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Trends in Non-Orthogonal Multiple Access Techniques

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Abstract: Non-Orthogonal Multiple Access (NOMA) is a crucial technology that allows the Fifth-Generation (5G) wireless networks to cater to the growing call for of massive connectivity, high data rates, low latency, and, increased spectral efficiency. Unlike conventional Orthogonal Multiple Access techniques, NOMA serves multiple customers in a single resource block including a time slot, frequency or code. The distinction between signals is achieved by the use of different power levels. The important purpose of this paper is to offer a quick review of NOMA along with the recent advances and challenges.

Keywords: Non-Orthogonal Multiple Access (NOMA), Successive Interference Cancellation (SIC), Power Domain NOMA.

I. INTRODUCTION

Wireless communications have advanced during the last decade. The wide variety of users depending on wireless communication has improved exponentially leading to increasing demand for large connectivity, high spectral efficiency, increased data-rates, and low latency. Multiple Access techniques play a critical role in successfully using communication resources [1]. All the traditional Multiple access strategies used in the sooner and existing technology of wireless communication were based on a common concept of orthogonal signals for unique users by means of allocating one of a kind resources for the reason that orthogonalization simplifies receiver design and decreases inter-user interference [2]. With the advance of the Fifth-Generation (5G) technology, the wireless network will have increased data rates, high spectral efficiency, and low latency. Non-Orthogonal Multiple Access (NOMA) is a key 5G generation that objectives to remedy those problems. Saito et al created the term NOMA [3].

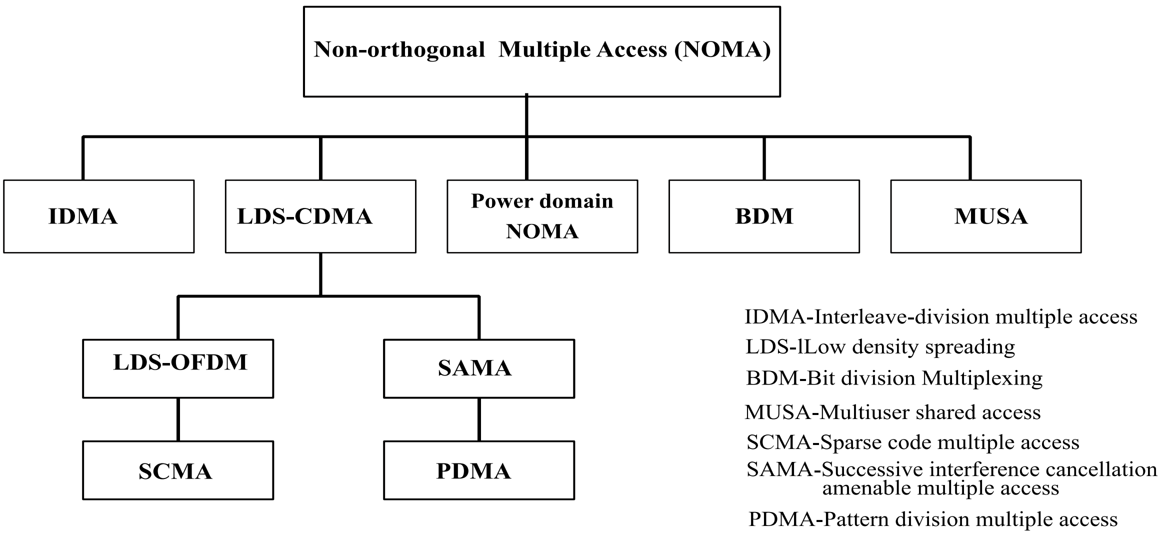

Fig. 1. Advancements in NOMA [6]

Time Division Multiple Access (TDMA), Frequency Division Multiple Access (FDMA) and Code Division Multiple Access (CDMA) are the commonly used Multiple Access techniques termed as the Orthogonal Multiple Access or abbreviated as OMA. In TDMA, FDMA or CDMA a single orthogonal resource block like a time slot, frequency and code are used by a single user [6]. These strategies cannot provide high spectral performance as required by the fifth-generation (5G) wireless communication. Non-Orthogonal Multiple Access (NOMA) objectives to resolve this problem by means of efficient use of the spectrum [4]. In NOMA multiple users are served on the single orthogonal resource block like time slot, frequency or code, unlike OMA. The Base Station (BS) groups the users and their messages are superimposed by allocating specific power coefficients. The distinction between signals at a user is achieved by allocating one of a kind power ranges to different users. Usually, a person with poor channel situation is paired with a person having a better channel condition. More power will be allocated to the person with poor channel condition and after allocating the power coefficients the messages are superimposed and transmitted. The user with the higher channel condition can decode its message by way of Successive Interference Cancellation (SIC) [5]. NOMA may be paired with other technologies like MIMO, massive MIMO, Physical Layer Security, The Internet of Things (IoT), mm-Wave communications, Cognitive radio, Cooperative communication, and Visible light communication effectively. In most of the works related to NOMA, they are classified into Power domain NOMA and Code domain NOMA [5]. It includes low-density spreading (LDS), sparse code multiple access (SCMA), multi-user shared access (MUSA) [14], Successive Interference cancellation Amenable multiple access (SAMA) etc. Some other closely-related multiple access schemes, such as Spatial Division Multiple Access (SDMA), Pattern Division Multiple Access (PDMA) and Bit Division Multiplexing (BDM) have also been proposed [5]. The advancement of NOMA is depicted in Figure 1.

