOMA is good in performance from transmission speed point of view. It is seen from above fig that at same SNR value the sum transmission rate is almost double for RA-NOMA. It is increasing continuously on increasing the value of SNR.

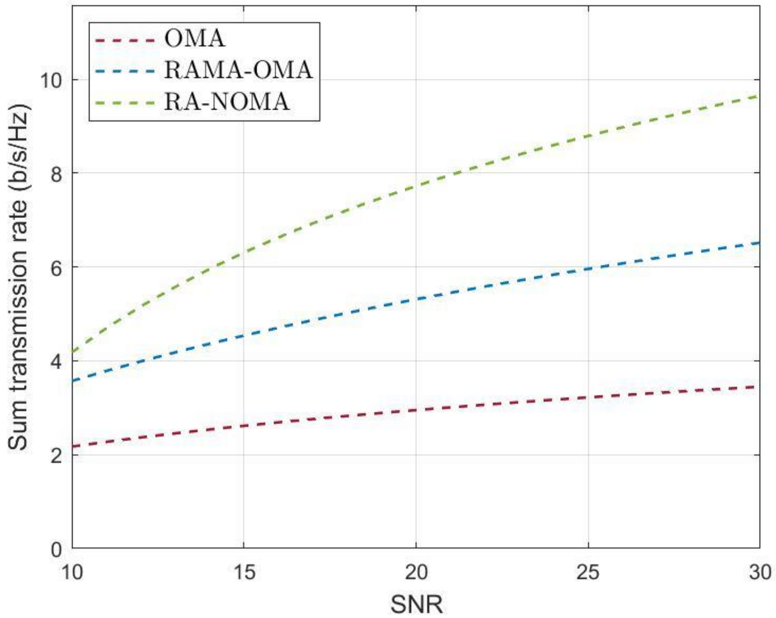

Fig.5: Simulation Result (Sum Transmission Rate V/S SNR)

CONCLUSION

In this paper wireless communication system has been examined for 5G. As it is well known that OMA technique is best suited for 4G but it is not applicable for 5G. NOMA has the key feature to overcome the drawbacks of OMA. Reconfigurable antenna system is applied for both OMA and NOMA. In this paper work sum transmission rate (b/s/Hz) is calculated with respect to SNR. The analysis has been done on the basis of MATLAB simulations. It is seen in the simulation plot that RA-NOMA shows higher transmission rate than OMA and RAMA-OMA. Hence it can be concluded that RA-NOMA is better candidate technique for 5G.

Here are some ways in which the integration of reconfigurable antennas and NOMA can be beneficial in

5G communication systems:

***Improved Spectral Efficiency*:** Reconfigurable antennas can be tuned to different frequency bands, allowing for better utilization of available spectrum. When combined with NOMA, which allows multiple users to share the same frequency band non-orthogonally, this can lead to improved spectral efficiency.

***Enhanced Spatial Multiplexing*:** Reconfigurable antennas can adapt their radiation patterns to spatially multiplex multiple users. In NOMA, where users with different quality-of-service requirements share the same resources, spatial multiplexing gains become crucial for increasing system capacity.

***Dynamic Adaptation to Channel Conditions*:** Reconfigurable antennas can dynamically adjust their parameters based on real-time channel conditions. In NOMA, where users may experience different channel conditions, this adaptability can help optimize the transmission for each user, leading to improved overall system performance.

Mitigation of Interference: NOMA systems inherently involve users sharing the same frequency resources. Reconfigurable antennas can help mitigate interference by adapting their radiation patterns or using advanced beam-forming techniques to focus the signal where it's needed and reduce interference for other users.

***Energy Efficiency*:** Reconfigurable antennas can contribute to energy efficiency by dynamically adapting to the communication requirements. In NOMA, optimizing power allocation for different users is a key aspect, and reconfigurable antennas can complement this by adjusting their parameters to maximize energy efficiency.

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