The remaining portion of the paper is arranged in the following manner. In section II, the essential ideas of NOMA are given, whereas Section III describes different kinds of NOMA. Section IV describes the long-run analysis, directions and challenges to NOMA implementation and conclusion are provided in the last section.

II. NON-ORTHOGONAL MULTIPLE ACCESS (NOMA) BASICS

We are conversant in standard Orthogonal Multiple Access (OMA) techniques like Time Division Multiple Access (TDMA), Frequency Division Multiple Access (FDMA), Code Division Multiple Access (CDMA), Orthogonal Frequency Division Multiple Access (OFDMA) [6]. All of those techniques serve one user in every orthogonal resource block. NOMA has an improved spectral efficiency compared to OMA. Take into account a scenario wherever a user with a poor channel condition is to be served, in case of OMA, a bandwidth resource is allotted to the current user despite his poor channel condition. This harms the spectral efficiency and throughput of the system. However, within the case of NOMA, it ensures that the user has a channel with the worse condition is served and therefore the user with a stronger channel condition will utilize the bandwidth resources of the weak user [6]. Because of this NOMA assures user fairness moreover as enhanced spectral efficiency. Research works conducted in NOMA counsel that it supports massive connectivity that makes it a wonderful candidate to be placed to use in 5G. The standard approach is to cluster the users and superimpose their messages by allocating different transmission power coefficients. Usually, there'll be a user with smart channel conditions and one with poor channel conditions. a lot of power is allotted to the user with poorer channel conditions. In every cluster, the user with the higher channel will decrypt the signal sent to the user with the poorer channel, and therefore the interference will so be eliminated by a method referred to as successive interference cancellation (SIC). This is often typically termed as Power domain NOMA. In NOMA, multiple users are multiplexed within the power domain and de-multiplexed on the receiver side employing a successive interference cancellation (SIC) [6], [7].
In Downlink NOMA, we assume there are two users and a single transmitter and receiver antenna. Let x_1 and x_2 be the two signals and the transmitted signal is denoted as z.

$$z = \sqrt{p_1}x_1 + \sqrt{p_2}x_2$$

Where, p_1 and p_2 denote the transmission power.
The received signal at user i is given as

$$y_i = h_i z_i + w_i$$

Where, h_i is the channel coefficient between the user i and BS and w_i denotes the receiver Gaussian noise.

In uplink NOMA, the user i transmits the signal x_i with transmission power p_i.
The received signal at the BS is denoted by

$$y_i = \sqrt{p_1}h_1x_1 + \sqrt{p_2}h_2x_2 + w_i$$

Different types of NOMA has been developed, which includes Single-carrier NOMA and Multi-carrier NOMA. Non-Orthogonal Multiple Access is a way to efficiently use the spectrum by allotting same orthogonal resource block to multiple users and this can be done by using different power coefficients for different user signals. This is termed as Power-domain NOMA [6]. Power Domain NOMA and other variations of NOMA will be discussed in the next section.

III. VARIANTS OF NOMA

A. Power-domain NOMA

A NOMA downlink scenario with two users User 1 and User 2 as shown in the figure. User 1 and User 2 are considered in this example. Let h_1 and h_2 denote the channels of User 1 and User 2 respectively and $h_1 \leq h_2$. Let α_1 and α_2 denote the power coefficients and $\alpha_1 \geq \alpha_2$. Since more power is allocated to User 1 which is the user at the cell edge and has poor channel conditions and User 2 being close to the base station has a better channel and hence the power allocated to User 2 is lower than User 1. Since User1 has poor channel conditions, it can decode its signal directly as it has the highest power coefficient and it just has to find the signal with largest power coefficient and treat the signal of User 2 as noise. On the other hand, User 2 will have to perform Successive Interference Cancellation (SIC). In SIC, User 2 decodes User 1's message first and then discards it as noise and finally decodes its message [6].

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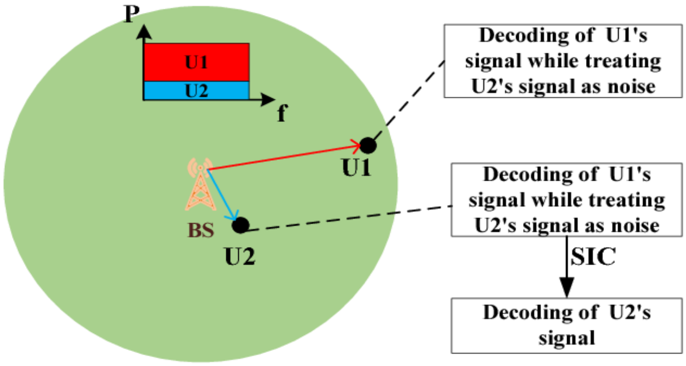

Fig.2 NOMA downlink scheme with two users, User 1 and User 2, and one subcarrier [7].

B. *Cognitive Radio(CR) NOMA*

Cognitive Radio (CR) NOMA is a variant of Power-domain NOMA. In Power-domain NOMA the user with a poor channel gets served thereby ensuring user fairness but it fails to consider the QoS constraints of the user. Whereas in CR-NOMA, the power is allocated to the user in such a way that QoS constraints are satisfied. Considering the same exmp of downlink NOMA as shown in Power-domain NOMA. User1 will be served to satisfy its QoS requirements & User 2 is served with the remaining power [6], [7].

C. *LDS, SCMA and PDMA*

Multi-carrier NOMA uses the concept of grouping different users and then allocating different sub-carriers to each group. This avoids interference between groups [6]. Low-Density Spreading (LDS), Sparse Code Multiple Access (SCMA), Pattern Division Multiple Access (PDMA) are different types of Multi-carrier NOMA. In LDS and SCMA, the user signal is spread over multiple sub-carriers but the number of sub-carriers assigned to each user is less than the total number of sub-carriers. In PDMA, the number of sub-carriers assigned to one user may not be less than the total number of subcarriers. The user signal is multiplexed into several sub-carriers and they are mapped to the sub-carriers with different power scales and phase [6], [13].

IV. FUTURE RESEARCH CHALLENGES

NOMA may be integrated with many technologies consisting of massive MIMO, mm-Wave, IoT, Cognitive Radio, Simultaneous wireless Information and power transfer (SWIPT), Physical layer security (PLS), etc. Works related to MIMO-NOMA already exist, however extending NOMA to massive MIMO is challenging. Due to the capabilities of massive MIMO like large antenna arrays, spatially correlated or beam space sparse channels and hybrid beamforming structures, present MIMO-NOMA designs may be inapplicable and need to be modified [8].

Recent advances in mm-Wave communications fulfil the high data rate requirements. However, mmWave channels are scattered in spatial/angle domain such that several simultaneous connections at very high frequencies is restricted. Massive MIMO together with NOMA can conquer this limitation [2], [9], [10].

Cognitive Radio senses the surroundings and adjustments its working traits accordingly. The most important function of Cognitive Radio is spectrum sharing via which the primary spectrum is shared with the secondary user without causing any interference. A combination of Cognitive radio and NOMA can improve its spectral performance and an increase in the number of users [2].

Another promising research course is Physical layer security (PLS) of NOMA networks. PLS exploits the characteristics of the channel inclusive of noise, fading, and interference. The essential goal of PLS is to degrade the link between transmitter and eavesdropper and to enhance the link among the transmitter and the supposed user. Since NOMA makes use of Successive Interference Cancellation (SIC), it is liable to eavesdropping and it may benefit from PLS [6], [11].

Energy harvesting is an emerging trend that harvests energy from Radio Frequency (RF) signals, which makes the system more self-sufficient. [2], [12]. Simultaneous Wireless and Information Transfer (SWIPT) and Wireless Powered Communication are two energy harvesting concepts [2]. In SWIPT, power is also transmitted alongside information signal. This power can be utilised by other users. Whereas in WPCN, wireless transfer of power occurs [2]. These techniques can enhance NOMA remarkably.

V. CONCLUSION

NOMA is an important 5G technology that helps to attain high spectral efficiency, massive connectivity and low latency. NOMA provides an efficient spectrum utilization eliminates the need for orthogonality between signals, such that the same orthogonal resource block can be assigned to multiple users without interference. In this paper, the basic concepts of NOMA were discussed along with different variations of NOMA like Power domain NOMA, Cognitive Radio NOMA, LDS, PDMA and SCMA. The future research challenges of using NOMA with other technologies such as Massive MIMO, SWIPT, Cognitive Radio, mmWave were discussed.

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